The Orthopaedic Journal

Harvard Medical School

Index

Program Director's Corner

George S.M. Dyer, M.D.

This issue of the Orthopaedic Journal at Harvard Medical School has special significance to me as publishing this issue marks the end of my first year serving as program director for Harvard's orthopaedic residency. Not very long ago I was a resident myself, and I had the privilege then of serving as editor of this Journal.

The Journal and our residency program have each evolved, in complementary and parallel ways, becoming more refined, more modern, and better centered on educating our residents. This Journal was once a flat-spine printed magazine, with a hefty cost to publish and a production schedule that was driven by the demands of the layout process and the print shop's calendar. It is now a visually appealing, interactive web page which can be dynamically improved throughout the year. It used to be a limited-run printing, mailed selectively to HCORP graduates and physicians in our geographic area. It is now universally accessible on-demand through the internet. Especially exciting this year is the addition of a virtual alumni network that allows current residents, recent graduates, fellows and established surgeons to get in touch with one another around the country.

Our residency program is evolving too. Our residency once had very little curricular planning; the breadth and richness of our clinical activities was enough to ensure a great training experience even without much of a syllabus. Recently our alphabet soup of governing organizations, the Accreditation Council on Graduate Medical Education (ACGME), the Residency Review Committee (RRC), and the American Board of Orthopaedic Surgery (ABOS), has created a standard set of discrete training objectives for all residency programs. Called "Milestones," these 13 procedures (and non-procedures) are designed to ensure that all residents get a systematic and evaluated exposure to the core of our specialty. They are not optional, even for programs like ours that did pretty well without them. This means that the Harvard orthopaeid residency, like our Journal, will become more dynamic and adaptable over time. We've experimented with some new training venues, like the Trauma Bootcamp described in this issue. We are also working on innovative new rotations such as a month-long rotation for all our interns at the end of the coming year, just before they move full-time into orthopaedic rotations.

We are as proud of our past as we are excited by our future. The new format of this Journal and our new alumni map and database should make it easier than ever for you to keep in touch and stay up to date on our new happenings. We look forward to hearing from you in the years ahead.

George S.M. Dyer, M.D.

Program Director, Harvard Combined Orthopaedic Residency Program

Letter from the Editors

Terrill P. Julien, M.D. & Bryce T. Wolf, M.D.

Bryce T. Wolf, M.D.

Terrill P. Julien, M.D.

I t is with great pleasure to present the 2013 edition of The Orthopedic Journal at Harvard Medical School. Now in its fifteenth year of publication, the journal has continued to evolve and provide a window into the Harvard Affiliated teaching hospitals. The Harvard Orthopaedic community is comprised of many talented clinicians, scientists, and support staff. We thank them for their contributions to this year's edition, marvel at the breadth and depth of their work, and congratulate them on their efforts.

This past academic year saw several challenges from work-hour restriction reform to the evolution of core competencies. None of us will ever forget the tremendous outpouring of support and dedication from the members of the Harvard Orthopaedic community on the afternoon of April 15th, 2013 during the Boston Marathon bombings. The call to duty and embodiment of the Hippocratic Oath we all swore was seen in true display as residents and staff at every level put the care of the patients first and delivered compassionate care until the early morning and continued care for the ensuing months. It was my proudest day to call myself a Harvard Orthopedic resident.

The 2013 edition represents a major investment of time and expertise on the part of the faculty, fellows and residents who submit articles for the clinical content and on the part of the department chiefs who summarize the vast clinical and research work at their institutions. Special thanks are reserved for the Harvard Executive Committee who have come together to finically support the journal. The addition of Dr. George Dyer, a former Editor-in-Chief of The Orthopedic Journal, as the new Program Director gives the editorial board continued optimism and direction for future publications.

This year, The OrthopedicJournal is dedicated to Dr. Barry Simmons as a tribute to his enthusiasm for teaching, mentorship of residents and fellows, academic achievements, and outstanding patient care. As both a mentee and former resident on the Hand and Upper Extremity Service at BWH, I can attest to his clinical wisdom, surgical skill, and tireless dedication to both residents and patients. Dr. Simmons is worthy of our highest accolades, and I am happy that we may provide a forum to recognize his contributions to our community.

Finally, we wish to thank our fellow editors – Eric Fu, Shawn Anthony, Carl Harper, Beverlie Ting, Lauren Ehrlichman, Youssra Marjoua and Ehsan Saadat – as well as Jennifer Duane and Nicole Wolf for their dedication, camaraderie, and hard work. We have been fortunate to work with you and wish you all the best in future years.

Terrill P. Julien, M.D. & Bryce T. Wolf, M.D.

Editors-in-Chief

Dedication

Barry P. Simmons, M.D.
Peter M. Waters, M.D.

Barry P. Simmons. Even his name reveals the contrasts that highlight his uniqueness. The informal Barry punctuated with the formal middle initial P. Similar to the seeming disconnect of a classic bow tie, kaki pants and comfortable clogs he often wears to work. Completely relaxed with a dignified Ivy touch. Barry's distinctive approach has always been fresh air to the HCORP residents. Dial it down a notch in terms of anxiety and pressure; dial it up a notch in terms of expectations for learning and surgical skill development. Embrace the people around you in a fun and warm way, but be prepared to be serious and professional with patients and staff. The ebb and flow of calmness, humor, and connection that defines the temperament of Barry's service results in high quality care and has helped attract many Harvard residents to careers in hand surgery.

Barry grasped a vision a long time ago that hand surgeons should involve care of the entire upper limb. Brachial plexus to finger tip. He built a hand and upper limb program reflecting that vision with mostly cooperative, and occasionally competitive, efforts with the arthroplasty, trauma and sports teams. Fortunately, his chair at the Brigham and Women's, Tom Thornhill, and counterpart at the Children's Hospital, Jim Kasser, helped guide the growth of varied, high level expertise within and amongst all the teams. The present faculty of the Harvard Hand and Upper Limb Service are the reality of Barry's foresight and leadership. Our program is most highly regarded nationally and has the good fortune to select from the best of candidates. Much of the credit goes to Barry for his ability to attract and nourish talent. However, even with high level expertise and complex care, , Barry always made it a priority to be certain the fellows and faculty knew the importance of the residents on rotation and their surgical role. Residents on service were well taken care of.

The residents and fellows have always been most important professionally to Barry. The time he spends reviewing applications in minute detail; talking with each candidate on interview day in an engaging and thorough way; and, being certain the applicants that match here will fit in seamlessly with his and our teams. That is magnified by the care Barry takes of the residents on service and the fellows during their year with us. His social leadership is exemplary and reflected by his legendary dinners in his home with laughter, conversation and Laura's fabulous meals and garden tours. We all have been lucky for his tutelage.

Finally, although his patients, the HCORP residents, and the Harvard Hand Surgery fellows are Barry's professional priorities, he never lost sight of his greatest priority: the love of his life Laura, their three daughters Quincy, Sara, Molly, and their expanding families. Barry's devotion to his family has been a guiding light of commitment to life beyond the walls of the hospital. It is an honor to write this dedication to my mentor in hand surgery, Barry P. Simmons MD.

Peter M. Waters, M.D.

Measuring Bohler's Angle with Oblique Lateral Radiographs: Implications for Management of Calcaneal Fractures

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Background: In the setting of calcaneus fractures, attempts at perfect lateral hindfoot images usually result in oblique x-rays. The purpose of this study is two-fold: (1) to assess whether orthopaedic surgeons can accurately measure Bohler's angles on oblique lateral radiographs; and (2) to determine how Bohler's angle (BA) is influenced by the obliquity of lateral radiographs.

Methods: Observed Bohler's Angle Measurement- A cadaver specimen was imaged using a C-arm to obtain a perfect lateral and oblique laterals up to 25 degrees in the anterior, posterior, cephalad and caudad directions. Orthopaedic attendings and residents were asked to measure the observed BA's. True Bohler's Angle Measurement - Metallic markers were placed in the anatomic landmarks needed to calculate the BA. The same series of oblique images were obtained. The true BA was then measured on each image.

Results: Observed Bohler's Angle - The observed BA's were significantly different from the control value for all images except for the posterior oblique image at 20 degrees. True Bohler's Angle - The greatest difference from the perfect lateral BA was found in the cephalad-oblique radiographs, whereas the BA remained relatively constant with posteriorly directed oblique radiographs.

Conclusions: Orthopaedic surgeons' ability to accurately measure BA significantly decreases with increasing obliquity of lateral radiographs. The true BA varies most with increasing obliquity in the cephalad direction, but less so with posteriorly directed radiographs. Understanding these subtle changes should enable surgeons to more carefully interpret data obtained from oblique lateral radiographs when deciding upon treatment based on Bohler's angles.

Level of Evidence: Level V

Keywords: bohler's angle, calcaneus fracture, radiographs

The calcaneus is the most commonly fractured tarsal bone, and it accounts for 1% to 2 % of all fractures. The majority of calcaneus fractures are caused by a fall from height or a motor vehicle accident, and typically result in depression of the posterior facet.[6] First described in 1931, the "tuber-joint angle" or Bohler's angle (BA) is used to determine the amount of posterior facet displacement and loss of calcaneal inclination. The Bohler's angle is obtained on a lateral foot radiograph. It is the angle formed by the intersection of a line joining the highest point of the anterior calcaneal process and the highest point of the posterior process, with a line drawn

projecting from the superior posterior calcaneal tuberosity.[2] It is widely accepted that in the uninjured adult population, a normal Bohler's angle is between 25 and 40 degrees.[2, 1] However, numerous papers suggest that there is variation among populations, with a range of values between 14 degrees in Malawians and up to 50 degrees in Ugandan subjects.[15, 8, 14, 7, 13]

Bohler's angle has been shown to have prognostic value in determining morbidity and outcomes following calcaneus fractures.[4] This radiographic parameter is often used to guide treatment, and the need for obtaining further imaging such as computed tomography (CT) scans. Unfortunately, lateral radiographs obtained in the trauma setting are often oblique due to difficulties in positioning the traumatized extremity, or due to limited positioning secondary to splint materials. These detail of these radiographs may influence the accuracy of the measured Bohler's angle, as skewed views can lead to more bony overlap that blurs the proper anatomic landmarks. Inaccurate assessment of Bohler's angles may lead to under- or overtreatment of patients with intra-articular calcaneus fractures.

The purpose of this study is two-fold: (1) to assess whether orthopaedic surgeons can accurately measure Bohler's angles on oblique lateral radiographs; and (2) to determine how Bohler's angle, as measured using consistent anatomic landmarks, is influenced by the obliquity of the lateral radiograph. We hypothesize that orthopaedic surgeons will inaccurately measure Bohler's angle on oblique lateral x-rays. We also hypothesize that the true Bohler's angle will vary based on the magnitude of the obliquity of the lateral image.

Materials and Methods
Observed Bohler's Angles

A fresh-frozen cadaver specimen was imaged using a large C-arm with laser positioner (General Electric, Fairfield, CT) to obtain multiple flu-oroscopic images. First, a perfect lateral image of the hindfoot was obtained. A perfect lateral requires that the medial and lateral articular surfaces of the talar dome be superimposed, that the tibiotalar joint remains open with a symmetrical joint space, and that the distal fibula continues to be superimposed by the posterior half of the distal tibia.[12] Next, a series of oblique images was taken with the beam directed anteriorly, posteriorly, cephalad and caudad. These images were taken in 5-degree increments from 0 to 25 degrees in each direction, with the C-arm's laser positioner utilized to maintain a constant reference point (Figures 1, 2). Forty-one orthopaedic surgeons, consisting of five foot and ankle and trauma specialists and 36 orthopaedic residents (Post-Graduate Years 1 through 5), were then asked to measure Bohler's angles on all images. All participants received written instruction on how to measure Bohler's angle as originally described by Bohler in 1931.[2] All images were presented in random order via a random order generator spreadsheet function (Excel, Microsoft Corp, Redmond, WA). All study participants used the angle-measuring tool found within the Picture Archiving and Communication System (PACS).
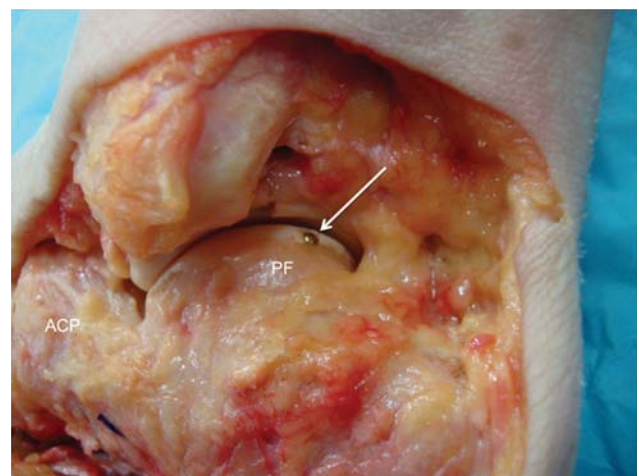

FIGURE 1. Dissected cadaver specimen with visible metallic marker placed in the superior most portion of the posterior calcaneal facet. ACP = anterior calcaneal process. PF = posterior facet. Arrow is pointing at metallic marker.
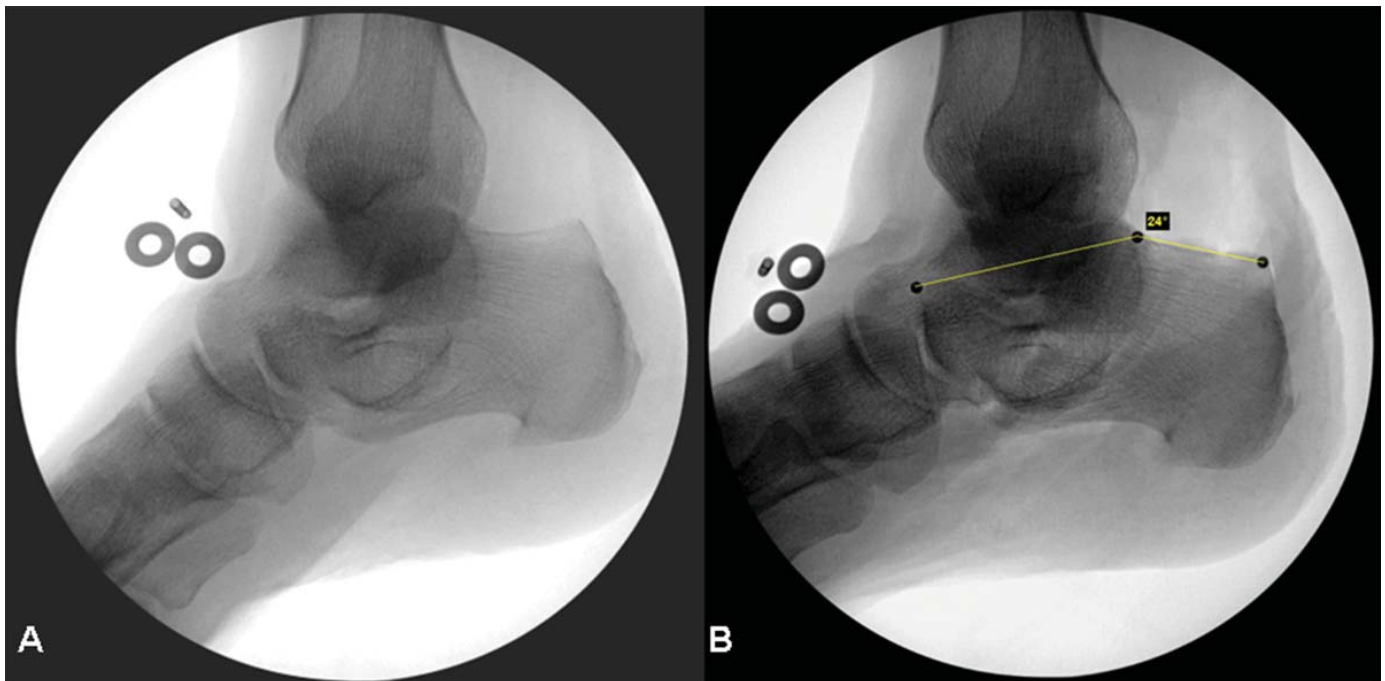
FIGURE 2. Representative oblique lateral images of the hindfoot with x-ray beam directed 25-degrees cephalad. (A) Without metallic markers. (B) With metallic markers.

True Bohler's Angles

To define the true Bohler's angles, the lateral soft tissues were dissected from the same cadaveric specimen and metallic markers were placed on the following bony landmarks: the anterior calcaneal process, the superior most portion of the posterior facet and the posterior superior tuberosity. The same series of oblique images was obtained with the large C-arm using the laser positioner to maintain a constant reference point (Figures 1, 2). The study's three authors independently measured the true Bohler's angle on all oblique images using the marked specimen. An average of the three authors' measurements was taken to represent the "true" Bohler's angle for each oblique image. The interobserver correlation coefficient (ICC) was calculated to assess agreement. An ICC > 0.8 is defined as excellent, 0.6 – 0.8 is defined as good, 0.4 – 0.6 as moderate and < 0.5 as poor agreement.[9] The true Bohler angle was used as the control value for the observed Bohler's angles.

An independent statistician entered all data into a statistical database (SPSS v.19.0, © SPSS Inc., Chicago, IL) for analysis. Descriptive statistics were computed to provide an overall summary of the study sample. For all analyses, a p-value < 0.05 was considered significant.

RESULTS
Observed Bohler's Angles

For all study participants, the observed Bohler's angles were significantly different from the control value for all images except for the oblique image in which the x-ray beam was directed 20 degrees posteriorly (p = 0.43). Anteriorly and caudally directed oblique images resulted in observed Bohler's angles that were lower than control values. Posterior and cephalad oblique images resulted in observed Bohler's angles that were greater than control values (Table 1), (Figures 3, 4).

True Bohler's Angles

The true Bohler's angle measured on the perfect lateral image was determined to be 35 degrees. The true Bohler's angle was found to

TABLE 1. Observed and true Bohler's angles				
Image Obliquity	**True Bohler's Angles**	**Observed Bohler's Angles**	**SD**	**p-Value**
Perfect Lateral	35	37	5.1	p = 0.007
Anterior 5	36	35	4.5	p = 0.037
Anterior 10	37	32	6.6	p < 0.001
Anterior 15	38	30	7.2	p < 0.001
Anterior 20	39	30	8.5	p < 0.001
Anterior 25	40	31	3.9	p < 0.001
Caudad 5	37	34	3.0	p < 0.001
Caudad 10	38	33	3.3	p < 0.001
Caudad 15	38	34	2.8	p < 0.001
Caudad 20	39	33	4.3	p < 0.001
Caudad 25	39	34	3.0	p < 0.001
Cepahald 5	34	37	6.5	p = 0.039
Cephalad 10	32	36	4.4	p < 0.001
Cephalad 15	29	32	5.9	p < 0.001
Cephalad 20	27	36	6.0	p < 0.001
Cephalad 25	24	35	5.0	p < 0.001
Posterior 5	35	41	5.9	p < 0.001
Posterior 10	34	36	4.7	p = 0.004
Posterior 15	35	37	3.6	p = 0.002
Posterior 20	37	37	3.9	p = 0.43
Posterior 25	37	39	4.1	p < 0.001

p-Values < 0.05 are statistically significant. Image obliquity, true Bohler's angle and observed Bohler's angle values are listed in degrees. True Bohler's angles represent the mean of the three authors' measurements. The interobserver correlation was excellent, ICC = 0.985 (p < 0.001). Observed Bohler's angles are listed as the mean value of all observers. SD = standard deviation.
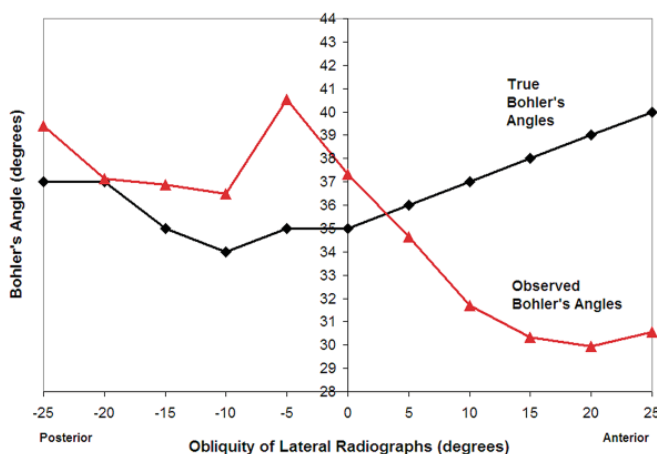

FIGURE 3. Observed and true Bohler's angles with changes in the obliquity of lateral radiographs in the anterior (positive values on x-axis) and posterior (negative values on x-axis) directions.
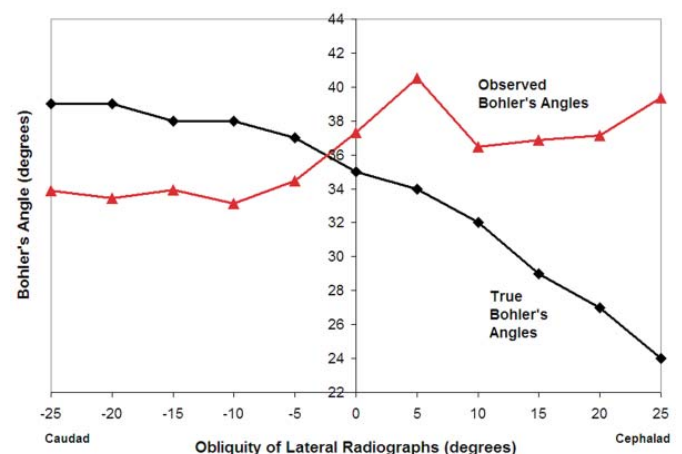

FIGURE 4. Observed and true Bohler's angles with changes in the obliquity of lateral radiographs in the cephalad (positive values on x-axis) and caudad (negative values on x-axis) directions.

increase with increasing obliquity as the x-ray beam was directed anteriorly and caudally, whereas the angle remained relatively constant when directed posteriorly. The true Bohler's angle decreased as the x-ray beam was directed cephalad. With increasing obliquity, the difference between the true Bohler's angle on the perfect lateral and oblique laterals was found to be smallest in the posterior direction (Figures 3, 4).

There was no significant difference between the true Bohler's angle values for the three authors. The agreement between the authors was excellent with an ICC of 0.985 (p < 0.001) for the mean of the true Bohler's angles.

Discussion

The study findings highlight the difficulty of accurately measuring Bohler's angle on oblique images. The results also highlighted that the true Bohler's angle varied based on the obliquity of the lateral fluoroscopic image. These findings are notable given that in the trauma setting, oblique lateral radiographs are often the norm due to difficulties in proper positioning of the traumatized extremity or limitations from splint materials. Numerous papers direct clinicians to the importance of Bohler's angle as a prognostic indicator for patient outcomes.[4, 3, 10] The randomized controlled study performed by Buckley et al. in 2002 suggests that anatomic or near anatomic reduction has a positive effect on patient outcomes.[4] Buckley and Meek in 1992 demonstrated that malreduced intra-articular fractures fared no better than those treated nonoperatively.[3] An accurate assessment of Bohler's angle and displacement of the posterior facet will avoid the over- or under-treatment of calcaneus fractures.

Observed Bohler's Angles

As demonstrated in Table 1, there was a statistically significant difference for nearly all oblique images obtained, including the perfect lateral image. Willmott et al. showed that Bohler's angle has good interobserver reliability and can be easily measured on a plain lateral radiograph.[15] Clint et al. also demonstrated excellent interobserver agreement in assessing Bohler's angle in children.[5] The work done by Willmott et al. and Clint et al., suggests that high quality lateral radiographs are needed to confidently estimate Bohler's angle, and accurately detect posterior facet displacement.

Our findings further illustrate that suboptimal imaging in the form of oblique hindfoot lateral x-rays will result in inaccurate calculation of Bohler's angle. The inability of the study participants to accurately measure Bohler's angle was a result of several factors. Oblique radiographs change the relationship between the three anatomic landmarks used to measure Bohler's angle, the anterior calcaneal process, the superior most portion of the posterior facet and the posterior superior tuberosity. A "flattening" of the posterior facet appears to occur with x-rays directed cephalad, whereas this relationship is reversed in the caudal and anteriorly directed x-rays. Oblique radiographs result in the three anatomic landmarks not easily visualized "en face" as would be expected in the perfect lateral x-ray. Instead, a double shadow of the landmarks is seen rendering it difficult for clinicians to estimate Bohler's angle.

True Bohler's Angles

As previously noted, the true Bohler's angle was found to vary based on the obliquity of the lateral fluoroscopic image, which is in direct contrast to the results of Malissard et al. In their study, Malissard et al demonstrated that Bohler's angle was constant despite an obliquity of up to 15 degrees in all planes.[11] Our findings suggest that Bohler's angle does indeed vary with a difference of up to 6 degrees when the x-ray beam is directed 15 degrees cephalad. This difference is increased to 11 degrees when the x-ray beam is directed 25 degrees cephalad. However even considering this information, the data still show that Bohler's angle does not vary significantly with posteriorly directed oblique radiographs – only a two-degree change with 25-degree oblique lat-

erals. This would imply that although posteriorly directed oblique images may be acceptable, clinicians should avoid oblique radiographs in the cephalad direction.

The results of our study should be interpreted in the following context: There were only 41 participants (five attending orthopaedic physicians and 36 orthopaedic residents in all levels of training) involved. A broader sample size of participants may change the direction of the results.

Conclusion

The study findings reveal that orthopaedic surgeons' ability to accurately measure Bohler's angle significantly decreases with increasing obliquity of lateral radiographs. In addition, the true Bohler's angle varies most with increasing obliquity in the cephalad direction, but less so with posteriorly directed x-rays. Although perfect hindfoot laterals are ideal, posteriorly directed oblique images may be acceptable. Oblique lateral radiographs in the cephalad direction should be avoided. Surgeons should be aware of variations in true Bohler's angle, as well as difficulties with accurately measuring this angle with oblique lateral x-rays when evaluating patients with intra-articular calcaneus fractures. Understanding these subtle changes should enable surgeons to more carefully interpret data obtained from oblique lateral radiographs, both when deciding upon the need for CT and/or when determining operative versus nonoperative treatment based solely on Bohler's angles.

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Analysis of Medial Collateral Ligament Injuries of the Knee

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Abstract: The medial collateral ligament (MCL) is the most commonly injured ligament of the knee. The typical mechanism is a valgus force on a flexed knee, but severe MCL injuries may be associated with other forces, particularly in high energy trauma and complex knee injury patterns. MCL injuries may occur as an isolated event or in the setting of multiligamentous, meniscal, and other associated knee pathology. Most MCL injuries are nonoperative and can be managed appropriately by primary care physicians or sports medicine specialists. A reasonable period of bracing and attention to the type of physical therapy utilized are essential for optimizing a rapid recovery and an excellent outcome. Most importantly, it is essential to rule out concomitant intra-articular pathology, particularly for higher grade injuries. An accurate history, a detailed physical exam, and appropriate imaging are necessary in all cases. Cruciate ligament rupture, meniscus tears, and osteochondral defects may require surgical intervention and should be rapidly detected. A literature review and our clinical experience support these basic principles.

Keywords: medial collateral ligament (MCL), medial knee injury, knee ligament injury, multiligament injury

The medial collateral ligament (MCL) provides primary resistance to valgus forces at the knee in flexion. It is the principal static stabilizer of the medial side of the knee, and provides resistance to valgus stress as well as internal and external rotation.[1, 2] A cadaver study by Haimes et al. showed that sectioning of the superficial MCL caused significant increases in valgus angulation at 15, 30, 60, and 90 degrees of flexion but not in full extension.[3] The MCL contributes to dynamic stability via its muscular attachments, including the pes anserinus, semimembranosus, and vastus medialis. The MCL also provides restraint to anterior tibial translation via attachment of the deep fibers of the MCL to the medial meniscus, which appear to stabilize the posterior horn, particularly in the setting of an anterior cruciate ligament (ACL)-deficient knee.[2, 4]

The posteromedial corner consists of the anatomic structures between the posterior border of the MCL and the medial border of the posterior cruciate ligament (PCL). The posteromedial corner is comprised of the posterior oblique ligament (POL), expansions of the semimembranosus, oblique popliteal ligament, and posterior horn of the medial meniscus.[5-7] This complex is a primary stabilizer of the extended knee and is the primary restraint to valgus stress and internal rotation in full extension.[2, 7] Haimes et al. demonstrated that transection of structures within the posteromedial corner in addition to the MCL significantly increased both valgus angulation and external rotation at all flexion angles.[3]

The MCL is also the most commonly injured

ligament of the knee.[8] The typical mechanism is a valgus force on a flexed knee, but severe MCL injuries may be associated with other forces, particularly in high energy trauma and in complex knee injury patterns. MCL injuries may occur as an isolated event or in the setting of multiligamentous, meniscal, and other associated knee pathology.

MCL injuries are classified clinically by grade, which refers to the amount of joint line opening with a valgus force, and by degree, which refers to the quality of the endpoint when laxity exists. According to the American Medical Association, clinical grade is evaluated with a valgus force at 30 degrees of flexion.[9] A grade 1 sprain is defined as 0-5mm valgus laxity which corresponds to stretching and minor tearing of the MCL. This correlates with the definition of a first-degree sprain, where there is tenderness over the MCL but no instability. A grade 2 sprain is defined as 6-10mm valgus laxity on exam which corresponds to a significant partial tear of the MCL. This correlates with the definition of a second-degree sprain where there is increased valgus laxity

with a firm endpoint. A grade 3 injury is defined as greater than 10mm of joint line opening which corresponds to a complete rupture of the MCL. This correlates with the definition of a third-degree injury where there is significant laxity with no appreciable endpoint.[9, 10] (Table 1)

There are several classification systems for MCL injuries which use a combination of clinical valgus laxity, quality of endpoint, and MRI findings to describe the severity of injury. There is no standardized method of classification but most surgeons use a system that combines these elements to describe the injury. The most commonly used system defines a grade 1 injury as a microscopic tear of the superficial MCL, with no instability or laxity to valgus stress, and a grossly intact ligament on MRI scan with periligamentous edema.[2, 10, 11] A grade 2 injury is an incomplete tear with both microscopic and gross disruption of the superficial fibers of the MCL. This causes 5-15 degrees of valgus instability at 30 degrees of flexion, but no rotatory instability or instability in extension. A grade 2 injury is characterized by a firm endpoint, and MRI scan

TABLE 1. Commonly used classification system for MCL injuries				
	Valgus Laxity (at 30° of flexion)	Quality of Endpoint	Other Examination Findings	MRI Findings	Pathology
Grade 1	0 – 5 mm	Firm endpoint	Tenderness over MCL with no Instability	Grossly intact ligament with periligamentous edema	Microscopic tear of the superficial MCL
Grade 2	6 – 10 mm	Firm endpoint	Increased valgus laxity with 5-15°of valgus instability at 30° of flexion No rotatory instability or instability in extension	Partial tear of the superficial MCL with surrounding edema	Incomplete tear with microscopic and gross disruption of the superficial fibers of the MCL
Grade 3	>10 mm	No appreciable endpoint	Significant valgus laxity with more than 15° of instability to valgus stress at 30° of flexion with no definite endpoint There may also be rotatory instability, instability in extension	Full-thickness tear of the superficial MCL and periligamentous edema	Complete rupture of the MCL complex

References[2, 10, 11]

demonstrates a partial tear of the superficial MCL with surrounding edema. A grade 3 injury refers to a complete tear of the MCL complex with more than 15 degrees of instability to valgus stress at 30 degrees of flexion with no definite endpoint. There may also be rotatory instability and instability in extension. MRI scan demonstrates a full-thickness tear of the superficial MCL and periligamentous edema.[2, 10, 11] (Table 1).

With a severe MCL injury, damage to other anatomic structures must be considered. The likelihood of damage to other ligaments increases with the grade of the MCL injury. According to Fetto and Marshall, in a study of 265 patients, the risk of having a concomitant ligament injury was 20% with a grade 1 MCL injury, 53% with a grade 2 MCL injury, and 78% with a grade 3 MCL injury.[8] The most common pattern of combined injury involves the MCL and ACL, comprising 7-8% of all ligamentous knee injuries[5, 12] and 70% of all multiligamentous knee injuries.[13] Most studies agree that the second most common combination involves the MCL and PCL, comprising approximately 1% of all ligamentous knee injuries[5, 12] though a large study by Kaeding et al.[13] found this pattern to be the least common, comprising 0.4% of all multiligamentous injuries.

The most worrisome is a multiligamentous injury involving the MCL plus two or three additional ligaments (ACL, PCL, and LCL in any combination), often associated with a history of knee dislocation. In general, traumatic knee dislocations are uncommon, accounting for <0.02% of all orthopaedic injuries, but since they often spontaneously reduce before initial evaluation, the true incidence is unknown.[14] According to Kaeding et al.,[13] the ACL/PCL/MCL combination comprises 4.2% and the ACL/PCL/LCL/MCL combination comprises 1.1% of all multiligamentous knee injuries. Dislocation commonly involves injury to multiple ligaments of the knee, resulting in multidirectional instability. Associated meniscal, osteochondral, and neurovascular injuries are often present and can complicate management.[14-16]

Rotatory instability, a positive dial test or a positive Swain test, and valgus laxity in full extension are indicative of injury to the posteromedial corner and should increase suspicion of injury to the cruciate ligaments as well.[3, 6] Combined MCL and posteromedial corner injuries may be more prevalent than previously thought. Sims et al.[6] performed a retrospective cohort study evaluating operative isolated and combined medial-sided knee injuries in 93 patients. They found that 99% of patients had an injury to the posterior oblique ligament, 70% had an injury of the semimembranosus capsular attachment, and 30% had complete peripheral detachment of the meniscus.

Halinen et al.[17] demonstrated that in multiligamentous knee injuries involving ACL rupture and grade 3 MCL injury, nonoperative and early operative treatment of the MCL injury with early ACL reconstruction yielded similar results at two year followup. Postoperative management included utilization of a brace at all times for 6 weeks followed by an additional 2 weeks during the day. Nonoperative management of the MCL with concomitant reconstruction of the ACL has demonstrated good results in the short term, but there is continued concern that an incompetent MCL can reduce the mechanical strength of the ACL graft leading to premature rupture.[17-20]

Acute reconstruction of the ACL (within 3 weeks of injury) initially appeared to have a greater risk of arthrofibrosis and decreased postoperative range of motion, particularly if the MCL was also reconstructed at the same time.[21, 22] Petersen et al.[23] studied patients with combined ACL and MCL injuries where the MCL was treated nonoperatively. Early ACL reconstruction (within three weeks of injury) was followed by postoperative brace treatment for 6 weeks. Late ACL reconstruction (after a minimum of 10 weeks) was preceded by 6 weeks of brace treatment followed by a period of accelerated rehabilitation. Patients with late ACL reconstruction had better postoperative range of motion resulting in a lower rate of repeat arthroscopy for loss of extension: 4/27 patients or 15% of the early reconstructions and 1/37 patients or 3% of the late reconstructions

required arthroscopy for stiffness. More recently Halinen et al.[24] studied a group of 47 patients with complete ACL and MCL ruptures. Subjects were randomized to early ACL reconstruction with MCL repair or early ACL reconstruction and nonoperative management of the MCL. They found that all patients achieved full knee extension. Nonoperative treatment of the torn MCL allowed faster restoration of flexion and quadriceps muscle power, but at 52 weeks there was no significant difference in outcomes between patients treated operatively and nonoperatively for the MCL.

For patients requiring surgery it is also essential to address meniscal tears, osteochondral defects, and other intra-articular pathology, particularly in multiligamentous knee injuries. Associated intra-articular injuries have an increasing prevalence in multiligamentous knee injuries, high grade MCL lesions, and chronic MCL injuries. A persistent effusion in the setting of a suspected isolated MCL injury should raise concern for intra-articular injury.[25] Miller et al.[11] reported that the prevalence of trabecular microfractures was 45% in a cohort of 65 patients with isolated grade 2 or grade 3 MCL injuries. These were primarily located on the lateral femoral condyle or lateral tibial plateau, and completely resolved within two to four months after injury in all cases.

A large study by Kaeding et al.13 analyzed the pattern of intra-articular chondral and meniscal damage in subjects with multiligament knee injuries undergoing surgery. Data from 2,265 subjects showed that the ACL/MCL injury pattern was the most common, comprising 70% of all multiligament injuries. Lateral meniscal damage was significantly greater and medial meniscal damage was significantly less in this group as compared to the group with ACL injury only. There was no significant difference in medial or lateral meniscal damage in the ACL/PCL/MCL or ACL/PCL/LCL/MCL groups as compared to the group with ACL injury only. Taken together, multiligament knee injuries had a 30% incidence of medial meniscus injury for patients who under-

went surgery less than 12 months after injury, and 64% for patients who underwent surgery more than 12 months after injury. The incidence of lateral meniscus injury was similar between groups. These findings paralleled the findings in the group with ACL injury only. Articular damage to the medial tibial plateau was significantly lower in the ACL/MCL group, and all other multiligament injury patterns showed chondral damage similar to the group with ACL injury only. Taken together, multiligament knee injuries that underwent knee reconstruction before 12 months had significantly less chondral damage on all surfaces compared with those who underwent knee reconstruction after 12 months. Overall, ligament injuries repaired acutely had significantly less articular and medial meniscal damage than repairs performed in a delayed fashion.

The correlation between knee ligament insufficiency, timing of reconstruction, and degenerative changes has been clearly shown in studies with isolated ACL injuries.[26-29] A study by Kennedy et al.[30] evaluated a series of 300 athletic patients under 40 years old with isolated ACL injuries. The researchers divided them into groups based on time from initial injury to ACL reconstruction. They found that the incidence of articular cartilage degeneration was significantly higher in patients who had surgery more than 6 months after injury (odds ratio = 4). In addition, the greatest severity of articular cartilage degeneration was found in the group that had the longest delay to surgery (>18 months). Likewise, there was a significantly higher incidence of medial meniscal tears in patients who underwent ACL reconstruction more than 12 months after injury (odds ratio = 8), but the odds of having a lateral meniscus tear did not change significantly with increasing time to surgery. Overall, acute ACL reconstruction with meniscal preservation has been shown to achieve the lowest incidence of degenerative change.[26, 27]

The literature suggests that low grade MCL injuries are common, and that relatively few high grade isolated and combined multiligamentous

MCL injuries ultimately require surgery. Evidence-based guidelines indicate that isolated MCL grade 1 and grade 2 injuries can be treated nonoperatively. Isolated grade 3 (complete disruption) MCL injuries have also been successfully treated nonoperatively in many series, including in elite athletes.[31, 32] Most MCL injuries are managed conservatively with bracing, physical therapy, and guarded return to activities. These are often appropriately treated by primary care physicians or sports medicine specialists. However, consideration may be given to operative management of grade 3 injuries in certain situations:

- Multiligamentous knee injury

- Chronic symptomatic valgus instability

- Pellegrini-Stieda lesion where ossification of the femoral attachment of the MCL with associated pain and restricted movements may require excision of the bony lesion and reconstruction of the MCL.[33, 34]

- Stener-type lesion where the distal MCL is torn and the pes anserinus tendons become interposed between the MCL and the tibia, interfering with healing.

In the setting of a multiligamentous knee injury, controversy exists with respect to operative stabilization or conservative management of the concomitant MCL injury. Patients likely prefer a knee that is mildly lax but functional with full range of motion as opposed to a stiff, painful, stable knee.[12] In the multiligament-injured knee, a well-accepted approach based on that described by Indelicato for ACL/MCL injuries is often utilized.[2, 25] This protocol involves physical therapy for several weeks, which provides time for the MCL to heal and allows the patient to regain full knee range of motion. Once the preoperative rehabilitation is complete, the patient undergoes operative reconstruction of the cruciate ligaments. After cruciate reconstruction, the MCL is tested at 0 and 30 degrees of flexion intraoperatively. If significant laxity to valgus stress is observed as compared to the contralateral side,

the MCL is surgically addressed. Indications for choosing either repair or reconstruction of the MCL and options for surgical technique are variables which seem to affect outcome but for which there is no consensus.

Physical therapy is another area of high importance for optimum outcome of both nonoperative and operative MCL injuries.[14] Early mobilization is an important principle of both operative and nonoperative treatment. In a study performed on dogs, transection of the superficial MCL was performed and subjects were separated into three treatment groups including early motion, immobilization for 3 weeks, or immobilization for 6 weeks. Early motion resulted in enhanced healing and improved biomechanical properties of the superficial MCL.[35] Mobilization after ligament injury improves the longitudinal alignment and concentration of cells and collagen and increases the ultimate load of the healing tissue.[2, 36, 37] In addition, early knee motion appears to be protective against damage to articular cartilage and degenerative changes of the joint.[38]

For postoperative rehabilitation of multiligamentous knee injuries, physical therapy is tailored towards optimizing healing of the cruciate ligaments. A hinged knee brace that provides stability in the coronal plane but allows full knee range of motion is often used to protect the MCL without immobilizing the knee.

Giannotti et al.[39] published guidelines for a functional rehabilitation program after isolated grade 3 MCL injuries. They state that "good to excellent results can be expected with a return to full preinjury activity level being the norm." A simple hinged knee brace is used initially to protect the knee from valgus stress. Depending on the activity, bracing may be continued until the patient feels stable and safe playing without it. The protocol outlines four phases covering a time span of 10-12 weeks. During phase 1 (0-4 weeks), goals are to decrease swelling, restore knee range of motion from 0-100 degrees, gain 4/5 quadriceps and hamstring strength, restore a normal gait pattern, and restore full-weight-bearing

status. Treatment during phase 1 includes cryotherapy, electrical muscle stimulation, stretching, range of motion exercises, and quadriceps and hamstring strengthening. During phase 2 (4-6 weeks), goals are to continue to control swelling, restore full knee range of motion from 0-140 degrees, and gain 5/5 quadriceps and hamstring strength. Treatment during phase 2 includes cryotherapy, closed chain exercises, and static proprioceptive exercises. During phase 3 (6-10 weeks) goals are to regain the ability to perform squats, return to light jogging and agility skills, and possibly progress to sport-specific skills and competition. Treatment during phase 3 includes treadmill jogging, dynamic proprioceptive exercises, slide board training and rebounder training. During phase 4 (8-12 weeks) goals are to attain 95% quadriceps index and 90% single leg hop index, return to full running and sport-specific drills, and resume competition. Treatment during phase 4 includes plyometric training, full agility and sport-specific drills, continued dynamic proprioceptive exercises and rebounder training, and road running. In general, return to competition is allowed after the following are achieved: there are no signs or symptoms of instability and there is a normal ligament exam; quadriceps strength is at least 90% when compared to the contralateral extremity; and sport-specific skills, agility testing, and athletic activities do not cause any pain.[39]

Methods

We evaluated our own data and performed an analysis of the patterns of MCL injuries and the management of these injuries by a single surgeon at the Sports Medicine Center at the Massachusetts General Hospital between July 2001 and August 2011. After IRB approval was obtained, patients with MCL-injured knees were identified in the electronic medical records system. The database was queried using the diagnosis codes 844.1 (sprain or strain of the MCL in the knee) and 717.82 (old disruption of MCL in the knee). In addition the database

was queried using the procedure codes 27405 (primary repair of collateral ligament and/or capsule of the knee) and 27599 (unlisted procedure, femur or knee). Injuries included any type of isolated MCL or multiligamentous knee injury where the MCL was repaired or reconstructed. Medical records were reviewed in order to determine demographic information, mechanism of injury, anatomical structures involved, pattern of injury, time from injury to surgical intervention, operative indications, method of surgical repair or reconstruction, whether additional surgeries were required, and clinical and functional outcome.

Results

Each year, approximately 4000 patients were seen and approximately 800 surgeries were performed. Over the ten year period, 385 patients were evaluated with MCL injuries of all grades, accounting for less than 1% of the total clinic volume. Of these, only 19 patients had operative repair or reconstruction of the MCL for a total of 20 surgeries (one required revision). Thus, only 5% of MCL injuries evaluated underwent surgery, which reflects approximately 0.25% of the total surgical volume the clinic. Clearly MCL repair and reconstruction were rarely performed.

Of the population of patients evaluated with MCL injuries, 351 were acute injuries and 34 were chronic injuries at the time of presentation. Of the 351 acute injuries, 175 (50%) were isolated MCL injuries; 136 (39%) involved the MCL and one or both cruciate ligaments; 63 (18%) involved the MCL and one or both menisci; and 43 (12%) involved the MCL, one or both cruciate ligaments, and one or both menisci. Of the 34 chronic injuries, 10 (29%) were isolated MCL injuries; 20 (59%) involved the MCL and one or both cruciate ligaments; 8 (24%) involved the MCL and one or both menisci; and 6 (18%) involved the MCL, one or both cruciate ligaments, and one or both menisci. (Table 2)

TABLE 2. Pattern of knee ligament injury and chronicity of injury in patients evaluated for MCL injury of any grade*				
	Isolated MCL	MCL plus one or both cruciates	MCL plus one or both menisci	MCL plus one or both cruciates AND one or both menisci	Total
Acute	175 (50%)	136 (39%)	63 (18%)	43 (12%)	351
Chronic	10 (29%)	20 (59%)	8 (24%)	6 (18%)	34

*All operative and nonoperative cases

The demographics and mechanism of injury of the 19 operative cases showed the following: men outnumbered women by 17 to 2 (90% men); the average age at the time of surgery was 33 (range 16 to 64); two patients were professional athletes and were injured playing their sport; and there were 13 sports injuries, 6 high energy trauma injuries, and 2 injuries at work. There were 4 chronic injuries, defined as presenting more than 6 months after injury. There were 4 patients with prior surgery in the ipsilateral knee. There were 7 left and 12 right knees, and all MCL injuries were classified as either grade 2 or grade 3.

Almost all operative cases had more than one incompetent ligament at the time of injury.

- **Isolated MCL injury:** 2 out of 19 (10%)

  o Both patients with isolated MCL injuries had undergone a prior remote ACL reconstruction and had no history of previous MCL injury.

  o Injury to the posteromedial corner was also diagnosed in both cases.

- **ACL + MCL combination:** 7 out of 19 (37%)

  o One patient in this group had a remote ACL reconstruction and MCL repair. He sustained a new injury and ruptured both the ACL graft and MCL repair. He underwent repeat ACL reconstruction and MCL repair, but the revision MCL repair failed and he required MCL reconstruction.

- **PCL + MCL combination:** 2 out of 19 (10%)

  o Both patients had chronic injuries (time from injury to surgery was more than 9 months in both cases).

- **ACL/PCL/MCL combination** (all were documented dislocations): 5 out of 19 (26%)

- **ACL/PCL/MCL/LCL combination** (all were documented dislocations): 3 out of 19 (16%)

Most patients had concomitant injuries in the same knee. As indicated above, 9/19 patients (47%) had one cruciate ligament ruptured and 8/19 patients (42%) had knee dislocations with both cruciate ligaments ruptured. In addition, 14/19 patients (74%) had meniscal pathology requiring partial resection or repair. Osteochondral defects, chondral injury, or significant degenerative changes of the cartilage were found in 10/19 patients (53%) (Table 3).

Overall, our experience was similar to that of previously published studies in terms of the following parameters: demographics; mechanism of injury; time from injury to surgical intervention; pattern of ligamentous injury deemed appropriate for surgery; prevalence of concomitant intra-articular injuries; and the direct relationship between chronicity and prevalence of both meniscal injury and articular cartilage defects.

There are two apparent exceptions which deserve further explanation. First, our results suggest that the risks for meniscal injury and cartilage defects were highest in the MCL/PCL group

TABLE 3. Pattern of knee ligament injury in patients undergoing MCL repair						
	Isolated MCL	MCL & ACL	MCL & PCL	MCL & ACL/ PCL	MCL& ACL/ PCL/ LCL	Total
Ligaments Injured	2/19 (10%)	7/19 (37%)	2/19 (10%)	5/19 (26%)	3/19 (16%)	19/19 (100%)
Meniscus Injury	Prevalence* 2/2 : 100%	Prevalence 5/7 : 70%	Prevalence 2/2 : 100%	Prevalence 2/5 : 40%	Prevalence 3/3 : 100%	Prevalence 14/19 : 74%
	Medial 1/2 : 50%	Medial 3/7 : 43%	Medial 2/2 : 100%	Medial 1/5 : 20%	Medial 1/3 : 33%	Medial 8/19 : 42%
	Lateral 1/2 : 50%	Lateral 3/7 : 43%	Lateral 2/2 : 100%	Lateral 2/5 : 40%	Lateral 3/3 : 100%	Lateral 11/19 : 58%
	Both 0/2 : 0%	Both 1/7 : 14%	Both 2/2 : 100%	Both 1/5 : 20%	Both 1/3 : 33%	Both 5/19 : 26%
OCD, Chondral Injury, or Degenerative Changes of Cartilage	2/2 (100%)	3/7 (43%)	2/2 (100%)	2/5 (40%)	1/3 (33%)	10/19 (53%)
Posteromedial Corner Injury	2/2 (100%)	0/7 (0%)	0/2 (0%)	1/5 (20%)	1/3 (33%)	4/19 (21%)

*Prevalence refers to the total number of patients having any meniscal injury

MCL = medial collateral ligament, ACL = anterior cruciate ligament, PCL = posterior cruciate ligament, LCL = lateral collateral ligament, OCD = osteochondral defect

where 2/2 patients (100%) had defects in articular cartilage as well as both medial and lateral menisci (Table 3). However, both of the MCL/PCL patients in our series had chronic injuries. Prior studies have demonstrated that the prevalence of degenerative changes, including meniscal tear and articular cartilage defects, is higher in chronic injury groups.[13, 26-29] Our results also suggest that the risk for meniscal injury was highest in the chronic injury group, in which 4/4 patients (100%) had a meniscal injury and 3/4 patients (75%) had defects in both medial and lateral menisci (Table 4). Our results also suggest that the risk for articular cartilage defects was high in both the intermediate and chronic injury groups, where 3/4 patients (75%) had evidence of chondral damage at the time of surgery (Table 4). It is possible that that the meniscal injuries and cartilage defects noted in the MCL/PCL group were

primarily related to chronicity rather than ligament injury pattern.

The second apparent exception is related to the unanticipated finding that both patients with isolated MCL injuries had concomitant meniscal, articular cartilage, and posteromedial corner injuries. All of these injuries were observed in 2/2 patients (100%) (Table 3). However, both of these patients had prior trauma to the same knee and had required ACL reconstruction in the past. This history suggests that there may be a cumulative effect of multiple traumas or a component of mild chronic ligamentous insufficiency contributing to the observed pathology.

Surgery was most frequently performed between 30 and 90 days after injury. This delay was intended to allow the acute knee effusion to resolve, give the MCL time to heal independently, and allow the patient to regain full range of

TABLE 4. Timing of surgical intervention and concomitant meniscal injury or articular cartilage defect				
	Acute: Surgery <30 days Post-injury	**Subacute: Surgery** 31-90 days Post-injury	**Intermediate: Surgery** 91-180 days Post-injury	**Chronic: Surgery** >181 days Post-injury	**Total**
Total numbers	2/19 (10%)	9/19 (47%)	4/19 (21%)	4/19 (21%)	19/19 (100%)
Meniscus Injury	*Prevalence** 2/2 : 100% *Medial* 1/2 : 50% *Lateral* 1/2 : 50% *Both* 0/2 : 0%	*Prevalence* 6/9 : 67% *Medial* 3/9 : 33% *Lateral* 5/9 : 56% *Both* 2/9 : 22%	*Prevalence* 2/4 : 50% *Medial* 0/4 : 0% *Lateral* 2/4 : 50% *Both* 0/4 : 0%	*Prevalence* 4/4 : 100% *Medial* 4/4 : 100% *Lateral* 3/4 : 75% *Both* 3/4 : 75%	*Prevalence* 14/19 : 74% *Medial* 8/19 : 42% *Lateral* 11/19 : 58% *Both* 5/19 : 26%
OCD, Chondral Injury, or Degenerative Changes of Cartilage	2/2 (100%)	2/9 (22%)	3/4 (75%)	3/4 (75%)	10/19 (53%)

*Prevalence refers to the total number of patients having any meniscal injury

OCD = osteochondral defect

motion with physical therapy. In the case of severe trauma, however, repair was often delayed for more than a year. Only 2/19 cases (10%) underwent staged surgery, and these were for knee dislocations in the setting of high energy trauma. Acute surgical repair (<30 days post-injury) was performed in another 2/19 cases (10%); both were professional athletes. The majority, 9/19 cases (47%), underwent subacute repair (31-90 days post-injury); 4/19 cases (21%) underwent intermediate repair (91-180 days post-injury); and 4/19 cases (21%) underwent delayed repair (> 181 days post-injury) (Table 4). The surgical patients with higher energy trauma, knee dislocations, other concomitant injuries in the same knee, and chronic injuries had generally poorer outcomes with respect to stability, pain, and development of degenerative changes in the knee.

In our series there were 18 MCL repairs and 2 reconstructions in 19 patients (one was a revision). We follow a specific protocol when considering surgery for the MCL. For acute knee injuries, we recommend physical therapy for four to six weeks with a short period of bracing. This provides time for the MCL to heal and allows the patient to regain full knee range of motion. Once this period of rehabilitation is complete, isolated MCL injuries are examined for persistent valgus laxity, quality of endpoint, and pain. Depending on the findings surgery may be considered. If there is a concomitant injury to one or both cruciate ligaments, they are reconstructed, and immediately afterward an intraoperative examination of the MCL at 0 and 30 degrees of flexion is performed. If there is significant valgus laxity compared to the contralateral knee, the MCL is repaired, with or without repair of the posteromedial corner as indicated at the time of surgery. In our practice MCL repairs are performed using

a pants-over-vest imbrication technique. MCL reconstructions are reserved for failed repairs or cases with severely attenuated tissues.

Summary

Evidence from the literature and our experience supports several conclusions:

• Most MCL injuries are nonoperative and can be managed appropriately by their primary care physicians or sports medicine specialists. This is likely the reason that such a common injury comprises such a small proportion of a surgeon's practice.

• An appropriate period of bracing and attention to the type of physical therapy utilized is essential for optimizing rapid recovery and an excellent outcome.

• Most importantly, it is essential to rule out concomitant intra-articular pathology, particularly for higher grade injuries. An accurate history, a detailed physical exam, and appropriate imaging are necessary in all cases. Cruciate ligament rupture, meniscus tears, and osteochondral defects may require surgical intervention and should be rapidly detected.

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Granular Cell Tumor Presenting as a Pediatric Spinal Deformity

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Abstract: Granular cell tumors (GCTs) occur very rarely in the pediatric population. A granular cell tumor arising from the epidural spinal canal itself has never been described in a pediatric patient. We present a case of an epidural-based granular cell tumor that presented with a rapidly progressive scoliotic deformity in a 12 year-old boy. The computed tomography (CT) and magnetic resonance imaging (MRI) studies showed a dumbbell-shaped lesion, consistent with a neurogenic paravertebral tumor. However, the pre-operative needle biopsy showed positive immunohistochemical staining for S-100 and histology was consistent with a granular cell tumor. A single-stage resection of the tumor with posterior segmental instrumentation yielded a successful result.

Keywords: astrocytoma, epidural, granular cell, paravertebral, neurofibromatosis, scoliosis

Granular cell tumors (GCTs) occur infrequently in the spine. Several studies have contributed to our understanding of the histology, origin and clinical course of these tumors. While the tumor was first described by Abrinkossoff in 1926, there is still debate regarding the true cell origin of the tumor. The vast majority of GCTs are benign, with malignant tumors accounting for less than 1%.[9] To date, granular cell tumors have been described in the breast, larynx, appendix, palm, eye, peripheral nerves and chest wall.[1,6,9,16,19] Granular cell tumors in the spine are extremely rare, with few reported to date. We report a case of a 12 year-old boy with a GCT found on imaging for atypical scoliosis. To our knowledge, the have been no reports in the literature of a GCT occurring this early presenting as neurogenic scoliosis.

Case Report

A 12-year old boy presented to our spine clinic for evaluation of a scoliotic deformity that was initially noticed by his pediatrician approximately one year earlier. He denied any activity-related or night pain. Family history was negative for neurofibromatosis, Marfan's Syndrome, cardiac or renal abnormalities. His father was diagnosed with scoliosis as a child but required no treatment. His father's history was also significant for medullary thyroid cancer and a lower extremity soft tissue sarcoma, both treated successfully with surgery, chemotherapy and radiation. Our patient had an unremarkable initial physical examination with no signs of hyperlaxity (0/5 on the Marshall scale) or spinal tenderness. He had no café au lait spots, hairy patches or dimples. He had level shoulders and pelvis. His initial Adam's forward bending test showed an axial trunk rotation by scoliometer reading of 7 degrees in the midthorax. His neurologic exam was benign.

Given the appearance of a new curve and a clinically suspicious reading on scoliometer testing, standing spinal radiographs were obtained which showed a Lenke 2 double tho-

racic curve which measured 25 degrees to the left in the upper thorax and 25 degrees to the right in the lower thorax by Cobb measurement. Pelvic films showed a Risser stage zero.

As he was asymptomatic, it was elected to monitor him clinically with repeat examinations and radiographs. He was seen in clinic four months later with a stable exam and radiographs. At the eight-month follow-up, radiographs demonstrated curve progression from 25 to 30 degrees in both curves. An MRI was obtained to rule out intraspinal abnormalities based on his young age of presentation and a new clinical exam finding of 2 beat ankle clonus.

The MRI showed a large, enhancing epidural lesion at T5 which extended out of the left T5-T6 neural foramen into the adjacent soft tissues (Figure 1a, 1cb, 1c). There was impingement on the spinal cord by the mass at that level without any signal changes within the cord. The mass measured 1.8 x2 2.4 cm and was low intensity on T2 (Figure 1b). A CT scan was obtained which showed no destructive elements of the mass or cortical breakthrough, but the diagnosis remained unclear. A percutaneous biopsy was obtained revealing polygonal tumor cells with finely eosinophillc cytoplasma and a moderate degree of nuclear atypia. Immunohistochemical stains revealed an S-100 positive tumor that was also negative for synaptophysisn, chromogranin and epithelial membrane antigen (EMA).

In consultation, it was felt that this was likely a benign process. The differential included meningioma, schwannoma, neurofibroma and based on immunohostochemistry, a granular cell tumor. After extensive patient and family counseling and education,

FIGURE 1. (A) Coronal T2-weighted MRI showing the tumor exiting the neuroforamen into the adjacent soft tissue at T5 (B) Saggital T2 showing the extent of the tumor from T4 to T6 (C) Axial T1-weighted showing the extent of the mass.
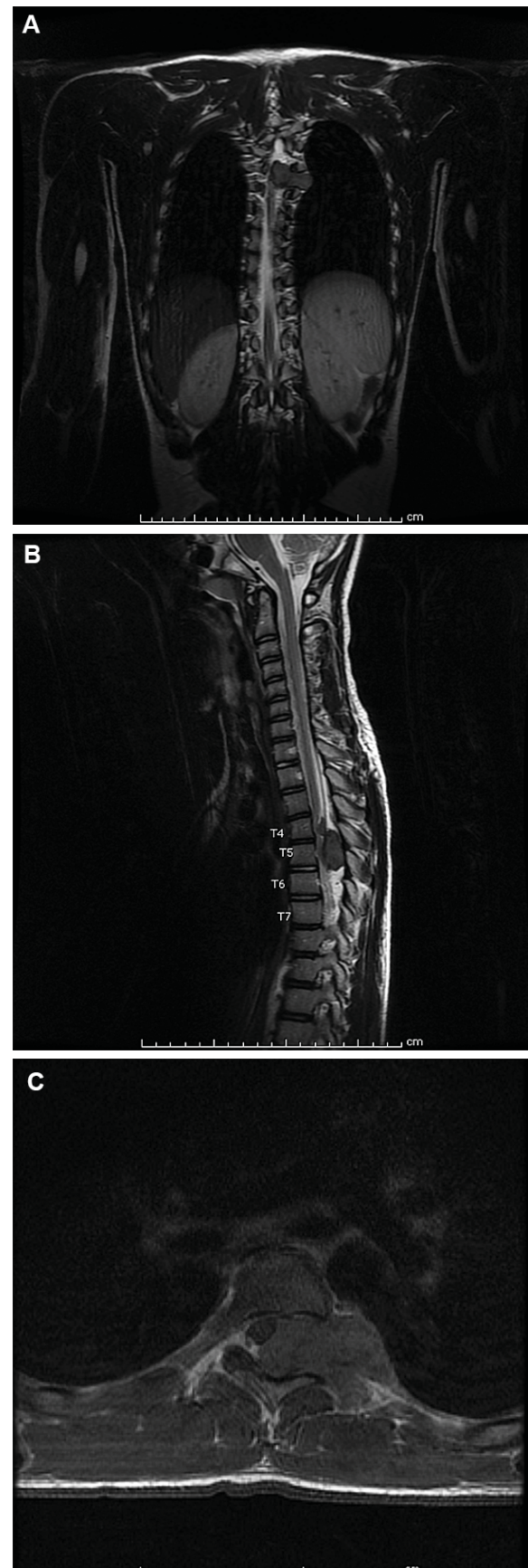
the decision was made to proceed with surgical intervention to prevent the risk of further spinal deformity and spinal cord compromise. During surgery, at the T5, an extradural mass was found extending between the facet joint of T5 and T6, exiting out of the neuroforamen and impinging on the adjacent soft tissues. The facet of T5 was completely removed to allow for adequate visualization from T4 to T6. A plane was developed between the dura and the tumor which allowed for complete excision of the mass. Grossly, this was a tan/pink irregular tissue with some overlying adipose tissue measuring 3.0 x 2.5 x 1.5cm. (Figure 2). Following debulking and hemostasis, pedicle screws and titanium rods with a single cross-link were placed from T3 to T6 with allograft and autograft bone. The wound was explored and was subsequently closed in layered fashion with a submuscular drain.

FIGURE 2. Gross specimen with tan, irregular borders and overlying adipose tissue measuring 3.0 x 2.5 x 1.5cm

Macroscopic Description

Histologically, sections of the tumor showed a well-circumscribed mass and strands of polygonal cells separated by thin fibrous septa. The cells had characteristic, copious, finely granular, eosinophilic cytoplasm. Despite a moderate degree of nuclear atypia, rare (1/10 HPF) mitoses were seen and no necrosis was present (Figure 3). Immunohistochemical stains were also performed, confirming the findings from the initial biopsy, which were S-100 and inhibin positive and, negative for synaptophysisn, chromogranin and EMA (Figure 4). Additionally, Olig-2 staining was neg-
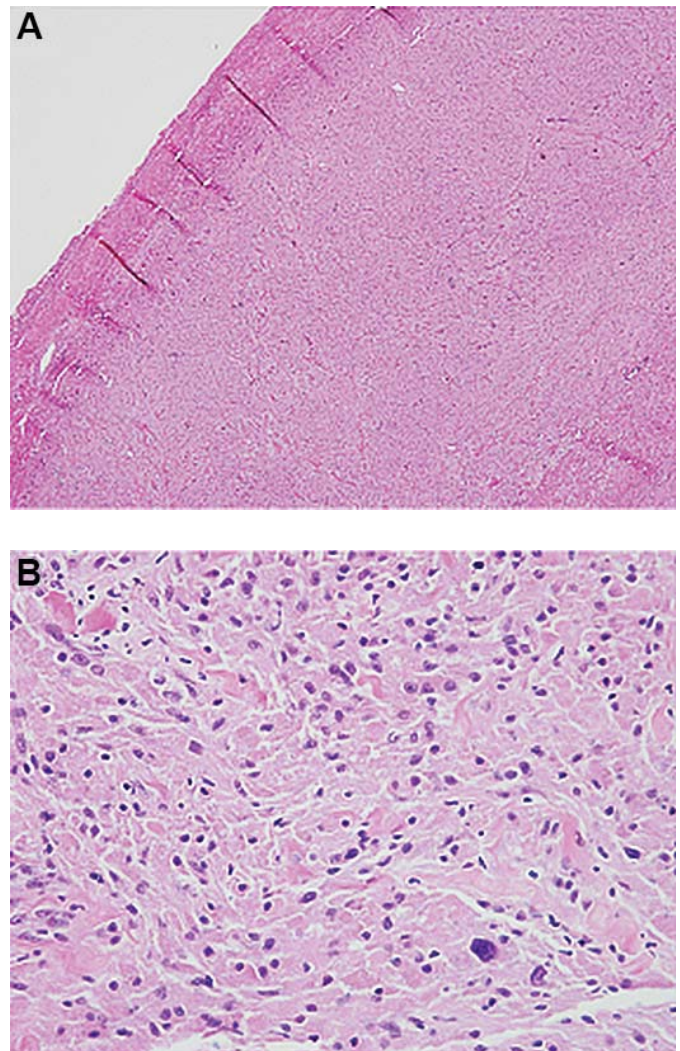
FIGURE 3. Hematoxylin and eosin stain revealed (A) a well-circumscribed mass composed of nests and strands of polygonal cells separated by thin fibrous septa. (B) The cells had abundant, finely granular, eosinophilic cytoplasm and a mild degree of nulcear atypia.
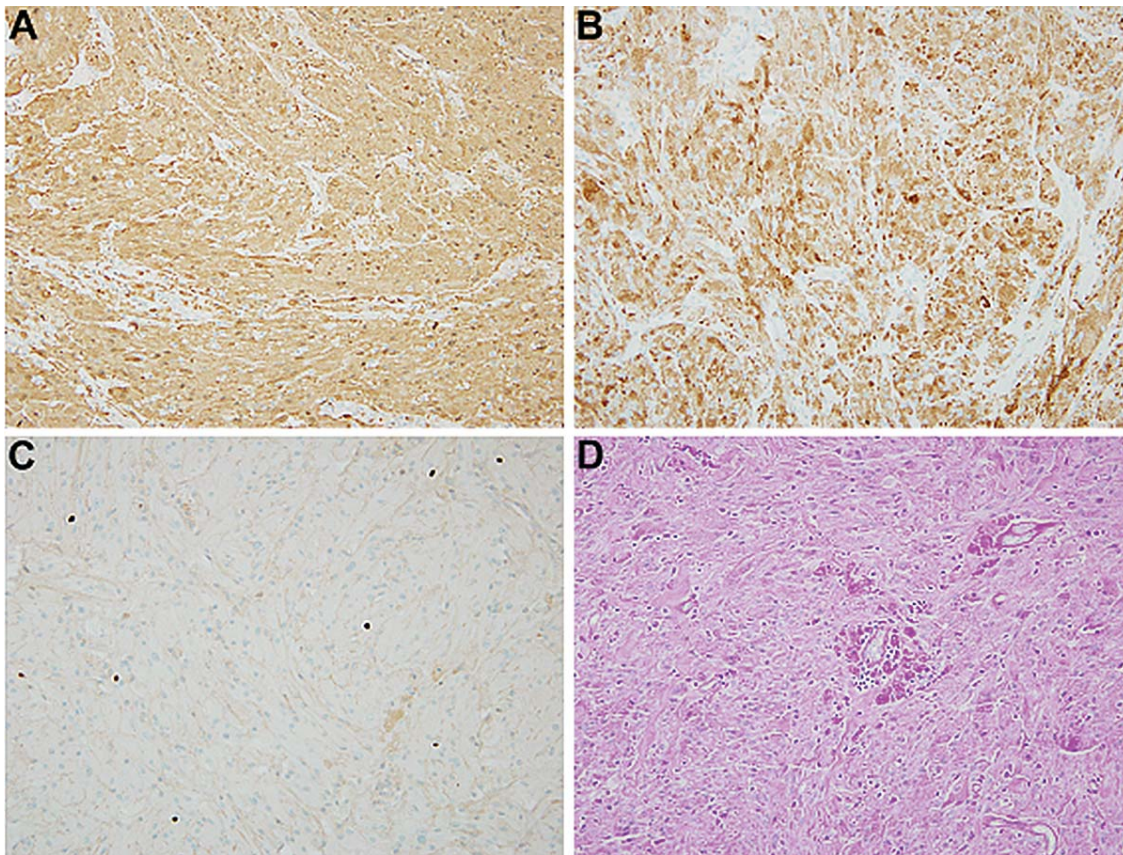
FIGURE 4. Neoplastic cells are diffusely immunoreactive with S-100 protein (A) and inhibin (B). The proliferation index by Ki-67 (MIB-1) was low (C). In addition, the cytoplasmic granules were periodic acid Schiff (PAS) positive (D).

ative and PAS staining showed granular cytoplasmic positivity. The proliferation index by Ki-67 (MIB-1) was estimated at 1-3%.

His post-operative course was uncomplicated and he was discharged home on post-op day five. On follow-up clinical evaluations, he is pain free and progressing well. At his one-month visit, his lower right thoracic curve was stable at 30 degrees and he was fitted for a brace (Figure 5). At his four-month follow-up, he had a stable curve and was wearing his brace 18-20 hours daily and tolerating it well.

FIGURE 5. Initial preoperative standing plain films with a high left thoracic curve of 25° and a right thoracic curve of 25°. Post-operative films show a stable curve.
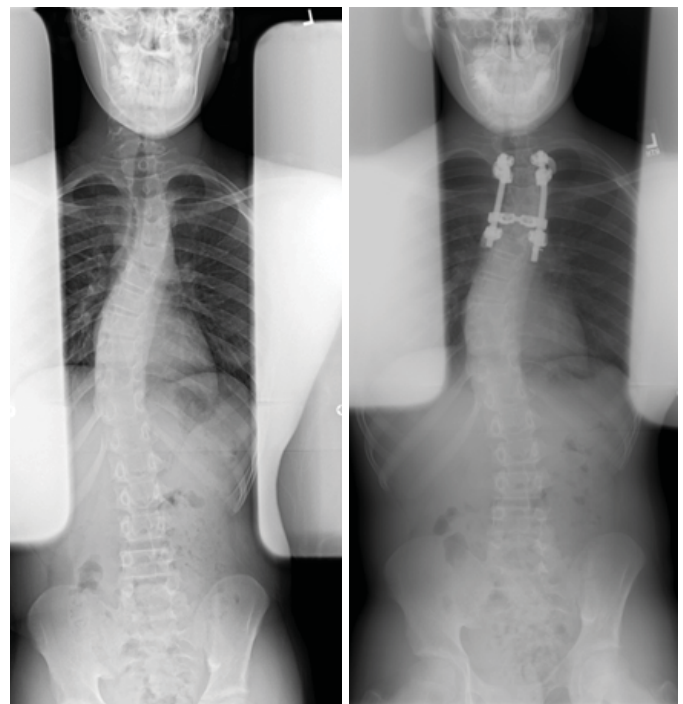
Discussion

Granular cell tumors (GCTs) occur very rarely in the pediatric population. The typical presentation is between the third and sixth decades with a female to male ratio of 2:1.[9,11] Most reports demonstrate their occurrences in epithelial tissue, the GI tract and occasionally in the spine and central nervous system (CNS).[1,2,6-9,12,13,16,17,19,20] The most common presentation is in the epithelial tissue where it presents as small, non-tender solitary nodules.[12] GCTs associated with spinal cord are exceptionally rare, with only four intradural cases in the literature to our knowledge.[4,7,19,20] A granular cell tumour arising from the epidural spinal cord has never been previously described. The distinctive pattern of granular cytoplasmic changes is due to the accumulation of lysosomes, although the histogenesis of the granular cell tumor is still uncertain.[5] It was first named "myoblastenmyome" in 1926 by Abrikossoff, but the cumulative evidence from many reports incorporating electron microscopy and immunohistochemical studies has ruled out this possibility and support a Schwannian differentiation.[14,15]

The pathological diagnosis of these tumors can be difficult. The granular appearance can share similar traits as infarcts, inflammatory processes and all manner of neoplasms. Therefore, initial biopsies should not be solely relied on for diagnosis.[3,21] For spinal tumors in this location, the differential will include schwannoma, neurofibroma, meningioma, ganglioneuroma, paraganglioma, and granular cell astrocytoma. Schwannoma and neurofibroma are the most important differential diagnostic considerations as they also be positive for S-100 protein, but negative for inhibin and tend to be more spindled and without cytoplasmic granularity. Meningiomas may have a whorled cytologic appearance, psammoma bodies, and are usually EMA positive. Paragangliomas have a zellballen pattern, with chief cells positive for chromogranin and synaptophysin, while sustentacular cells showing S-100 protein reaction. Ganglioneuroma has large, interspersed ganglion cells with prominent nuclei, showing a strong staining for synaptophysin and neurofilament protein. Similarly, the GFAP and OLIG-2 positivity would help to confirm the diagnosis of a granular cell astrocytoma (Table 1).

MRI is commonly used to aid in the diagnosis of this tumor. On the T1-weighted images, the tumors are well-defined, hypo-intense lesions compared to the spinal cord. T2-weighted images show a hyper-intense lesion which increases uniformly with contrast.[7,19]

The mainstay of treatment for this tumor is largely surgical excision. When occurring in the lumbar spine in an asymptomatic patient, some authors have recommended close observation for
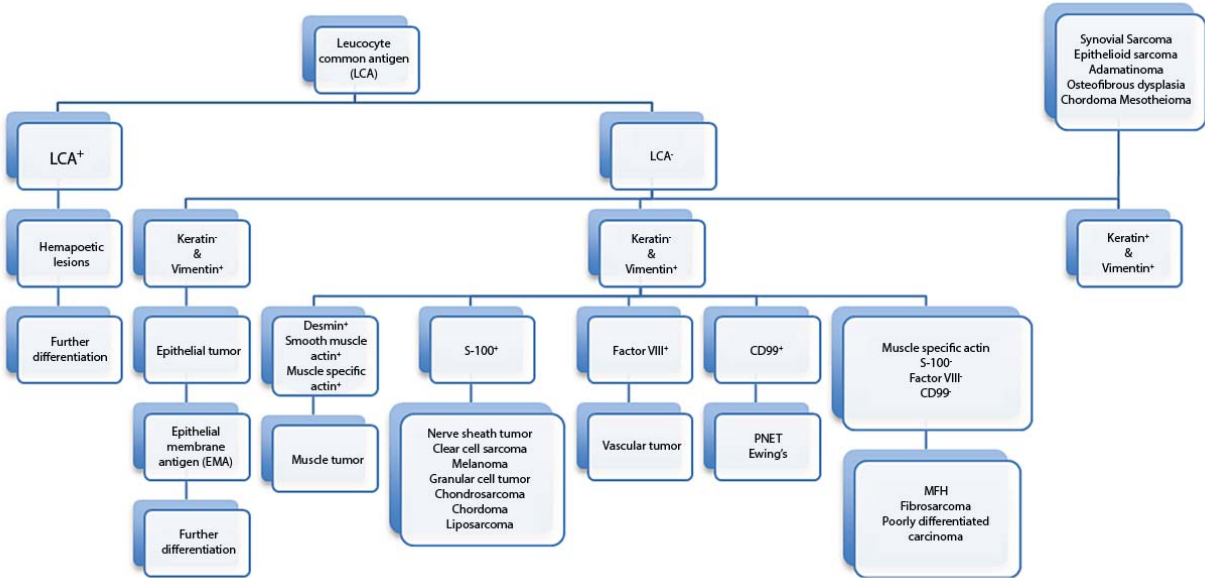

TABLE 1. Immunoperoxidase staining flowchart for poorly differentiated tumors.

signs of neurologic decline. However, although the majority of GCTs are benign, due to the anatomic constraints in the thoracic spinal canal and the risk of spinal cord compression, surgery should be considered early in the course.[18] Although Barrenechea described good results in a series of 13 patients from 1997-2004 who underwent endoscopic removal of paravertebral tumors via a hemilaminectomy followed by a thoracoscopy generally, the treatment is a posterior midline or paraspinal approach followed by excision.[2] Reported recurrence rates are approximately 7% in the case of incomplete resection.[9,10,14,15] In our patient, the extent of the tumor required spinal destabilization which was addressed with posterior stabilization and the patient has done well over time.

Conclusion

To our knowledge, this is the first report of an intraspinal GCT presenting as with scoliosis in the pediatric literature. The report underscores the importance of a systematic workup of patients who present with an atypical or progressive scoliotic deformity including close clinical follow-up, accurate physical examination, advanced imaging and an interdisciplinary approach to surgical decision-making.

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Spontaneous Dissociation of Prosthetic Humeral Head: A Case Report

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Abstract: Dissociation of a Morse taper arthroplasty is an uncommon occurrence, especially in the shoulder, reported in only one publication in the English literature.[1] In response to reported dissociations of Morse taper modular humeral components, Blevins et al. identified conditions that would interfere with the Morse taper interface strength. The relevant cases were reported only in a single component design and occurred between 1988-1992. Subsequent reports of consecutive arthroplasties with this prosthesis failed to document further episodes of Morse taper dissociation.[2]

In contradistinction, dissociation of the femoral heads in hip arthroplasty has been more commonly reported.[4,10-14] It most frequently occurs during reduction of a dislocated prosthesis that then needs to be surgically addressed. The dissociation is not always apparent on post-reduction radiographs, underlining the importance of scrutinizing the images for radiolucencies and the position of the head of the prosthesis in the acetabular cup.[7]

The present case pertains to a DePuy Global Advantage total shoulder prosthesis implanted in 2008. This prosthesis is a third generation anatomical model, unlike the 1988-1992 second generation component previously reported in the literature. Heretofore, there have been no cases of humeral head dissociation in third generation total shoulder prostheses.

The authors have obtained the patient's informed written consent for print and electronic publication of the case report.

Keywords: dissociation, shoulder, arthroplasty, case report, metallosis, articulation

A 65-year old female patient presented to our clinic three and a half years status post right total shoulder arthroplasty for rheumatoid arthritis. At the time of surgery, she underwent uncomplicated insertion of a DePuy Global Shoulder prosthesis, whereby the rotator cuff muscles were reportedly intact. She described pain and poor function of the shoulder since the procedure, with increasing pain and decreasing function over the preceding 8 months. The pain was reported as a 6/10 at rest to a 10/10 at its worst and awakened her from sleep; she reported a subjective shoulder value of 25%. Crepitus was noted during physical examination. The patient denied any inciting event or trauma.

Radiographs taken the day of the initial visit revealed dissociation of the humeral head from the humeral stem. The male component of the Morse taper appeared to be articulating with the glenoid component. CT revealed adequate glenoid

FIGURE 1. Plain films of the dissociated prosthesis at initial presentation

bone stock, an asymptomatic os acromiale, and the dissociation of the Morse taper (Figure 1).

On physical examination, the patient demonstrated a pseudoparalytic shoulder with significant atrophy of the spinati muscles. There was marked tenderness to palpation over the proximal humerus at the site of the humeral com-

ponent, with the appearance of the humeral component statically subluxed anteriorly and superiorly (anterior/superior escape). Range of motion on the affected side was less than 25° of forward flexion and abduction (Table I). The patient demonstrated a 20° lag in external rotation at 0° along with positive lift-off, bear hug

TABLE 1. Strength and ROM at initial presentation		
	Right	**Left**
Forward Elevation	40 °	160 °
External Rotation at 0 °	20 °	50 °
External Rotation at 90 °	40 °	80 °
Internal Rotation	to the body	30 °
Isolated Abduction	20 °	100 °
External Rotation	2.4/2.3 kg	3.1/2.6 kg
Internal Rotation	2.8/3.1 kg	2.5/2.9 kg
Supraspinatus	1.3/0.8 kg	3.6/3.4 kg

*Plain films of the dissociated prosthesis at initial presentation

FIGURE 2. Deterioration of the glenoid bone stock due to articulation of male Morse taper component with glenoid polyethylene component

FIGURE 3. Metallosis and scarring within articular space as observed during revision

and belly press tests, although examination was difficult due to pain. Furthermore, the patient has documented rotator cuff deficiency with tears of the subscapularis and supraspinatus.

Due to a variety of medical and family issues, the patient delayed surgical intervention despite her discomfort for a period of nine months. At her immediate pre-operative visit, radiographs confirmed persistence of the Morse taper dissociation.

The decision was made to proceed with conversion to reverse arthroplasty with transfers of the latissimus dorsi and the teres major tendons to improve function and diminish pain. Intraoperative findings included significant glenoid damage, resulting from articulation of the humeral male Morse taper component with the glenoid polyethylene component, including fracture of the polyethylene (Figure 2). Due to the prolonged period of dissociation, moderate metallosis and marked scarring were also found with resultant component instability (Figure 3). The humeral head had migrated to the posterior aspect of the shoulder, and the subscapularis, supraspinatus,

FIGURE 4. (A) Passive Forward Flexion, 3 months status post revision and conversion to Reverse Arthroplasty (B) External Rotation at 90º, 3 months status post revision and conversion to Reverse Arthroplasty
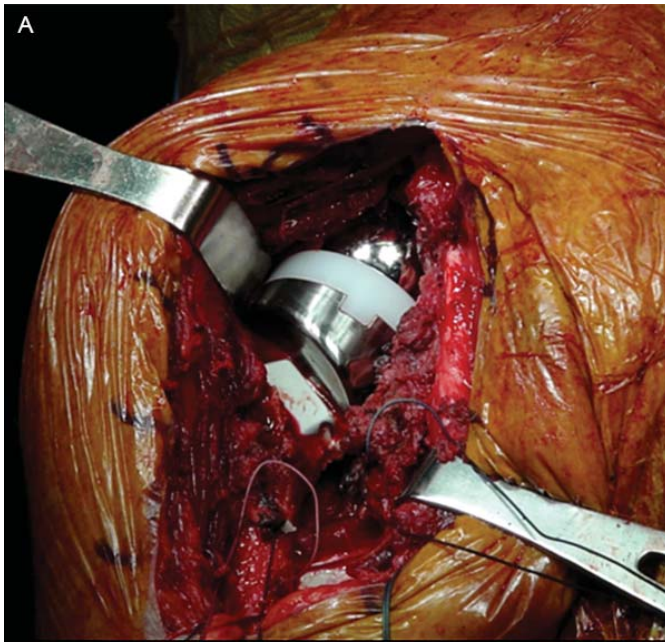
FIGURE 5. (A) Revision and Conversion to Reverse Arthoplasty (B) Plain films demonstrating well placed reverse prosthesis 3 months status post revision and conversion

and infraspinatus were noted to be deficient.

Three months after revision, the patient was doing well without pain and actively engaged in physical therapy. She demonstrated forward flexion to 80° actively, and 150° passively with active external rotation to 45° bilaterally (Figure 4a-4b). Radiographs from the three month visit show a well placed reverse prosthesis without evidence of hardware complications (Figure 5a-5b).

Discussion

This case marks the first time in the literature that spontaneous dissociation of a humeral head in the third generation shoulder arthroplasty has been reported. It also represents a deviation from the literature on dissociation of a Total Hip Arthroplasty, which is often precipitated by a dislocation or other trauma. However, similar to cases of dissociations in the hip literature, this case was not caught at the onset of the patient's discomfort. Consequently, the patient spent several months with a dissociated humeral head, leading to significant inflammation and metallosis. The metallosis itself is an unnecessary contributor to the patient's prolonged discomfort.[8] Additionally, the degree of metallosis and subsequent scarring necessitated extensive debridement, which, coupled with the loss of glenoid bone stock due to articulation of the humeral component, inherently limited the options for revision arthroplasty and may have a negative impact on the patient's long-term functional outcomes.

Furthermore, metallosis itself has the potential for significant negative impact. A potential cause of polyneuropathy is cobalt-chromuim metallosis from hip arthroplasty.[3] The long-term implications of debris from metal-wear were reviewed in 2007, pertaining to their potential toxicity, local and systemic implications, and influences on carcinogenesis.[5] Although, as pointed out by Khan, et al., a causal relationship between orthopedics prostheses and toxic met-

al levels has not yet been demonstrated,[6] and levels sufficient to be toxic are highly unlikely to be reached from deterioration of an implant, let alone metallosis.[9] At best, metallosis is a localized inflammatory reaction of the peri-prosthetic bone and surrounding soft tissues in response to metallic debris. This inflammatory response is a common secondary complication in revision arthroplasty.

Conclusion

In the interest of patient outcomes in the face of a dissociated prosthetic humeral head, early detection is important. Careful inspection of radiographs is essential for identifying these cases. Early detection will hopefully preserve limited glenoid bone stock and prevent the development of significant metallosis. Early diagnosis and treatment may therefore improve patient outcomes.

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Load-sharing Construct Allowing for Immediate Weightbearing and Mobilization in a 18 year old with Bilateral Calcaneus Fractures: A Case Report

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Patient AR is a healthy 18-year-old male who sustained bilateral closed calcaneus fractures after an axial loading injury while skiing. The patient presented to the emergency department of Massachusetts General Hospital complaining of bilateral foot pain and swelling.

Physical examination revealed bilateral foot tenderness and edema in an otherwise alert and oriented patient. His skin was intact and his lower extremity compartments were soft and compressible with intact neurovascular examinations. Plain x-rays of both feet were obtained and revealed bilateral calcaneus fractures (Figures 1A, 1B). CT scan of the right foot revealed a Sanders type I calcaneus fracture with minimal involvement of the posterior facet and normal Bohler's angle. CT scan of the left foot revealed a tongue type fracture with flattening of Bohler's angle and increased relative displacement. (Figures 2A, 2B).

After proper consultation, a decision was made to treat both sides surgically via percutaneous approaches to accelerate the rehabilitation course of the patient and allow early weight-bearing.

Surgical Intervention

The patient was taken 1 week post-injury to the operating theatre. Under general anesthesia with bilateral popliteal blocks, the patient was first placed in the right lateral decubitus
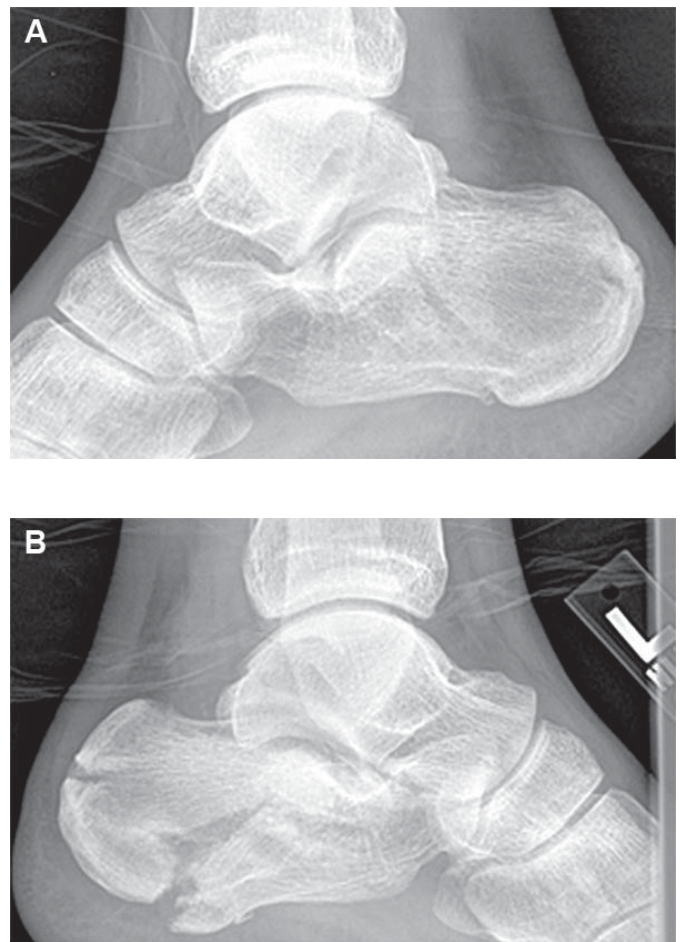
FIGURE 1. (A) Right Sanders I calcaneus fracture (B) Left tongue type calcaneus fracture demonstrating displacement and flattening of Bohler's angle
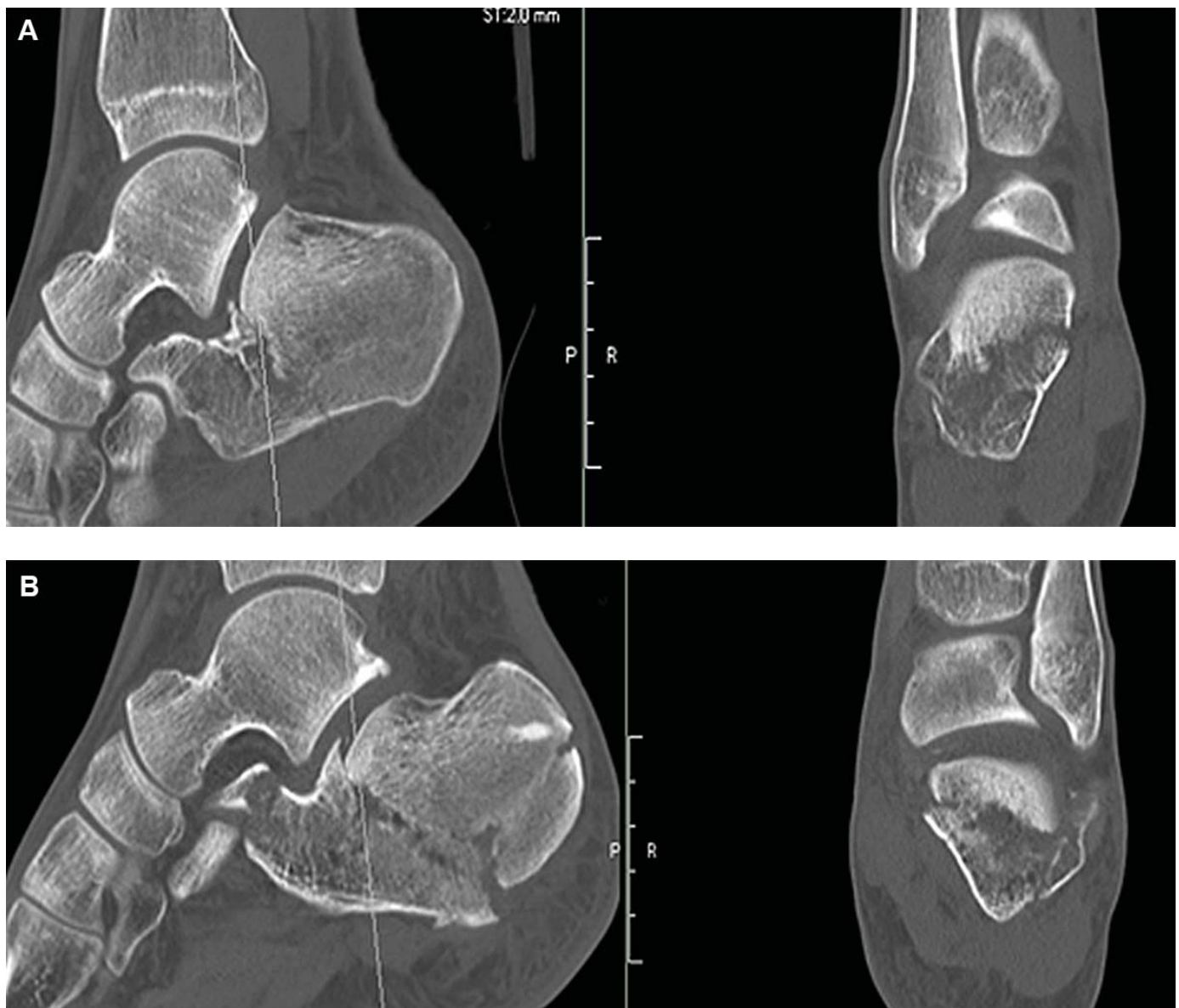
FIGURE 2. CT Scans (A) Right calcaneus (B) Left Calcaneus

position. Closed reduction of the tongue-type fracture was performed percutaneously with the Essex-Lopresti technique. Reduction was maintained via a schanz pin driven through the tuber into the anterior body of the calcaneus. Adequate reduction and restoration of the Bohler's angle was confirmed via intra-operative fluoroscopy and fixation was performed using two 6.5 mm cannulated fully threaded cancellous screws. The patient was then repositioned into the left lateral decubitus position. Fixation of the right side was performed percutaneously via two 6.5 mm solid partially threaded screws placed axially. Three 3.5 mm cortical screws were then placed percutaneously from lateral to medial directly underneath the axial screws acting as bicortical struts for support. Under fluoroscopy, perfect lateral images were taken until the drill sleeve formed a "perfect circle" lying just underneath the axial screws to allow for an interference fit with the intention of increasing construct rigidity (Figure 3).

The position of the screws was checked under fluoroscopy and found to be satisfactory. All the wounds were thoroughly irrigated and closed

FIGURE 3. Intraoperative image demonstrating rafting screws placed using "perfect circle" technique of the drill sleeve for proper screw positioning

FIGURE 4. Darco heel wedge shoe

using 3-0 nylon sutures. The patient was placed in bulky Jones splints and made non-weight-bearing in his bilateral lower extremities.

At the two-week post-operative visit (3 weeks post-injury) his surgical incisions were found to be well healed. The patient transitioned to a short air cast boot on the left side and instructed to continue non-weight-bearing and began self-directed range-of-motion exercises. On the right-side, he was placed in a Darco heel wedge shoe and allowed to fully weight-bear. This specific type of shoe off-loads pressure on the heel by approximately 25% and transfers weight bearing loads to the mid and forefoot (Figure 4).

At the patient's five-week post-operative visit, plain x-rays of both sides showed maintained reduction and position of the screws. Patient activity was progressed to touch-down-weight-bearing in his boot on the left. On the right-side he was transferred to a regular post-operative shoe with continued full-weight-bearing. He was fully weight-bearing bilaterally in a regular shoe without assistive devices at 2 months postoperatively and went on to successful healing. (Figures 5A, 5B, 5C, 5D).

Outcome scores were obtained at approximately 3 months postoperatively. His American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score was 94/100. His Short-Form (SF)-36 physical function score was 70 and norm-based physical function score 44.6 (compared to average physical function score for males 18-24 years old being 54.26).

Discussion

We present the case of an 18-year-old male who sustained bilateral calcaneus fractures treated with a percutaneously placed load-sharing construct to stabilize a non-displaced calcaneus fracture. The clinical benefit of this intervention was to allow for immediate weight-bearing and early mobilization in the setting of bilateral injuries.

Most authors have recommended nonoperative management of Sanders type I fractures given the minimal displacement and relative preservation of the posterior facet of the calcaneus.[1, 2, 3] Crosby and Fitzgibbons evaluated the outcomes of non-operative treatment of calcaneus fractures and concluded that all patients with non- or minimally-displaced type I fracture had better results in comparison to displaced type II and III fractures.[4] Given the relatively high rate of wound healing complications using traditional operative exposures, Sanders type I fractures have been historically treated nonoperatively. Successful conservative treatment of calcaneal fractures traditionally consists of non-weight bearing in a cast
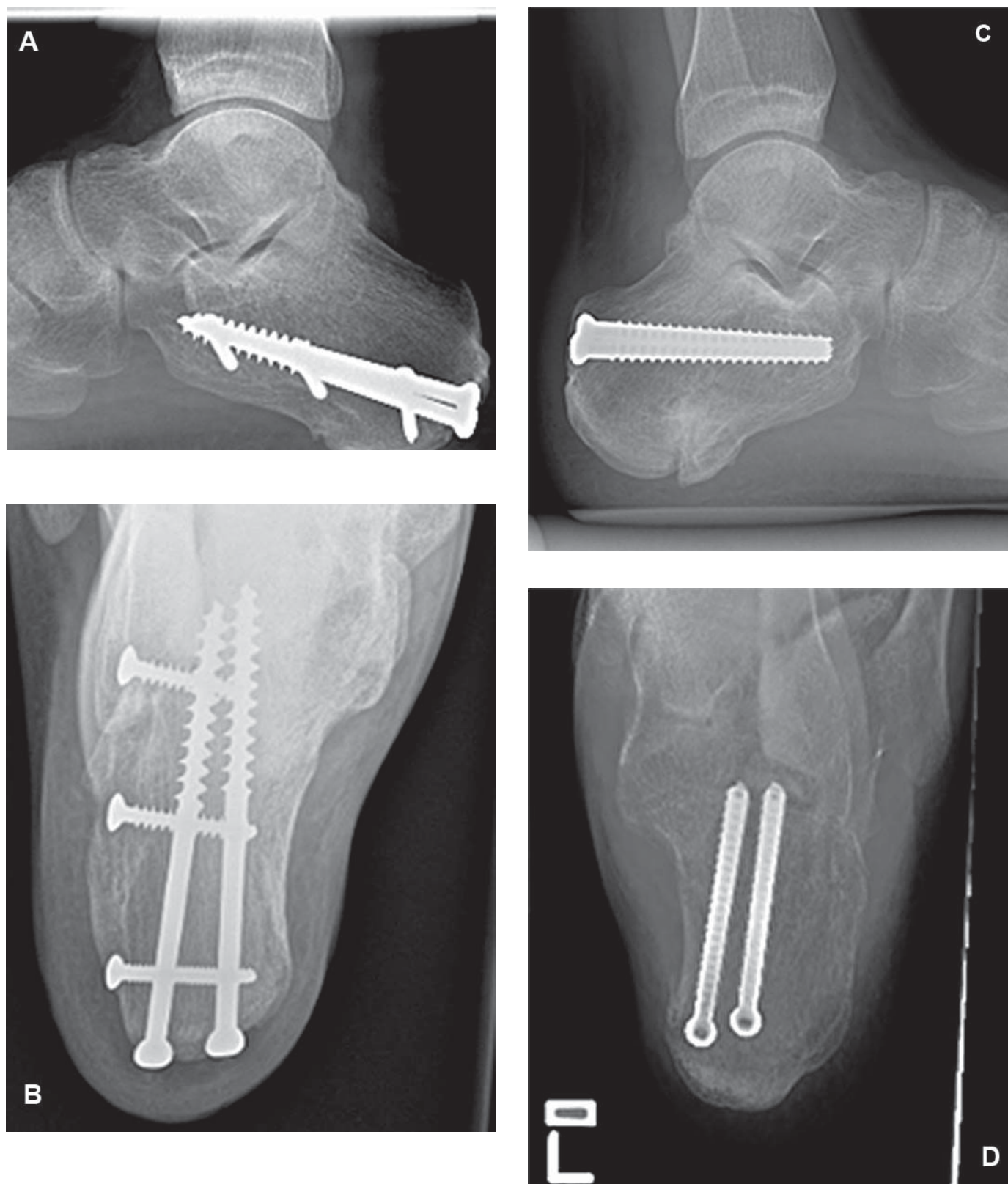
FIGURE 5. (A) Right calcaneus lateral view (B) Right calcaneus Harris heel view (C) Left calcaneus lateral view (D) Left calcaneus Harris heel view

or boot for a period of 2 - 3 months. The main drawback with prolonged immobilization and nonweightbearing is increased collagen breakdown, disuse osteopenia, muscle atrophy, joint stiffness and general deconditioning. Fiorre, et al. found a positive correlation between the amount of bone resorption and the length of immobilization and suggested that uncoupling between bone formation and resorption with consequent disuse atrophy develops during this period.[5]

In the presented case study, the major clinical benefit of operative intervention was an earlier transition to full weight-bearing for an otherwise healthy young patient with bilateral calcaneus fractures. Faster return to weight-bearing theoretically decreases muscle atrophy and joint stiffness, and allows for earlier return to activities of daily living and work. Percutaneous reduction and fixation mitigates the major surgical risk of post-operative wound breakdown and infection.

Examining the internal architecture of the calcaneus, five distinct trabecular patterns can be identified. The primary compressive group is directed in a dorso-plantar direction from the posterior facet and fans towards the posterior inferior tuber. The secondary compressive group is centered at the Angle of Gissane and directed towards the anterior inferior calcaneus and calcaneal-cuboid articulation. The primary tensile group is directed antero-posteriorly towards the posterior surface while the secondary group lies more anteriorly. The fifth trabecular pattern extends from the tuberosity towards the insertion site of the tendo-achilles.[6,7,8] They are arranged in a unique fashion with a small triangular area relatively void of dense trabeculae lying at the mid portion of the calcaneus which represents the weakest part of the calcaneus. This neutral triangle, which is devoid of dense trabecular bone and directly plantar to the inferior anatomic apex of the talus, is the site of the primary fracture line in calcaneus fractures. Mahato, et al.[9] demonstrated that 70 % of the body weight forces are distributed across the superior articular surface of the calcaneus with the remaining 30% through the sustentaculum.[9] This fact, along with the understanding of the calcaneal trabecular patterns and cancellous bone density, helps explains the formation of the primary fracture line.

Understanding the load distribution on the calcaneus and pathomechanics of fracture line development and displacement, we aimed to devise a load sharing construct to stabilize this patient's non-displaced right calcaneus fracture to allow for immediate weightbearing in the setting of bilateral injuries. Two large solid 6.5 mm screws, with increased resistance to bending forces compared to cannulated screws, were placed traversing the calcaneus as internal struts to reinforce the stability of the calcaneal long axis. The calcaneus, similar to the metatarsals and unlike other load-sharing bones, is loaded perpendicular to its long axis. Therefore to prevent cantilever bending of the cancellous screws, three 3.5 mm bicortical screws were placed in a lateral to medial direction functioning as struts to support the overlying axial screws from failing, thus creating a supported beam construct.

No previous study has compared operative to conservative treatment for non-displaced calcaneal fractures nor specifically examined the morbidity of prolonged non-weight-bearing and immobilization in this setting. This case report illustrates the utility of a load-sharing construct to allow early weight bearing and faster return to pre-injury level of activities. Due to his bilateral calcaneus fractures, this patient would have traditionally undergone 2-3 months of non-weight-bearing and reliance on a wheelchair during this time. Our load-sharing construct for the right calcaneus fracture allowed for full weightbearing in an offloading shoe at 3 weeks post-injury which accelerated his recovery and allowed for crutch mobilization. Furthermore this allowed for rapid mobilization with outcome scores obtained at 3 months postoperatively demonstrating excellent AOFAS hindfoot scores and SF-36 physical function scores approaching norms for his demographic peer group.

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Biceps Tenodesis in a 22-year-old Female Softball Pitcher: A Case Report

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Abstract: Injury to the long head of the biceps (LHB) is a common source of pain in the shoulder, typically presenting with rotator cuff involvement. In the case of trauma to the LHB, patients may be indicated for a biceps tenotomy versus tenodesis, with the latter recommended for younger patients. The following case study will present a 22-year-old Division III collegiate softball pitcher who sustained a traumatic, isolated proximal biceps rupture without rotator cuff damage. He was subsequently managed with biceps tenodesis and physical therapy, and was able to make a successful return to fast underhand softball pitching.

Keywords: long head biceps tendon, tenodesis, arthroscopy, shoulder, pitcher

The long head of the biceps tendon (LHB) is an intra-articular structure of the shoulder, running within the bicipital groove and exiting the intra-articular space.[24] Its exact role in glenohumeral mechanics is not definitively understood, yet damage to the LHB tendon is a frequent source of pain in the shoulder. LHB pathology is divided into three types: instability, inflammatory and traumatic conditions.[34] Isolated, traumatic biceps tendon ruptures are relatively rare, as tears classically co-present with chronic microtrauma within the shoulder.[26] A review of the literature reveals that, to date, there are no well-controlled, randomized clinical trials that decisively determine whether tenotomy or tenodesis of the LHB is the superior treatment, although tenodesis is generally preferred for patients under the age of 50.[5, 27] As patient outcomes display little variability between the two procedures, the role of the tenodesis is primarily considered a cosmetic one, as the Popeye's sign appears in approximately 43% of patients with ruptured LHBs.[3] In the athletic population, however, there is a general consensus that the biceps should be preserved, particularly in overhead athletes. To date, there are few reports of successful management of biceps rupture treated with tenodesis that have resulted in return to competitive overhead sport.

Various methods of arthroscopic or open tenodesis have been reported, which can comprise soft tissue suturing or the use of suture anchors, interference screw, screw and washer, and bone tunnels. LHB fixation is typically performed above the bicipital groove or beneath the pectoralis major muscle.[5]

Case Report

A 22-year-old right hand dominant female Division III college softball pitcher presented to an outside orthopaedic surgeon with diffuse rotator cuff related overuse symptoms. She was originally prescribed oral corticosteroids to address the pain.

She was advised to begin a general rotator cuff strengthening program and continue pitch-

ing. Three weeks into her rotator cuff strengthening program, she sustained a sudden injury while pitching in a game. She reported feeling a pop in her right shoulder during the follow-through phase of her pitch. She was evaluated by her team physician following the injury and told she had a "career-ending injury." After being seen by a physical therapist one day after her injury she was advised to seek an orthopaedic consult, as she had an obvious deformity of her biceps tendon consistent with the Popeye's sign.[27] The patient displayed nearly full shoulder active range of motion of 150° of forward flexion and 70° of external rotation, and could rotate internally rotate behind her back to her upper lumbar spine bilaterally. Rotator cuff strength testing for the supraspinatus, infraspinatus and subscapularis each scored 5/5 by manual muscle testing. She reported no tenderness at her acromioclavicular joint and had a negative cross-arm adduction exam. She complained of tenderness over her proximal biceps groove and noted pain with Speed's Test. The patient was neurovascularly intact. Overall, she subjectively rated her right shoulder value as 50%, scoring her contralateral side as 100%.

The patient's MRI confirmed the presence of a right superior labral tear and ruptured proximal biceps tendon, evident on the sagittal oblique view,near the humeral metaphysis (Figure 1) as well as the coronal view (Figure 2). Her rotator cuff was intact. Given the patient's age, activity level and the acute nature of the injury, it was recommended that the patient undergo surgery to perform a biceps tenodesis through an arthroscopic approach.

The patient was taken to surgery 13 days post-injury, 2 days after our clinical evaluation. Examination under anaesthesia revealed a stable shoulder with 2+ anterior, 2+ posterior and 1+ inferior laxity with Sulcus sign, which diminished with external rotation. Arthroscopic evaluation demonstrated that the cartilage of the humerus and glenoid was intact, as was the anterior, posterior and inferior labrum. The rotator cuff was pristine, and a visualization of the subacromial

FIGURE 1. Sagittal oblique view of MRI illustrating torn biceps tendon

FIGURE 2. Coronal view of MRI showing torn biceps tendon

space revealed an unharmed bursal side of the subacromial space. The superior labrum presented with an avulsion-type tear, and we confirmed a complete detachment of the biceps tendon, retracted down to the intertubercular groove.

The superior labrum was debrided back to a stable margin, having been avulsed from its superior attachment. There was no tissue amenable to repair. Hemostasis was secured after the torn degenerative labrum was debrided.

The arthroscope was then directed into the subacromial space, where the bursal side of the rotator cuff was inspected and noted to be intact. No bony decompression was performed.

In order to address the biceps tendon, the arm was placed in forward flexion with the scope still in the subacromial space. The biceps was found proximally and traced down to the distal end of the intertubercular groove. The pectoralis major muscle was identified, and the biceps was held in place in the supra-pectoral region while the humerus was prepared. A small incision was placed for percutaneous insertion of an Osteoraptor (Smith and Nephew, Andover MA) anchor. The anchor was inserted in the supra-pectoral region. Using an accessory portal, the biceps was held under tension whilst the

sutures were retrograded in a lasso-loop fashion to retrieve the biceps tendon and eliminate the Popeye's deformity (Figure 3). The patient's arm was brought through range of motion and the biceps deformity was no longer present. All wounds were irrigated and closed, and the patient was placed in a standard sling (Figure 4).

At 2-week follow-up, the patient reported minimal discomfort and was tolerating the physical therapy regimen well. All of the patient's neurovascular structures, including axillary, median, radial and ulnar nerve distributions were intact. At 14-week follow-up, she had normal biceps contour and displayed full active range of motion in abduction, forward flexion, and internal and external rotation. Isometric right rotator cuff strength by hand held dynamometry revealed 7.9 kg in abduction and forward flexion (left 6.3 kg), 7.5 kg in external rotation (left 5.3 kg), 9.5 kg in internal rotation (left 6.9kg) with manual muscle testing revealing 5-/5 in biceps flexion and supination as compared to the contralateral side. Her Shoulder Pain and Disability Index (SPADI) score was 3%.

At 9 months follow-up: she had a SPADI score of 0%, full AROM in all planes, a negative Speed's test with no pain to palpation of her proximal biceps and normal biceps contour.
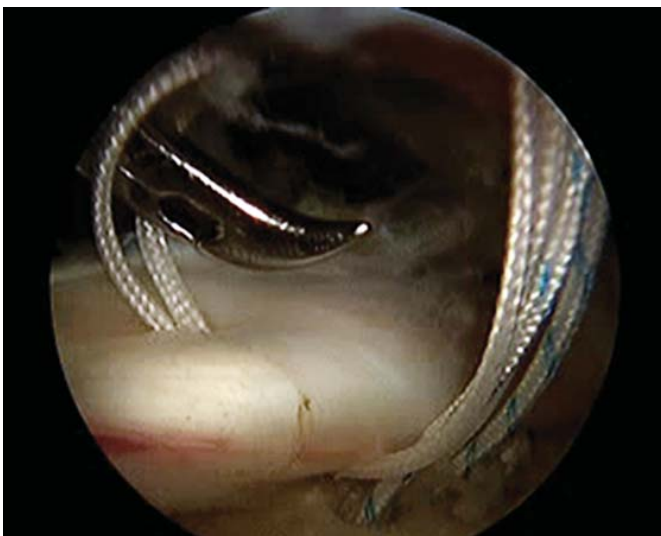

FIGURE 3. Passing sutures during arthroscopic biceps tenodesis

FIGURE 4. Final appearance after biceps tenodesis

FIGURE 5. Axial view of MRI depicting anchor from tenodesis

FIGURE 6. Axial view of MRI illustrating healed biceps tendon

Isometeric right rotator cuff strength by hand held dynamometry revealed 8.3 kg in abduction and forward flexion (left 7.8 kg), 9.3 kg in external rotation (left 9.0 kg), 10.6 kg in internal rotation (left 10.5kg) with manual muscle testing revealing 5/5 in biceps flexion and supination as compared to the contralateral side.

Over the course of this 9-month time period, she had attended 12 physical therapy sessions and had been completely compliant with her progressed home exercise program. Her MRI demonstrated complete healing of the tenodesis (Figure 5, 6). She was advised to begin and progress a throwing program over the next 2-3 months. She stayed in close contact with her physical therapist during this process and had no setbacks. At 11 months after her surgery, the patient had returned to pitching for her collegiate softball team, with minimal discomfort that resolved one or two days after pitching. The patient reported being overall very happy with her outcome and planned to continue with her shoulder strengthening and throwing program. At the 2-year post-

operative point she continued to have a SPADI score of 0%, full AROM in all planes, a negative Speed's test, and a normal biceps contour. Isometeric right rotator cuff strength by hand held dynamometry revealed 8.0 kg in abduction and forward flexion (left 7.8 kg) , 9.0 kg in external rotation (left 9.0 kg), 10.2 kg in internal rotation (left 10.3 kg) with manual muscle testing revealing 5/5 in biceps flexion and supination as compared to the contralateral side. She reported that she had successfully completed her collegiate pitching career without any further shoulder injury.

Discussion

The sport of softball has enjoyed increasing popularity over the past several decades and is reported as one of the largest female team sports in the United States from the youth through collegiate ranks.[25,17,18] In particular, collegiate fast pitch softball at all three divisions has experienced significant increases in participation over the past decade.[2,17,18] According to the NCAA participa-

tion report[17] there were 13,496 females participating in collegiate softball (Divisions I through III) in the 1996-1997 season and 16,997 total participating collegiate softball players in the 2006-2007 season. As participation in the sport has increased, so too has the need for research contributing to the diagnosis, management and ultimately prevention of common injuries, particularly with regard to the position of pitcher.

In fast pitch softball, pitchers use an underhand throwing motion that is commonly referred to as the windmill technique and can require up to 485 degrees of total shoulder circumduction to complete.[3] It is commonly divided into 6 phases (Table 1). Unlike baseball, there are no regulations on pitches thrown or innings pitched and as a result, pitchers often pitch consecutive games and days with some reports of over 1200-1500 pitches thrown in a weekend.[30,31] The biomechanical requirements of this throwing motion have been analyzed in several studies;[3,15,20,21,25,30,31] however the amount of research

available lacks significantly compared to that for overhand pitching in baseball. This may be due to the historical belief that the windmill style is less stressful on the upper extremity than overhand pitching.[3,10] When looking at the literature on injury patterns in softball, however, it appears that windmill pitching may present a greater risk for injury than once thought.[9,25]

Hill and colleagues looked at injury incidence in female college pitchers (Division I, II, and III) through a survey which also included demographics, pitching and game data, and information on training programs utilized by the players during the 2001-02 calendar year. Injuries were reported by 131 (72.8%) of the 180 who completed the survey with 57 (31.7%) reporting more than one injury in that time frame. Injuries were further classified into acute (36), chronic/overuse (92), and unspecified (3). 44% of all the injuries were related to pitching and 41% of those pitching injuries were related to the shoulder.[10] Kranjik et al reported a rate of 1 shoul-

TABLE 1. Description of Windmill Pitching Phases		
Phase	**Position**	**Motion**
1		Windup First ball motion forward to 6 o'clock, varied from subject to subject; arm extension ranged from 0°to 90°
2	6 to 3 o'clock	Body weight placed on ipsilateral leg, trunk faced forward, arm internally rotated and elevated at 90°
3	3 to 12 o'clock	Body weight transferred forward, body begins to rotate toward pitching arm, arm is elevated to 180°, and the humerus is externally rotated
4	12 to 9 o'clock	Body remains rotated toward pitching arm, the arm is adducted toward next position, and body weight lands on the contralateral foot
5	9 o'clock to ball release	Momentum is transferred to adducted arm, body is rotated back to forward position, and more power is transferred to arm just before ball release
6	Follow- through	Arm contacts lateral hip and thigh, forward progression of humerus is halted, and ball release to completion of pitch

der injury per 10,000 activity exposures in high school softball compared to 1.72 shoulder injuries per 10,000 activity exposures in high school baseball players.[13] The most common shoulder injuries in both sports were classified as strains/incomplete tears and were more likely to occur in practice than in a game situation in both sports. Marshall et al, using the NCAA injury surveillance data base from 1988-1989 through 2003-2004, found overuse shoulder injuries among the most common conditions in NCAA women's softball.[16]

Anecdotally, a common complaint of softball pitchers is anterior shoulder pain and given the demands on the biceps, and repetitive nature of the activity, this may be a potential source of pain in softball pitchers.[30,31] Rojas et al. in a study that looked at biceps activity in female fast pitch windmill pitchers found higher biceps activity in all phases compared to baseball pitching.[25] In particular, they report significant biceps activity particularly during phase 5, which is the 9 o'clock position to ball release phase. This coincided with the highest demands for reducing elbow velocity and resisting shoulder distraction forces prior to ball release. After ball release the authors suggest that biceps activity may continue as a means of decelerating the arm and reducing distraction during follow through, while others have stated that the deceleration demands may be facilitated by pitchers whose pitching arm strikes the lateral hip which decelerates the arm.[2,15] Additionally, given the large range of motion required for windmill pitching the authors theorize that there is a large excursion of the biceps tendon which also could predispose it to injuries.[25] The process of long head biceps tendinopathy and risk for spontaneous tear has been analyzed on an anatomical basis and it appears likely that the demands of windmill pitching can predispose an athlete to biceps pathology.[19,28]

In conclusion, acute rupture of the LHB in young adults is a rare occurrence, with limited reports in the literature. Provided there is no damage to the rotator cuff, a biceps tenodesis may be performed instead of a superior labral repair, and full motion may be regained as in the case of this 22-year-old patient who returned to competitive underhand fast-pitching softball.

FIGURE 7. Patient returns to pitching 11 months after surgery

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The Use of Dual C-arms During Fixation of Calcaneal Fractures: A Technique Tip

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Abstract: We describe a simple technique using dual C-arms (large and mini c-arm together) for open reduction internal fixation of calcaneal fractures in the lateral decubitus position which (1) decreases the difficulty of obtaining proper intraoperative imaging, (2) limits c-arm movement which decreases risk of contamination and operative time and (3) minimizes the drawbacks of each imaging fluoroscopic modality.

Keywords: dual C-arms, fluoroscopy, calcaneus fracture

This technique assumes that the patient undergoing calcaneal fixation is in the commonly used lateral decubitus positioning. For illustrative purposes of this technique, the patient is in the left lateral decubitus position (right-side up) on a flat radiolucent table and is prepped and draped in the usual fashion. The nonoperative leg (left leg) is maintained in a more extended position so as not to obscure imaging of the injured side when the x-ray beam is shot through the table. The operative extremity is flexed 45-degreees at the hip and knee and placed on a high bolster. An outline of the extremity can be made with a surgical marker on the underlying surgical drape for more consistent positioning of both the extremity and the C-arm. The large C-arm and mini C-arm are draped prior to incision. (Figure 1)

FIGURE 1. Setup demonstrating positioning of dual c-arms

FIGURE 2. Obtaining a perfect lateral view of the foot using the large c-arm

To obtain a lateral foot image, the large C-arm should be placed on the left side, perpendicular to the operative table with the image intensifier under the OR table (Figure 2). Adjust the large C-arm by angling and arcing in various planes until a perfect lateral view of the calcaneus is obtained. After the large c-arm is angled appropriately it is locked and secured and moved out of the operative field. When lateral images are required during the procedure it can be wheeled into the pre-determined area without the need to make any further adjustments. To obtain Broden views, the large C-arm should be centered on the fibula with slight external rotation of the limb and the appropriate amount of ankle dorsiflexion or plantarflexion as needed. To obtain a Harris heel view, the mini C-arm – which is turned horizontally – is placed on the contralateral side of the operative table is utilized. When a Harris heel view is required, the foot is dorsiflexed and the mini C-arm is advanced forward with the x-ray source placed near the popliteal fossa. The C-arm can then be rotated on its axis until a Harris heel view is obtained (Figure 3).

FIGURE 3. Utilizing the mini C-arm to obtain a Harris heel view

Discussion

The most commonly used approach for operative fixation of calcaneal fractures is the extensile lateral approach. Unfortunately, it has been associated with high wound complication rate that ranges from 1.8-27%[1, 2, 3, 4, 5, 6, 7, 8, 9, 10] . In an attempt to improve patient outcomes and avoid surgical complications, minimally invasive procedures have evolved including the sinus tarsi and percutanous approaches. However, these techniques afford limited direct visualization of the fracture and an increased use of indirect reduction techniques. These techniques often require an increased use of intra-operative fluoroscopy and are more dependent on the ability to obtain adequate intra-operative images to compensate for limited direct visualization of fracture reduction and fixation.

The use of either the regular large C-arm or the mini C-arm is mostly surgeon dependent and each imaging modality has its benefits and drawbacks. Large C-arms produce better image quality and a wider image field. However, they are difficult to move and require assistance from a radiology technician. Pally et al recently demonstrated great inconsistency in the terminology used between orthopedic surgeons and radiation technologists.[11] As a result, surgeons may become frustrated with time wasted due to miscommunication and increase in radiation dose exposure due to inappropriate images obtained. Harris heel views, in particular, are more difficult to obtain with the large C-arm due to the width of the arm, obstruction from the operating table and need to reposition which can be time-consuming.

Additionally, the large C-arm delivers a higher dose of radiation compared to the mini C-arm. A study by Dawe et al. revealed that the mini C-arm reduces radiation dose and costs when compared to standard fluoroscopy.[12] This has been shown in other studies which favor the use of mini c-arm over the larger counterpart when imaging the extremities due to less radiation exposure in spite of a larger number of images obtained with the mini C-arm in comparison to the large C-arm for each operation type.[13, 14, 15] Our technique minimizes overall radiation exposure when using the large C-arm in 2 ways. (1) Standardizing the location of the foot and securing the coordinates of the large C-arm results in less wasted images taken prior to obtaining the desired view. (2) Use of the mini c-arm to obtain Harris heel views decreases utilization of the large c-arm for this purpose.

Due to their size, mini C-arms are easier to maneuver during surgery. On the other hand, mini C-arms generally generate poorer image quality when compared to their larger counterpart. Perhaps the most concerning drawback is that mini C-arms carry a higher risk of contamination from the floor, the undersurface of the operating table or even the surgical gowns during repetitive manipulations to turn the C-arm horizontal or vertical to the ground. Peters et al. showed that the rate of contamination of the C-arm drape increases gradually with time. They recommended minimal contact with the C-arm to decrease the incidence of contamination.[16] Bible et al. tried to determine the most sterile regions of the surgical gown and concluded that contamination rates were greater at levels 24 inches and less or 48 inches and more relative to the ground.[17] With the mini C-arm turned vertically, for example when a lateral foot view is obtained, the mini C-arm falls below this safe zone and risk of contamination is greatly increased (Figure 4).

FIGURE 4. The mini C-arm turned vertically demonstrating the risk of contamination

We recommend maintaining the mini C-arm horizontal to the ground and using it exclusively for obtaining the Harris heel view so as to minimize the risk of contamination.

decreases the risk of contamination and decreases operative time and potential surgeon frustration due to ease of obtaining proper intraoperative imaging.

Conclusion

We describe an easy technique using dual c-arms for calcaneal open reduction internal fixation being performed in the lateral decubitus position which limits overall radiation exposure,

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Approach to Management of the Patient with the Multiligament-Injured Knee

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Background: Multiligament knee injuries are typically the result of severe trauma, and can result in loss of limb or limb function. At the present time, there is controversy regarding initial treatment and optimal surgical management.

Questions/purposes: The objectives of this study were (1) tTo offer an algorithm for management of the patient with a multiligamentous injury to the knee .(2) to describe the clinical and functional outcomes of a consecutive series of patients with multiligament knee injuries managed with this approach by a single surgeon (3) to present a novel surgical technique for the treatment of multiligamentous knee injuries.

Patients and Methods: We present data on sixteen consecutive knees in 16 patients, 11 male and 5 female, mean age 44 (range 24-65) years with a diagnosis of a multiligament knee injury (defined as a disruption of two or more ligaments that include the PCL). All patients underwent standard preoperative evaluation and were treated according to our algorithm for surgical reconstruction of multiligament-injured knees. Mean follow-up since surgery was 3.87 (range 2-9) years. Outcome measures were determination of range of motion, testing with KT-2000 arthrometer, and Tegner and Lysholm scores.

Results: Common mechanisms of injury were MVA in 7 patients (44%) and sports in 3 patients (19%). Of the four major knee ligaments, 4 patients (25%) had two injured ligaments, 11 patients (69%) had three injured ligaments, and 1 patient (6%) had four injured ligaments. There was an associated common peroneal nerve injury in 3 patients (19%) and there were no patients with associated vascular injuries. Six patients (38%) underwent staged reconstruction, with the remainder of patients undergoing single-stage reconstruction. Following surgery, mean range of motion (ROM) in flexion was 111 (range 95-138) degrees, and mean ROM in extension was -2 (range -12-0) degrees. Mean Tegner score before injury was 6 (range 0-9) and mean Tegner activity level after reconstruction was 4 (range 1-7). Mean post-operative Lysholm score was 78 (range 30-118). Mean KT-2000 anterior manual maximum difference was 2.5 (0.3-6.7) millimeters and mean posterior difference was 2.2 (0.0-3.3) millimeters. Following surgery, one patient (6%) had symptomatic recurrent instability that required a revision.

Conclusions: Our current algorithm used to treat this series of multiligament knee injuries demonstrated satisfactory clinical and functional outcomes, with few complications. An algorithmic approach to treatment as presented by the authors can minimize adverse sequellae associated with surgical treatment of multiligament knee injuries.

Keywords: medial collateral ligament (MCL), medial knee injury, knee ligament injury, multiligament injury

Level of Evidence: Level IV, case series.

Although they account for less than 0.02% of all orthopaedic injuries, multiligament knee injuries may lead to neurovascular compromise that can threaten the affected limb.[8, 15] Multiligament knee injuries are defined as disruption of at least 2 of the 4 major knee ligaments, and typically occur as a result of acute, traumatic knee dislocation.[1, 5, 21] In addition to ligament damage, the energy required for traumatic knee dislocation frequently causes other associated injuries such as fracture and neurovascular damage.[5, 8, 21] Even if neurovascular compromise is avoided, the morbidity resulting from multiligament knee injuries is substantial and includes

pain, instability, and stiffness of the affected joint.[5]

The optimal treatment of multiligament knee injuries is a complex problem. This is currently an area of controversy in the field due to a paucity of high-level evidence to guide management. Historically, treatment involved closed reduction and casting or cast-bracing immobilization.[9] With recent advances in operative technique, multiligament knee injuries are now typically managed surgically.[8, 9] Cohort studies to date have suggested that surgical treatment yields superior outcomes compared to nonoperative management, as measured by International Knee Documentation Committee (IKDC) scores and higher rates of return to work and sports.[2, 14, 16, 23] In addition, cohort studies have suggested that for most injury patterns, early surgery (<3 weeks from the injury to the operation) yields improved outcomes compared to delayed surgery, as measured by Lysholm scores and IKDC scores.[4, 6, 10, 20, 22] Finally, studies addressing repair versus reconstruction of damaged structures indicate that reconstruction of the posterolateral corner (PLC) is associated with lower revision rates than repair of the PLC, and that reconstruction of the cruciate ligaments yielded superior functional and clinical outcome compared to repair of these structures.[7, 11, 18]

To our knowledge, there have been no randomized-controlled trials addressing the impact of different management options on outcomes of patients with multiligament knee injuries. Multiligament knee injuries do not lend themselves well to randomized controlled trials for various reasons, including the heterogeneity of multiligament knee injuries (both pattern of ligament injury and associated ipsilateral and contralateral leg injuries), the high rates of associated trauma, and the relatively low incidence of these injuries. In light of these challenges of studying the multiligament-injured knee, it is imperative that authors continue to report well-designed case series and descriptions of algorithmic approaches to management of these injuries.

Through this case series, we intend to (1) describe our approach to the patient with a knee dislocation, and 2) to report on the outcomes of these patients following our reconstruction algorithm of multiligament-injured knees.

Patients and Methods
Patients

Between 2003 and 2008, 16 consecutive patients with 16 multiligament-injured knees (defined as disruption of 2 or more ligaments that include the PCL) and no other major trauma underwent surgical reconstruction performed by the senior author. With appropriate Institutional Review Board approval, the prospectively collected data were retrospectively reviewed, and all patients were invited for follow-up examination to assess clinical and functional outcome. The follow-up examinations were performed by a single clinician. Outcome measures collected were the Lysholm score, Tegner activity scale, KT-2000 arthrometric testing (MedMetric, San Diego, CA), and clinical examination of range of motion (ROM). Multiligament knee injuries were classified according to the classification system of Schenck.[17]

Clinical Assessment

All patients underwent standard preoperative evaluation, including neurovascular evaluation, determination of instability pattern, soft tissue assessment, and diagnostic imaging with MRI.

Physical Examination

Anterior cruciate ligament injuries were diagnosed with a positive Lachman test, anterior drawer test, and pivot shift test. PCL injuries were diagnosed with a positive posterior drawer test at 90 degrees and positive posterior sag. Grade III injuries were indicated for surgery. MCL injuries that required surgical repair were grade III injuries with no end point to valgus stress. PLC injuries that required surgical repair or reconstruction were unstable to varus stress and had a positive dial test at 30 and 90 degrees of knee flexion.

Vascular Assessment

Vascular assessment was performed on all patients. Formal arteriography was reserved for patients with diminished or abnormal palpable pulses, ankle-brachial index less than 0.8, or a knee dislocation resulting from high energy trauma.

Neurologic Assessment

Baseline EMG studies were obtained at approximately 2 weeks after injury if a patient was diagnosed with a peroneal nerve injury. If a neurotmesis was present, acute nerve exploration and cable grafting was indicated. If an incomplete injury was diagnosed, repeat EMG studies were obtained 6 months to check on the recovery status.

Imaging

All patients were assessed with plain radiographs to rule out fracture and confirm reduction of the joint. MRI scans were performed on all patients to not only to confirm the ligamentous injuries diagnosed by physical examination, but to identify their exact site of injury. In particular, collateral ligaments were examined to see if the tear was mid substance vs. an avulsion injury, and to identify any associated intra-articular damage.

Surgical Technique

Surgery was typically deferred until range of motion was restored to at least 120 degrees, and for at least 3 weeks to give the joint capsule time to heal in order to avoid fluid extravasations from arthroscopy.

The patient is placed in the supine position with a leg post with a well padded thigh tourniquet placed as proximally as possible. No intra-operative fluoroscopy is used. To begin, a diagnostic arthroscopy is performed using standard inferolateral and inferomedial portals. Any associated articular cartilage or meniscal injuries are addressed.

PCL Reconstruction

PCL reconstruction is indicated for all multiligament injured patients with grade III PCL injuries. Reconstruction is performed using a 10 mm Achilles tendon allograft. The PCL remnants are debrided and an accessory posteromedial portal is established. A 70° arthroscope is used during debridement of the posterior aspect of the proximal tibia under direct visualization. A PCL tibial guide (Arthrex, Naples, Fl) is inserted at a 70° angle and a 10 mm tibial tunnel is drilled under direct visualization. The PCL femoral guide (Arthrex, Naples, Fl) is then placed approximately 6 mm posterior to the articular surface in the 11:30 position for left knees (12:30 position for right knees), a short longitudinal incision made over the anteromedial aspect of the distal femur, and an 10 mm femoral tunnel is drilled outside-in. The Achilles tendon allograft is passed in antegrade fashion. A 25 mm interference screw is used to secure the femoral tunnel. Screw diameter is determined based on graft-tunnel fit. Cycling of the knee should reveal less than 1 mm of graft motion in all cases. The tibial tunnel is left unsecured.

ACL Reconstruction

The tibial guide is inserted through the inferomedial portal using a 55 degree angle. The entrance point on the tibia should be at least 2cm above the PCL tibial tunnel, and approximately half way between the tibial tubercle and the tibial attachment of the MCL. The tip of the guide is placed in the central aspect of the ACL tibial footprint, at the level of the anterior horn of the lateral meniscus. A 10mm tunnel is then drilled for the patellar tendon allograft. A reverse chamfer drill is used to smooth the posterior aspect of the tibial tunnel at the entrance into the joint. A 6mm femoral guide is then placed through the tibial tunnel, and aimed at 2 or 10 o'clock position on the intercondylar wall. The femoral tunnel is then reamed with a 10mm drill through the tibial tunnel with the knee flexed to 90°. The graft is passed in retrograde fashion. A femoral interference screw is used to secure the femoral attachment of the graft. The tibial attachment is left unsecured.

MCL Repair / Posteromedial Corner Reconstruction

The MCL is examined under anesthesia pre-op-

eratively. MCL repair is performed in the acute setting when the ligament is avulsed from either its femoral or tibial attachment site. Typically, suture anchors are used to re-attach the attachment site. For acute mid substance tears a ligament repair with capsular imbrication is performed.

For more chronic injuries with a mid-substance tear and residual valgus instability after cruciate fixation, a MCL reconstruction is performed with posteromedial corner reconstruction.

The isometric attachments of the femoral and tibial attachment sites are determined by inserting a Kirchener wire into the medial femoral epicondyle and at a point in the medial tibia 6-8 cm distal to the medial joint line. It should be remembered that the MCL has an attachment site slightly posterior to the mid-coronal plane of the tibia. A heavy suture is then looped around the wires and the knee put through a range of motion from 0-90 degrees. If there is undue (>2-3mm) excursion of the suture with flexion and extension, the attachment sites should be relocated and repeat testing performed.

Once the attachment sites have been determined, we prefer a split Achilles tendon allograft for surgical reconstruction. The calcaneal bone block is prepared to fit loosely through a 10mm spacer. It is inserted into a 10mm x 30mm drill hole in the medial femoral epicondyle, and secured with a composite interference screw. One limb of the Achilles tendon is tubularized, and "docked" into a drill hole made in the tibia of 7mm, which is secured with both an interference screw and by tying the sutures over the lateral aspect of the tibia. The knee should be placed in 30 degrees of flexion when reconstructing the MCL. The function of the posterior oblique ligament can then be re-approximated by suturing the posterior limb of the graft into the posteromedial capsule. This posteromedial aspect of the reconstruction contributes substantially to the resultant valgus and posteromedial rotational stability.

LCL Repair / Posterolateral Corner Reconstruction

For acute injuries, LCL repair is performed

when the distal attachment site is avulsed from the proximal fibula, often with the distal tendon of the biceps femoris. Three drill holes are placed through the proximal fibula, and the tendons of the LCL and biceps femoris are whipstitched. The sutures are passed through the bone tunnels in the proximal fibula, and tied distally. The tear in the posterolateral capsule is repaired. However, even in the acute setting, residual varus instability can persist. In these cases, a PCL reconstruction/augmentation is performed.

Multiple different types of posterolateral reconstructions have been described, and there are certainly many approaches that can be used successfully. In the subacute setting, we perform a fibular-based reconstruction. A soft tissue allograft such as a posterior tibial tendon or semitendinosis is whipstiched. A 6mm drill hole is made from posterior to anterior in the fibular head leaving at least a 1 cm proximal bone bridge proximally. The lateral femoral attachment site is identified, a kirchener wire placed, and a heavy suture passed around the wire and through the fibular head in a triangular shape. The knee is put through a range of motion from 0-90 degrees to insure that there is not undue (>2-3mm) excursion of the suture. The soft tissue graft is passed through the fibular head, and "docked" into an 8mm x 40mm femoral tunnel. The knee is flexed to 30 degrees, with a slight valgus and internal rotation force. The graft is secured in the bone tunnel with a composite 8mm x 30mm interference screw. The suture ends are passed through the femur, and tied over the medial femoral cortex to re-enforce the stability of the graft.

In the more chronic setting with severe posterolateral rotation stability (as evidenced by a dial test of 30 degrees or more), a formal popliteus reconstruction using a popliteal "bypass" graft is performed. We prefer to use a split Achilles tendon graft, where the bone block is fixed in the femoral tunnel with an average graft length of 20 cm. The anterior limb of the graft is then passed from posterior to anterior through the fibular head, secured with an interference screw,

TABLE 1. Rehabilitation Protocol	
Phase	**Activity**
One 0-2 weeks	Partial weight bearing w/brace, passive knee flexion 0-90 degrees.
Two 2-6 weeks	Continuous passive motion (CPM) 10 hrs/day for weeks 3 and 4.
Three 6-12 weeks	No brace and full weight bearing.
Four 12-18 weeks	No restrictions on ROM. Begin single leg progression avoiding hamstring resistance. Patients are fitted for sports brace.
Five 18 weeks - onward	No restrictions. Ease back into activities slowly starting with the return to run progression.

and sewed back upon itself as it exits anteriorly. The posterior limb is passed from posterior to anterior through the proximal aspect of the lateral tibial metaphysis, exiting at the level of Gerdy's tubercle and fixed with an interference screw in order to recreate stability from the popliteus tendon. Once the collateral ligaments are secured, the knee is flexed to 90 degrees with an anterior drawer applied. A 9 x 30 mm Milagro (Depuy Mitek, Raynham, MA) interference screw is inserted until it reaches the posterior tibial cortex, typically 60-65mm posteriorly in the tunnel to fix the PCL in the tibial tunnel. This technique will shorten the effective length of the graft and increase its stiffness, .3 , thereby improving the posterior stability of the joint.3 Fixation is augmented with a 9 x 30 mm interference screw more anteriorly.

Next, the knee is brought into full extension. The ACL tibial tunnel is secured with the graft under full tension in extension with an interference screw.

Rehabilitation

All patients underwent our standard postoperative rehabilitation for these injuries (Table 1). Our standard postoperative rehabilitation protocol consists of five phases to protect the reconstructed ligament and ease patients back to activity with an early emphasis on range of motion. Phase one is from 0-2 weeks, and involves partial weight bearing with a hinged brace locked at zero degrees with passive knee flexion 0-90 degrees. Phase two is from 2-6 weeks with partial weight bearing and continued use of the brace for ambulating 0-90 degrees. At this phase in the rehabilitation protocol, patients use a continuous passive motion (CPM) machine for 10 hours a day for weeks three and four to gain their full range of motion. Phase three is 6 to 12 weeks with no brace and full weight bearing. At this point patients should have full range of motion. From 0-12 weeks patients should focus on closed-chain strengthening and proprioception exercises. Phase four is 12-18 weeks post-operatively with no restrictions on ROM. Patients should continue closed chain strengthening and start single leg progression avoiding hamstring resistance. At this point, patients are fitted for a sports brace. Phase 5 is from 18 weeks onward with no restrictions and patients should ease back into their activities slowly starting with the return to run progression. Patients can return to most strenuous job-related activities in 4-6 months, light sports in 6 months, and heavy sports in 8 months. Following surgical dislocation of a dislocated knee, return to running is permitted at

4 months with a custom fit brace, with return to contact sports at 8 months. It typically takes at least one full year for a patient to optimize their outcome following reconstruction with regard to muscle strength, joint motion, speed and agility.

Data Analysis

Data are presented with mean values and ranges for the relevant variables. The paired Wilcoxon test was used to compare the preoperative and postoperative scores and to compare the clinical scores between the involved and noninvolved knee. Spearman correlations were used to evaluate the influence of the clinical results on functional outcome scores. P values were considered significant when P<0.05.

Results

Patient demographics are listed in Table 2. The average age of patients was 44 (range 24-65) years old. There were a total of 16 knees, 11 male (69%) and 5 female (31%). Mechanisms of injury involved a motor vehicle accident (MVA) in 7 knees (44%), sports trauma in 3 knees (19%), and other mechanisms of injury in 6 knees (38%). Of the 4 major knee ligaments, 2 ligaments were injured in 4 patients (25%), 3 ligaments were injured in 11 patients (69%), and 4 ligaments were injured in 1 patient (6%). Three patients (19%) had associated common peroneal nerve injuries, whereas no patients (0%) had associated vascular injuries.

Table 3 classifies the injury pattern according to the Schneck classification of multiligament-injured knees and indicates the usage of staged reconstruction for each injury pattern for our series of cases.17 One injury (6%) was KD-1, 3 injuries (19%) were KD-II, 5 injuries (31%) were KD-III involving the MCL/PMC, 6 injuries (38%) were KD-III involving the LCL/PLC, and 1 injury (6%) was KD-IV. Six patients (38%) underwent staged reconstruction, 1 patient with ACL/PCL/MCL injuries, 4 patients with ACL/PCL/LCL injuries, and 1 patient with ACL/PCL/LCL/MCL injuries. All other patients

TABLE 2. Patient Demographics (N=16 Knees)

Age (years)	44 (24-65)
Gender (n)	
Male	11 (69%)
Female	5 (31%)
Mechanism of Injury (n)	
MVA	7 (44%)
Sports	3 (19%)
Other	6 (38%)
Number of Ligaments (n)	
2	4 (25%)
3	11 (69%)
4	1 (6%)
Common Peroneal Nerve Injury	3 (19%)
Vascular Injury	0 (0%)
Time from Surgery to Follow-up (years)	3.87 (1.34-9.1)

TABLE 3. Patterns of Ligament Injury

Injury Pattern	N=16 Knees	Staged Reconstruction
PMC/PLC	0	N/A
KD-I	1 (6%)	0/1
KD-II	3 (19%)	0/3
KD-III		
ACL/PCL/MCL	5 (31%)	1/5
ACL/PCL/LCL	6 (38%)	4/6
KD-IV		
ACL/PCL/MCL/LCL	1 (6%)	1/1

KD = knee dislocations, MCL = medial collateral ligament (including posteromedial corner), LCL = lateral collateral ligament (including posterolateral corner), ACL = anterior cruciate ligament, PCL = posterior cruciate ligament. Classification methology described by: Schenck RJ. Classification of knee dislocations. *Oper Tech Sports Med.* 2003;11:193-198

underwent single-stage reconstruction. On average, patients underwent follow-up for clinical and functional outcome 3.9 years after surgery (range 1.3 to 9.1 years). Table 4 describes the clinical and functional outcomes of patients managed with our algorithm for reconstruction of the multiligament-injured knee. Mean range of motion (ROM) in flexion was 111 degrees (range 95-138 degrees). Mean ROM in extension was -2 degrees (range -12-0 degrees). Mean Lysholm score was 77.7 (range 30-118). Mean Tegner level before injury was 6 (range 0-9), and mean current level at the time of follow-up was 4 (range 1-7).

A ligamentous knee examination using a KT-2000 arthrometer revealed a mean anterior difference of 3 (range 0.3-7) millimeters and a mean posterior difference of 2.0mm (range 0.0-3.3).

Complications included the need for a revision due to recurrent instability. This occurred in 1 (6%) patient . No arthrofibrosis, intra-articular infection, deep venous thrombosis, or superficial wound infections were noted.

Discussion

In this study, no patient sustained a vascular injury. However, when a patient presents with a multiligament injured knee, there are several key issues to keep in mind. First, anytime there are 3 or more ligaments involved, the patient should be assumed to have sustained a knee dislocation. As such, it is imperative to rule out an associated vascular injury to the popliteal vessels. In particular, an intimal tear in the popliteal artery must be ruled out. Consultation from the institutional vascular surgery service should be routinely performed, and the use of a diagnostic algorithm and various modalities are often institution-specific. The senior author frequently requests an angiogram, especially in the setting of high energy, posteriorly directed trauma. Magnetic resonance angiography (MRA) shows promise as an alternative means of investigating the vascular status.[19] Ankle-brachial indices can also be helpful, espe-

TABLE 4. Clinical and functional outcomes of patients managed with our algorithm for reconstruction of the multiligament-injured knee

	Mean (range)
Total Mean ROM	
Flexion	111° (range 95-138°)
Extension	-2° (range -12-0°)
Lysholm Score	78 (30-118)
Tegner	
Level Before Injury	6(0-9)
Current Level	4 (1-7)
KT-2000 (mm)	
Anterior Difference	3(0.33-7)
Posterior Difference	2 (0.0-3)

cially in the subacute setting (> 24 hours after injury), and should be performed in conjunction with serial vascular examinations, including Doppler, by the primary orthopaedic surgery team. If less than 0.9, they have been shown to have a positive predictive value of 100%.[12] Meticulous documentation and communication are critical in this phase to avoid limb-threatening sequellae of these injuries.

In addition to ruling out a vascular injury, careful assessment of the peroneal and tibial nerves should be performed, especially in the setting of posterolateral corner injuries. Nerve injury has been reported in approximately 25% of knee dislocations,[13] and such injuries are typically the result of traction injuries. In this study, 3/16 patients (19%) sustained common peroneal nerve injury and no patients injured the tibial nerve. The peroneal nerve is injured far more commonly than the tibial nerve, and one-third of all injuries will recover spontaneously.[13]

If neurovascular injury has been ruled out, most patients will benefit from surgical ligamentous reconstruction, especially if they wish to return to

athletics or physically demanding professions. The primary considerations relating to surgical management are (1) timing of surgical intervention, (2) repair vs. reconstruction of torn cruciate and/or collateral ligaments, (3) type of graft to be used if reconstruction is chosen, (4) non-operative versus operative treatment of MCL injuries, (5) rehabilitation philosophy, and (6) application of specific return to play/work criteria.

Although there are different ways to approach knee dislocations, the results of this study demonstrate a high percentage of excellent outcomes using the following treatment philosophy.

Acute vs. Delayed Surgery

With regard to timing of surgical intervention, we reserve acute surgery for open dislocations, vascular injury, or uncontrolled instability. As none of these indications for acute surgery occurred in this study population, no patients in our study underwent acute surgery. For patients with vascular injuries, we prefer to repair any collateral ligament injuries when possible at the time of the vascular repair, and delay addressing the cruciate ligaments until the revascularization has been in place for at least 8 weeks. This is especially the case for lateral sided injuries, where the LCL and biceps femoris typically avulse from the fibular head and retract proximally. If gross stability remains a concern after revascularization, an external fixator can be placed. Return to surgery should then be delayed until the fixator is removed at 4-6 weeks and range of motion restored to at least 120 degrees, with use of a hinged-knee brace to maintain stability in this period.

In the absence of vascular injury or open dislocations, we will consider surgery in the subacute period if there is an avulsion of the LCL and biceps femoris complex from the fibular head. In this situation, we have found that direct repair of the LCL and biceps femoris complex is best performed within the first six weeks, and preferably the first 3-4 weeks. The popliteus is sometimes avulsed from the femur as well, and

can be repaired at the same time. In this study, /6 patients with ACL/PCL/LCL injury underwent early repair of the lateral side, followed by staged cruciate reconstruction. The other two patients with ACL/PCL/LCL injury had a single-stage repair due to the need to get back to their sport in the shortest period of time possible.

For most medial-sided dislocations, there is little necessity for acute intervention. In the author's experience, medial-sided dislocations have a higher risk of stiffness after surgery. We typically wait 6-8 weeks with early range of motion exercises in a hinged brace in order to restore motion and to facilitate non-operative MCL healing, especially in the case of mid-substance collateral ligament injury. If the MCL is completely avulsed from the femur, or there is significant retraction of the tibial attachments of the superficial MCL with grade III valgus laxity, then we will often perform surgical reconstruction of the ACL and PCL at 4-6 weeks once motion has been restored and the capsule healed, and perform a direct repair of the MCL at the same time. Waiting much longer makes this repair more difficult, as the MCL attachments can become encased in scar. For our case series, 4/5 patients with ACL/PCL/MCL injury were treated with a single-stage surgical intervention involving reconstruction of the ACL and PCL between 6-8 weeks after injury. 1/5 patients was treated more acutely, with surgery 10 days after injury, involving MCL repair and PCL reconstruction, followed by staged ACL reconstruction. This was due to the presence of a tibial avulsion of the MCL, which typically has persistent valgus laxity following non-operative treatment.

Similarly, there is little need for an acute repair in "simple" (i.e. no neurovascular injury) lateral-sided dislocations if the LCL is torn mid-substance. In this situation, primary repair is not possible. Posterolateral corner reconstruction must be performed, and we believe that this is best performed on a sub acute basis (4-6 weeks), once range of motion has been restored and associated trauma addressed.

Repair vs. Reconstruction of Ligaments

The question of repair versus reconstruction of ligaments is best addressed by separating the categories into cruciate injuries vs. collateral ligament injuries, as well as by the location of the tears (i.e. mid-substance vs. avulsion). In general, we believe that there is no role for direct ACL repair and little role for PCL repair unless there is a bony avulsion from its posterior tibial attachment site. In our series, all cruciate ligaments underwent allograft reconstruction. We prefer allograft because it minimizes iatrogenic trauma to an already traumatized knee. ACL repair has been shown to have very poor results. In the senior author's experience, PCL repair also has an unacceptably high failure rate, with more residual laxity than a well-done reconstruction.

With regard to the collateral ligaments, MRI is a very important aspect of the pre-operative surgical planning process. Mid-substance tears of the LCL and popliteus should be reconstructed. Fibular avulsions of the LCL/biceps femoris complex should be repaired. However, it is not uncommon for some residual post-operative varus laxity following direct repair. In order to minimize this persistent laxity, direct repair of the posterolateral joint capsule and popliteus (if possible) should be performed concomitantly. In our series, 3/6 patients with LCL/PLC injury underwent repair of these structures, whereas the other 3/6 patients underwent PLC/LCL reconstruction. Using our approach, the repair alone was performed in 3 patients because there was good posterolateral stability following the initial repair of the LCL and posterolateral capsule. Reconstruction was performed in 3 patients in whom persistent laxity persisted despite repair.

In our opinion, there is seldom an indication for primary reconstruction of the MCL in the acute or subacute setting. In our series, 2/5 patients with MCL injury underwent repair. MCL avulsions were directly repaired using suture anchors. Mid-substance tears are treated initially in a hinged-knee brace with early motion, which resulted in 3 MCL injuries able to be treated non-operatively prior to surgical reconstruction of the cruciate ligaments. Capsular imbrication can be considered if there is too much residual valgus laxity following reconstruction and fixation of the cruciate ligaments. If a knee dislocation is being reconstructed after a more chronic presentation (e.g. greater than 6 months), ACL/PCL and concomitant MCL reconstructed may be necessary. There were no such cases in our series.

Rehabilitation

It is commonly stated that the biggest problem with surgical treatment of a knee dislocation is stiffness, rather than instability. While true in some cases, the etiology of the multiligament injury, its initial treatment, timing of the surgery, whether the medial or lateral ligaments are involved, surgical technique, and post-operative rehabilitation play a more decisive role in whether this adage holds true. Knee dislocations that result from high-velocity trauma or a crush injury are more likely to result in stiffness due to the associated soft tissue trauma, especially if definitive surgical interventions of the ligaments are performed on an acute basis. Patients who are not treated with pre-operative rehabilitation to restore motion pre-operatively are also more likely to result in stiffness, just as occurs when an isolated ACL reconstruction is performed before motion is restored.

Medial dislocations tend to be stiffer. As a result, we prefer to begin early range of motion post-operatively. Because the lateral ligamentous complex is primarily extra-articular, stiffness is much less of an issue, while persistent laxity is more of a risk. Therefore, we tend to keep ACL/PCL/PLC procedures immobilized for 2-3 weeks while partial weight bearing to encourage PCL and PLC stability, and then unlock the brace for motion while ambulating. Continuous passive motion machines are very helpful to restore motion, minimize swelling, and decrease pain in some cases. Using this approach, there were no cases of arthrofibrosis in this series.

Conclusion

The current series presented here demonstrates favorable outcomes with use of the treatment algorithm presented. While addressing all of the associated injuries at the same surgical procedure is possible, especially for ACL/PCL/MCL injuries or in patients for whom return to play/work is a major concern, there should be little hesitation on the part of the surgeon to plan for a staged procedure if 1) there is an ACL/PCL/PCL injury pattern, 2) the patient is at high risk for stiffness, 3) there is a concern about the length of tourniquet time, or 4) a re-vascularization is needed. The post-operative rehabilitation for an ACL reconstruction is very different from that of a PCL reconstruction. The ACL is best when moved early, the PCL often benefits from initial immobilization. The ACL protocol emphasizes hamstring strength and function, while the PCL rehabilitation emphasizes the quadriceps. Therefore, especially for younger athletes, we do not hesitate to perform a primary PCL/PLC reconstruction, followed by 8 weeks of rehabilitation to restore motion and gain muscle control, followed by ACL reconstruction at the second stage. Any adhesions formed from the initial trauma and PCL reconstruction can also be resected at this second stage, thereby minimizing the risk of arthrofibrosis and patellofemoral pain.

The strength of this study is that a single surgeon performed all the cases with a standardized approach and standardized rehabilitation protocol. This study is limited by a retrospective review of prospectively collected data on a small series of cases.

While individualization of management decisions based on each patient's clinical presentation, as well as their baseline and future goals for function is warranted, adoption of an algorithmic approach can minimize the wide range of adverse sequellae associated with multiligament knee injuries. We advocate its use to give patients the best chance for knee stability and optimization of lower extremity function and return to sport and work.

Ethical Board Review Statement

All human studies have been approved by the appropriate ethics committee and therefore have been performed in accordance with the ethical standards in the 1964 Declaration of Helsinki. All persons gave their informed consent before their inclusion in the study. All studies were carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA).

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Syndesmotic Injuries: Is There a New Standard of Care?
A Case Report and Commentary

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Diagnosis and treatment of syndesmotic injuries, whether associated with malleolar ankle fractures, Maisonneuve fractures or purely ligamentous injuries, has been extensively researched. There has been increasing interest as more recent studies have demonstrated a relatively high rate of syndesmotic malreduction and resultant morbidity after surgical fixation. These studies suggest the need for more advanced imaging studies both preoperatively and intraoperatively, as well as a change in traditionally used surgical techniques, to ensure optimal treatment of syndesmotic injuries.

Obtaining plain radiographs of the injured ankle followed by fixation of the syndesmosis using classically taught reduction techniques with intraoperative fluoroscopy to ensure proper reduction has long been the standard of care. However, the current evidence suggests that doing things the old way may be the wrong way.

We present an illustrative case report as well as a commentary based on the current literature.

Case Report

Patient CS is a 31 year old female who sustained a closed ankle fracture in October, 2012 treated with open reduction internal fixation at an outside institution. She presented to Massachusetts General Hospital for a second opinion given continued pain and swelling approximately 7 months after surgery. She complained of irritation from the lateral plates and screws as well as anterolateral pain, especially when planting and pivoting on her operated lower extremity. She underwent a course of physical therapy, bracing and NSAIDS without relief.

Physical examination revealed mild ankle swelling and well-healed surgical scars. She had tenderness to palpation over her fibular hardware, pain over the anterior syndesmosis and pain with external rotation stress testing. Plain radiographs revealed a healed ankle fracture with a lateral plate and screw construct with syndesmotic stabilization via a suture button device (Figure 1A, 1B). A CT scan of the ankle was obtained to assess syndesmotic reduction which confirmed malreduction secondary to posterior placement of the suture button device. (Figure 2) Given the patient's pain, disability and continued failure of conservative treatment she was indicated for removal of hardware and revision syndesmotic fixation.

The patient was taken to the operating theatre and placed supine with a small hip bump on a flat Jackson table. She was prepped and draped in normal sterile fashion. Her previous lateral incision was incised and her previously placed fixation was removed. A medial incision was made to remove the suture button on the posteromedial tibia. The syndesmosis was exposed to directly visualize the incisura and
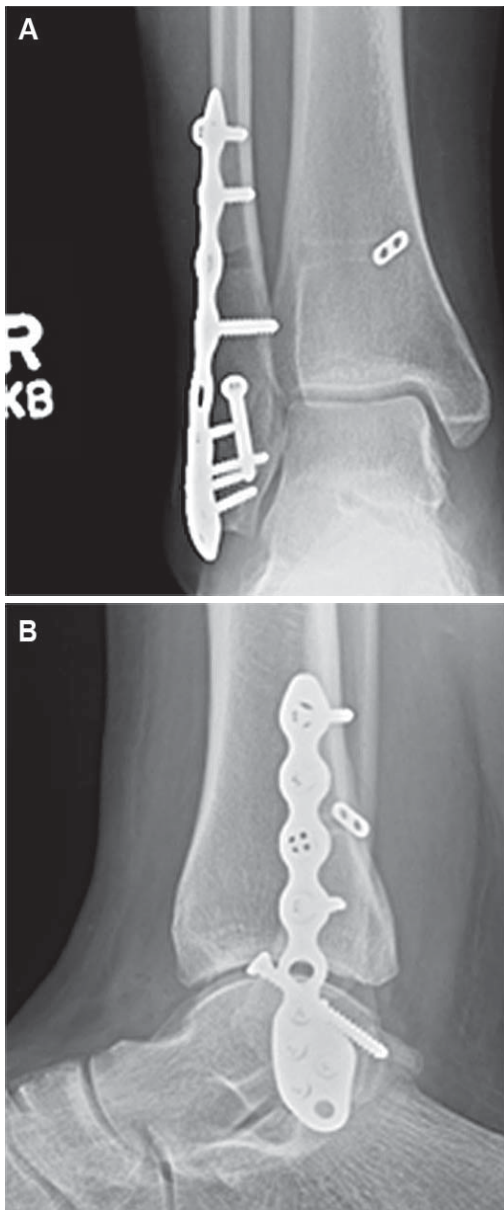
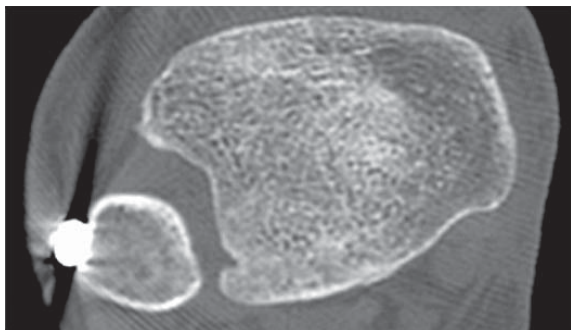FIGURE 1. Preoperative plain radiographs (A) AP (B) Lateral

FIGURE 2. Preoperative CT scan showing malreduced syndesmosis

the fibula was anatomically reduced and provisionally held in place with k-wires. The O-arm cone-beam CT scanner (Medtronic, Minneapolis, MN) was used to confirm anatomic reduction and the syndesmosis was stabilized using 3 suture button devices placed in divergent fashion using a plate as a washer. (Figure 3A, 3B)

The patient was seen 2 weeks postoperatively and was doing well. Sutures were removed, radiographs obtained and physical therapy initiated. The patient was made nonweightbearing in an aircast boot. She progressed her weightbearing at 6 weeks and had an uneventful recovery with improved function and decreased pain. (Figure 4A, 4B)
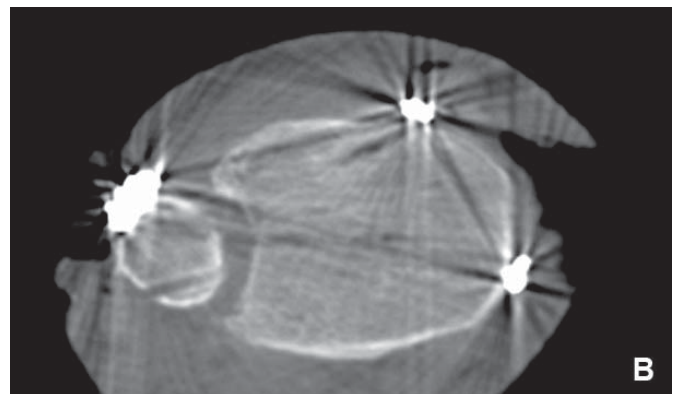

FIGURE 3. Intra-operative O-arm image after syndesmotic reduction and suture button fixation in a divergent fashion
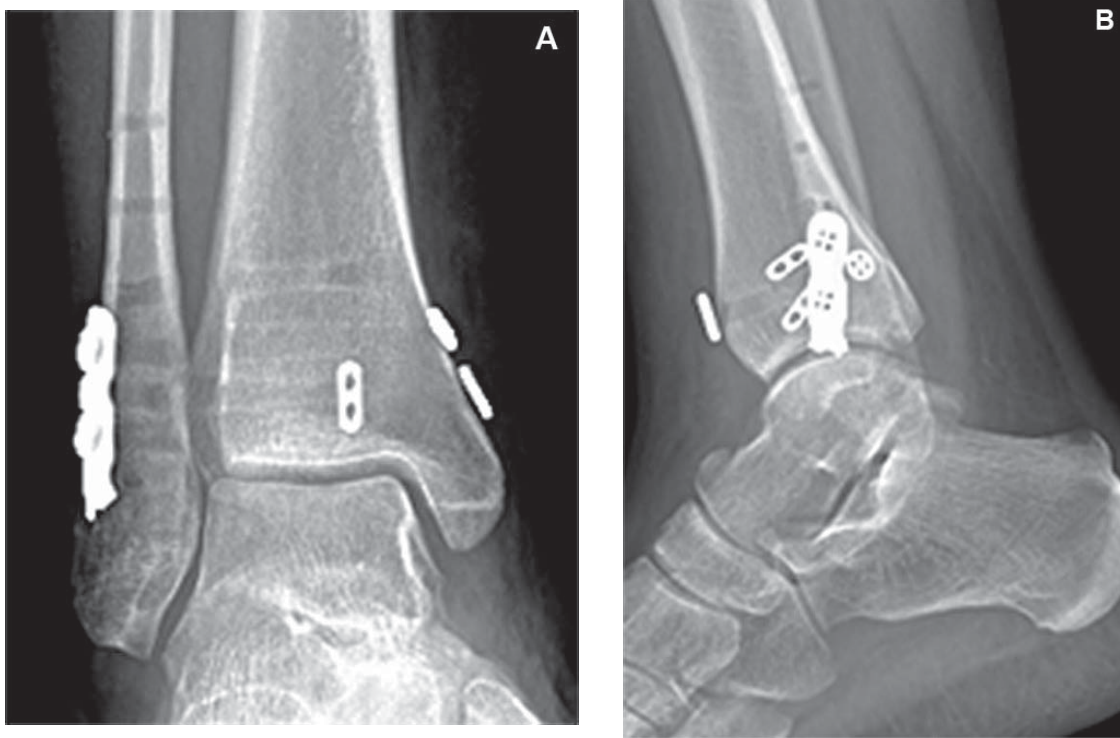
FIGURE 4. Post-operative plain radiographs

Discussion

Anatomical reduction of the syndesmosis is important for ankle stability and normal transmission of forces across the tibiotalar joint to minimize the incidence of posttraumatic arthritis.[1-5] Kennedy, et al. demonstrated that even subtle malreduction of the syndesmosis resulted in increased focal pressures across the ankle joint with consequent ankle arthrosis.[6] Similarly others have shown the rapid development of ankle arthritis at an average of 4 years following injury when the syndesmosis is malreduced.[7] Recent literature has shown a relatively high rate of syndesmotic malreduction after surgical fixation and resultant morbidity. Gardner, et al. evaluated a cohort of 29 patients with ankle fractures who underwent surgical fixation with 52% demonstrating malreduction on postoperative CT scans.[10] Miller, et al. similarly demonstrated close to 50% malreduction using traditional techniques in a cohort of 25 patients.[11] Sanders, et al. recently published a two year follow-up of 68 patients with known syndesmotic malreduc-

tion after surgical fixation demonstrating statistically worse clinical outcomes when evaluated using the SFMA and the ankle specific Olerud/Molander questionnaires.[31]

As more outcomes studies demonstrate increased morbidity with syndesmotic malreduction, this calls into question our ability to detect proper anatomic reduction. Are plain radiographs (or fluoroscopy) adequate to assess accurate reduction? Traditionally, intraoperative evaluation of syndesmotic reduction is performed via fluoroscopy. However, both static and stress radiographs have been suggested to be unsatisfactory in multiple studies.[23-27] Some studies have shown an average of 16% malreduction of the syndesmosis when reliant on plain films.[28-30] There is also lack of consensus in terms of the radiographic parameters used as well as their accuracy. Marmor, et al. demonstrated in a cadaveric study the inability of traditionally used radiographic parameters such as tibiofibular clear space and overlap to accurately assess anatomic reduction, in particular for rotational malreductions. Gard-

ner, et al. evaluated a cohort of 29 patients with ankle fractures who underwent surgical fixation. When comparing plain radiographs to axial CT scans obtained postoperatively, 6 (24%) cases were diagnosed with malreduction of the syndesmosis on plain films whereas, 13 (52%) revealed malreduction on CT scans.[10] While some authors have advocated the use of post-operative CT to assess syndesmotic reduction, this is problematic as post-operative analysis requires a return back to the operating theatre when revision syndesmotic fixation is required.

Current evidence suggests that intraoperative assessment using CT-type imaging modalities that can produce axial imaging of the distal tibia-fibular joint is the most effective means of accurately assessing anatomic reduction.[8-13] But what exactly is "anatomic" when imaging the syndesmosis using axial CTs? Dikos, et al. used axial CT scans to evaluate the normal anatomical variations in tibiofibular relationship. Not only did they find gender differences in certain anatomic parameters but they also found normal variation when a side-to-side comparison was performed. Despite this, they recommended using the patient's contralateral ankle as a guide when assessing syndesmotic reduction rather than depending on predefined measurements.[14] This was also reported in another study which recommended using comparative CT scans rather than plain images or single limb post-operative CT scan which were found to be of limited value when assessing syndesmotic reduction.[15] These data not only suggest the need to image the contralateral uninjured ankle, but also challenge the absolute accuracy of using this technique to assess anatomic reduction of the injured side. Furthermore this calls into question whether the rates of malreduction as demonstrated by previous studies was truly as high as reported.

What about surgical reduction of the syndesmosis using traditional techniques?

Although a variety of methods have been described for reduction of the syndesmosis, indirect reduction using reduction forceps with verification using intraoperative fluoroscopy is most commonly performed.[16-19] Traditionally, the forceps is placed obliquely, compression performed in the coronal plane with the ankle in neutral or slight dorsiflexion with fixation placed at 20-30 degrees from the horizontal due to the relative posterior anatomic position of the fibula compared to the tibia.[20] But is this technique reliable for anatomically reducing the syndesmosis? Phisitkul, et al. found in their cadaveric study that there is an optimal place for forceps placement to achieve accurate reduction and stated that syndesmotic malreduction can be produced if the forceps was placed at different landmarks. They discovered a degree of over compression in all clamping alignments however; they mentioned that its clinical significance is unknown.[21] Miller, et al. confirmed these findings in another study showing a high incidence of syndesmotic over-compression and malreduction. They demonstrated that for optimal reduction using the clamp forceps, it should be angled to 0° rather than 15° or 30° with the lateral screws directed at 0° and the posterolateral screws directed at 30° from the fibula in the coronal plane.[22]

If indirect reduction can lead to malreduction does open reducing the syndesmosis, ie directly visualizing the incisura, lead to anatomic reduction? Miller, et al. reported on open reduction of the syndesmosis. They compared a cohort of 149 patients who underwent open reduction of the syndesmosis to a previously treated group of 25 patients who underwent indirect fluoroscopy-assisted reduction. 24/149 (16%) in the direct visualization group were proven malreduced in postoperative CT scans in comparison to 13/25 (52%) in the control group. They further subdivided the direct visualization group into patients with posterior malleolar fractures who underwent ORIF regardless of the size of the fragment (including patients with ankle fracture-dislocations) and patients with purely ligamentous disruptions with syndesmotic screw fixation only. A trend toward significance was observed in the posterior malleolar group, which signi-

fies the importance of anatomical reduction of the posterior malleolus.[11] In another study, 68 patients were prospectively followed for a minimum of 2 years follow up. 2/13 (15%) who had open reduction were found to have malreduction when CT scan was performed (with comparison CTs obtained of the uninjured side) while 25/55 (44%) of the closed reduction group were proven malreduced.[31] While open-reducing the syndesmosis appears to improve the odds of obtaining an anatomic reduction as compared to indirect reduction, the literature continues to demonstrate a relatively high malreduction rate even when directly visualizing the syndesmotic joint.

In summary, the current literature suggests that in order to ensure anatomic reduction and improve patient outcomes the treating surgeon should: (1) obtain a CT scan of the contralateral unaffected side for comparison while also accounting for anatomic variation, (2) utilize intra-operative CT to assess anatomic reduction, and (3) make alterations in classically taught reduction techniques. But at what cost? It seems unreasonable and cost-prohibitive to assess every surgical patient with a known or suspected syndesmotic injury in this manner but yet it is unclear which patients may require a higher level of assessment. Intra-operative CT is a modality that is not commonly available at most institutions and there exists a significant cost consideration. Furthermore there are practical issues to consider. While images are obtained relatively quickly using the O-arm (approx. 2 minutes per scan), operative time is increased due to positioning of the O-arm as well as image acquisition. In addition the radiation exposure is slightly increased as each scan using the O-arm produces approximately 7.9 mGy of radiation (roughly equivalent to 5.6 radiographs).

Is there a simpler solution to this problem? A new method for intra-operative assessment of syndesmotic reduction was reported recently by Summers, et al. which appears promising.[37] They obtained mortise and lateral views of the contralateral uninjured ankle intraoperatively carefully examining symmetry of the clear spaces and lateral bony overlap. Following fixation, reduction was performed and confirmed using the contralateral ankle images as a template. This was immediately confirmed in the operating room with CT scan and if found to be malreduced, revision of the reduction was performed. 17/18 cases in their study showed anatomic reduction on CT scan. Only one case revealed syndesmotic malreduction and revision ORIF of the fibular fracture was done and resulted on anatomic reduction confirmed by a second CT scan.

More research needs to be performed to establish the most effective yet cost efficient method of assessing syndesmotic reduction given the poorer prognosis associated with syndesmotic malreduction. Imaging the contralateral uninjured ankle and open reducing the syndesmosis with judicious use of available advanced imaging modalities appears to improve outcomes.

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The Jaffe and Mankin Digital Image: Collections at the MGH

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Henry L. Jaffe MD was an extraordinary Pathologist who contributed more than anyone else to our knowledge of musculoskeletal pathology. Jaffe was born in New York City in 1896, attended and received a doctorate from New York University in 1920. He served at Bellevue Hospital and subsequently at Montefiore Hospital. He became interested in Pathology and became a student and colleague of David Marine at Montefiore. In 1924 Jaffe became Chief of Pathology at the Hospital for Joint Diseases, a post he held for four decades until his retirement in 1964, but he remained there as a consultant, teacher and spectacular collector of pathologic material. He became a very competent consultant for cases sent to him from all over the world, many of which he added to his remarkable collection. He wrote many articles on a variety of subjects related to Orthopaedic diseases and two famous books, which are not only still in print but are frequently consulted by orthopaedists and pathologists. These include "Tumors and Tumorous Conditions of Bones and Joints" (published in 1958) and "Metabolic, Degenerative and Inflammatory Diseases of Bones and Joints" published in 1972.

Dr. Henry Jaffe amassed an important collection of over 3,000 Orthopaedic cases over the course of his career which also included the case collections of Dr. Jakob Erdheim, a prominent Viennese Pathologist, who before he died in 1937 was able to have his collection smuggled in a rug out of Vienna. At the death of Dr. Jaffe in 1979 these collections were given to Dr. Henry Mankin, then Chief of Orthopaedics at Massachusetts General Hospital. A collector in his own right,

Dr. Mankin has amassed thousands of histological photographic slides of his patients as well as others seen at the Orthopaedic Oncology Unit in the Orthopaedic Department at MGH. From these three sources have arisen the now very large Jaffe - Erdheim- Mankin Collection of Orthopaedic cases that include photographs, x-rays, glass plates, histologic slides and documents on metabolic diseases of bone, skeletal disorders and tumors of bone and soft tissue.

Henry J.Mankin is an Orthopaedic Surgeon who performed his residency at the Hospital for Joint Diseases in New York City from 1957 to 1960 and served as a resident with Dr. Jaffe for 5 months, just before he began his Orthopaedic training. He subsequently served at the University of Pittsburgh from 1960 to 1966, as Chief or Orthopaedics at the Hospital for Joint Diseases until 1972 when he became the Edith M. Ashley Orthopaedic Professor at Harvard and Chief of Orthopaedic Surgery at the Massachusetts General Hospital. He established a program for caring for patients with bone and soft tissue tumors and spent considerable time in research and education, until his retirement from active practice after 30 years.

Dr. Mankin treated approximately 15,000 patients during his tenure as department chief at MGH and published approximatley 680 articles and 2 books on the subjects of bone and joint disease. He has established a database for the collection and storage of general information regarding over 19,000 patients treated by him and his associates. Table 1 illustrates the outline of information collected in this database. In

TABLE 1. Computerized data from Mankin-MGH Orthopaedic Data base	
Name:	Surgery A:
Age:	Surgery B:
Date:	Surgery C:
Sex:	Surgery D:
Unitno:	XRT:
Photono:	Chemo
Diagnosis:	MD:
Site:	Hospital:
PMD:	Death:
Stage:	Death Date:
Stage:	Remarks:

TABLE 2. Examples of Malignant Tumors	Jaffe Cases	Mankin Cases
Adamantinoma	14	7
Chondrosarcoma	187	136
Ewings Sarcoma	35	29
Lymphoma	205	35
Myeloma	75	10
Osteosarcoma	210	68

TABLE 3. Examples of Benign Tumors	Jaffe Cases	Mankin Cases
Giant Cell Tumor	153	39
Enchondroma	75	12
Osteoblastoma	48	0
Neuroblastoma	57	28
PVNS	65	16
Paget's Disease	123	51

TABLE 4. Examples of Other Diseases	Jaffe Cases	Mankin Cases
Gaucher Disease	5	67
Osteoporosis	33	7
Osteomyeletis	142	25
Osteonecrosis	75	10
Rickets	21	3
Syphilis	25	1

addition there are over 5,000 2x2 slides of histology and x-rays of his and his associate's patients collected from over his 30 years in practice and are being digitized. It should be noted that much of our current digitized collection is from the Jaffe material. To date the entire Jaffe/Erdheim collections have been digitized and current efforts are concentrated on the Mankin collection.

The purpose of this work is to preserve the material in these Orthopaedic cases and to make the images available to the medical community at large through access on the web.

Current Material which has been digitized

A total of 3850 Jaffe cases are included in our Imaging project resulting in over 19,000 digitized images. Thus far, over 900 Mankin cases have been included with over 2600 images all taken from 2 X 2 slides. Examples of cases organized by diagnosis for both series are shown in Tables 2,3 and 4.

The material which comes from several of the cases from both groups is shown in Figures 1, 2, 3 and 4. These are digitized material made from the Jaffe case studies or the Mankin 2 X 2 slides.
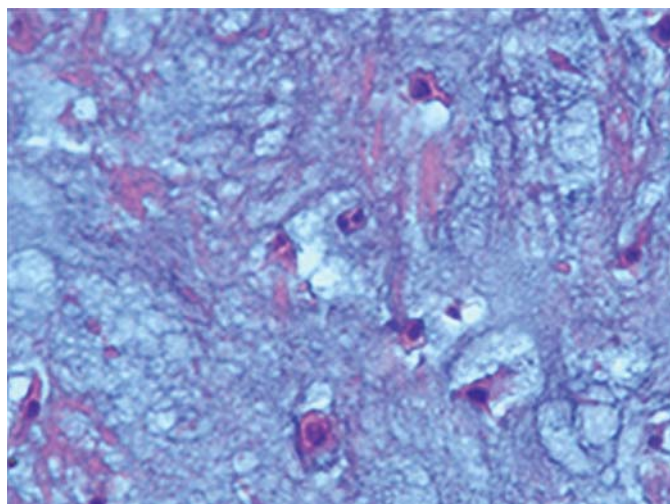
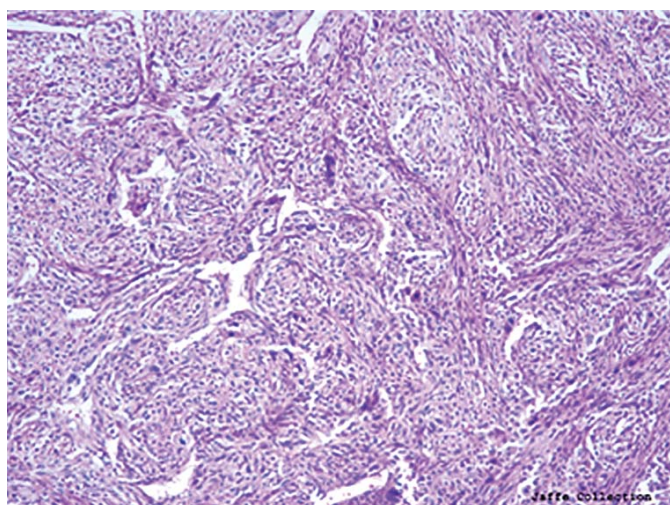FIGURE 1. Chondrosarcoma from the Jaffe collection

FIGURE 2. Osteosarcoma from the Jaffe collection
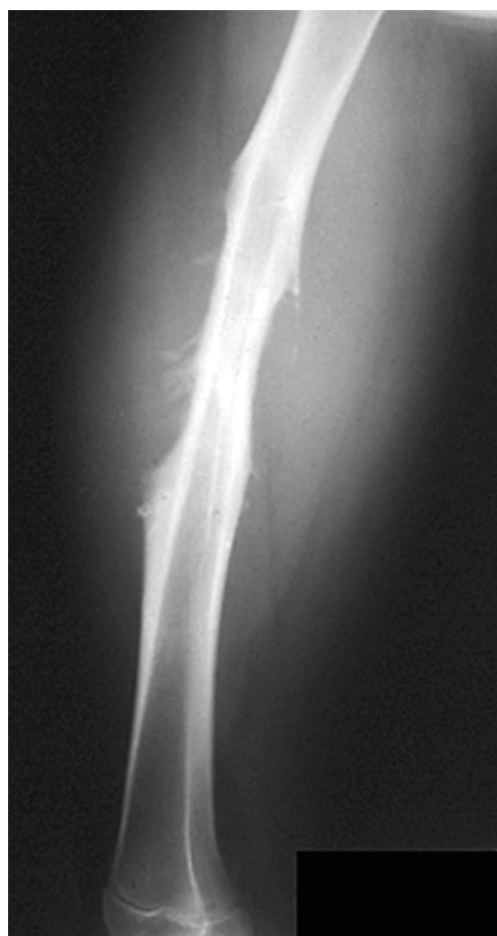

FIGURE 3. Ewings from the Mankin Collection

FIGURE 4. Gaucher's disease from the Mankin Collection

Ignorance is Bliss

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Quality, safety and value in healthcare are the "catch terms" of today with the new wave of healthcare reform in the United States. After almost fourteen years following the Institute of Medicine's report "To Err is Human" and almost twenty-four years after the Harvard practice study that revealed almost 200,000 deaths per year in the United States were the result of adverse events, quality and safety remain major problems for physicians, nurses, and hospitals. Little has changed...errors and adverse events continue at unacceptably high rates. Efforts to improve the safety of patients haven't worked... including pay-for-performance incentives, increased regulation, and advocacy for professionalism and altruism.

Historically, two outstanding physicians have made valiant efforts to reduce medical errors. There have obviously been many others, but this brief paper will focus on only these two...Ignaz Semmelweis and Ernest A. Codman.

But first a brief story about the inadequate medical care of a president of the United States. James Garfield was elected the 20th President of the United States in 1880. Eight months after election, he was shot by an insane man, Charles Guiteau. Garfield was shot twice. One bullet grazed his right arm; the other entered his right flank. Neither wound was life threatening. No major organ was injured. A Dr. D. Willard Bliss was called to treat the President by Robert Todd Lincoln, who had met Dr. Bliss at the bedside of his dying father (President Abraham Lincoln).

Robert Todd Lincoln was obviously unaware of the problems in medical care and professionalism that Dr. Bliss had been accused of publicly. Three major events stand out. First, there had been public reports and newspaper articles written about his poor care of patients at the Battle of Bull Run in 1863. Second, he had been previously arrested for government fraud after receiving a bribe. And third, he had been expelled from the Washington, D.C. Medical Society in 1853 for advertising and selling cundurango (bark of a South American vine) for the "wonderful remedy for cancer, syphilis, scrofula, ulcer...and all other chronic blood diseases."

After being called to treat President Garfield, Dr. Bliss took over, dismissing other physicians, and using an occasional consultant, as he deemed necessary. His major goal in treatment was to find and remove the bullet in Garfield's flank. To do this, Dr. Bliss probed the wound with his unwashed hands and unwashed instruments multiple times daily without the use of ether or chloroform. Although Lister had discovered "antisepsis" 15 years earlier (1865) and carbolic acid had been used in the United States at the Massachusetts General Hospital and by most U.S. surgeons by 1876, Bliss refused to accept Lister's treatment to avoid infection.

President Garfield died of massive sepsis on September 19, 1881, 80 days after being shot. His original wound had increased from a bullet size hole (.44 caliber) to 20 inches long; his weight had fallen to 130 pounds from 210 pounds. At autopsy the bullet was found behind the pancreas. It had penetrated the disc space between T12 and L1. No internal organs had been injured. He had multiple abscesses.

Charles Guiteau was convicted of murder and hanged on June 30, 1882. Prior to his execution he publicly proclaimed "Yes, I shot him, but his doctor killed him." The phrase "Ignorance is Bliss" became

popular and had new meaning after the original phrase "Where ignorance is bliss, 'tis folly to be wise', written by Thomas Gray in a poem in 1742.

Ignorance is bliss, 'tis folly to be wise can be applied to the entire effort at reducing medical/surgical errors and improving patient quality and safety. Examples of the medical profession's resistance to the important cultural changes required to improve patient safety and remain in "bliss", rather than becoming "wise", bring us back to our two examples…Ignaz Semmelweis and Ernest A. Codman.

Ignaz Semmelweis was chief of the obstetric service at the Vienna General Hospital in 1846. He was in charge of two wards…Clinic 1 in which physicians and medical students cared for women in labor and Clinic 2 in which midwives delivered the babies. Semmelweis was a keen observer. He noticed that the death rate from postpartum sepsis on Clinic 1 was 12%, but was only 2% on Clinic 2. The only other difference in the two clinics that he observed was that the medical students and physicians performed autopsies on the women and children who died the previous night in the early morning before they began to examine the women in labor and assist in deliveries. The midwives worked only in Clinic 2. Semmelweis had also observed the collections of pus in patients at autopsy and wrote "The transmitting source of those cadaver particles was to be found in the hands of students and attending physicians."

This insightful observation of Semmelweis's in 1846 was before the discoveries of Pasteur and Lister (1865). And yet he had the courage to insist that every physician and medical student wash their hands in a chlorine solution that he placed at the entrance to Clinic 1. The reaction by the doctors and students, similar to reactions we see today, was one of resistance. They objected to this "senseless ritual" imposed by Semmelweis. Yet, within one month of this new policy of hand washing, the mortality rate fell precipitously to 2% -- the same as Cinic 2.

Semmelweis defended his theory before the Medical Society of Vienna. A few physicians supported him but most did not. Opposition increased. His contract with the hospital was not renewed. Known as "lightheaded and popular…[with a] playful jocular nature," Semmelweis became increasingly inpatient with his colleagues. He became abusive with frequent angry outbursts…he became strident. Today he would be labeled a disruptive physician, a troublemaker.

Not known for publishing much, he didn't write his book "Etiology…And Prophylaxis of Childbed Fever" until 1961. He sent copies to the leading obstetricians and medical societies in Europe. Most ignored his book and other publications. Resistance to hand washing increased. Enraged, Semmelweis lashed out…accusing his colleagues of murder…"Since 1847 thousands of women and infants have died…you…have been a partner in this massacre. The murder must cease."

Eventually, unable to find work, Semmelweis became a heavy drinker. Once a happy and popular physician he died at the young age of 47 years. Angry, depressed and strident, he saw himself a failure and didn't understand why. A metaphor used today is called the Semmelweis Reflex or Effect. It refers to the reflex-like tendency to reject new knowledge because it contradicts established beliefs.

Ernest Amory Codman was born four years after Semmelweis's death. He was 11 years old when Garfield died. Appointed assistant surgeon at the MGH in 1897, he is believed to be the founder of the belief that outcomes or results of patients' care should be reported…his "end-result idea." However, George Hayward, assistant surgeon at MGH, had reported the result of 222 surgical cases treated at MGH in 1837 and 1838. He reported the discharge status of patients as well: much relieved, relieved, not relieved, died, unfit, or eloped (7 categories). And Frank Hamilton, a surgeon in Buffalo, New York, published a book in 1855 on the results of fracture treatment. His classification of results of fracture care consisted of five categories: united or not, when united, amount of shortening, remarks, and perfect or imperfect. He was aware that surgeons didn't have accurate data to judge the results of

their care. Litigation was rampant at the time, especially in cases of deformities after fractures. He was also upset that surgeons often stated "their patients all did well." Hamilton correctly observed "To be honest...they [surgeons] dare not record faithfully their results...the admissions of shortcomings...would be suicidal." He further wrote "The instinct of self-preservation prompts silence...the first step towards improvements... must be the faithful exposure...of deficiencies." After his public reporting of outcomes of fracture treatment, the juries stopped favoring plaintiffs. However, his hope that surgeons would agree on a standard of care was not achieved. Treatment uncertainty remained.

Codman's end-result concept was different than that of Hayward or Hamilton. He wanted the outcomes of treatment of all patients reported publicly at one year after treatment for both the physician and the hospital. He also insisted that an analysis...known today as root-cause analysis...be done to determine the cause of the bad result and how the adverse event could be avoided in the future. His classification system of errors was more comprehensive. Although he didn't name individual errors versus system errors, he included both in his system. Interestingly, his individual errors were recently reported by Matsen, et al in The Journal of Bone and Joint Surgery as common causes of malpractice suits against orthopaedic surgeons...100 years after Codman's publication. Codman's individual errors were: lack of technical skill or knowledge, lack of surgical judgment, lack of diagnostic skill and lack of care."

Codman met strong resistance from his colleagues to the importance of reporting outcomes and analyzing their poor results; similar to the resistance that Semmelweis faced almost 50 years earlier. He did have some support for his concept by hospitals and physicians around the country. But not at home; he made many of his colleagues very uncomfortable. He also engaged in a continuous battle with the MGH Director and Trustees because they would not agree to his sys-

tematic record review and would not serve on his hospital quality committee.

An avid hunter and fisherman, Codman had many friends. He was known as a "kind and sweet person." But as resistance to his end-result concept grew...a concept he was most proud of... he also became increasingly critical of his colleagues, angry, and combative. Codman became increasingly strident.

Then in 1914 he was asked by HMS Dean Edward Bradford (an orthopaedic surgeon) to organize a clinical congress of surgeons in Boston. He refused unless every case operated upon would have a brief clinical history and an end-result report mailed to all attendees one year after the congress. He also wrote in a personal letter about two cases that he had observed at a previous clinical congress "at a prominent hospital" that bothered him. In one case the patient died during the operation, but the surgeon did not inform the audience. He continued to operate, closed the incision and as Codman stated "smuggled" the patient out of the amphitheater. In the second case, the surgeon performed a routine hysterectomy "for supposed fibroid tumor." However after the operation, when the specimen was examined in pathology, "it proved to be a full-term pregnancy." Codman was upset for two reasons...one, the audience was not informed and two, when the surgeon's hospital colleagues heard about the discovery, the surgeon threw his resident under the bus, stating "that he had taken his house officer's diagnosis." Codman went on to write "Both surgeons held the respect of the entire community...[but] are no more to be held guilty than the rest of us who tacitly allow such things to occur."

Codman became totally fed up with his colleagues and the MGH's failure to implement his outcomes concept. He resigned from the staff, having reached the limits of rejection. Just as Semmelweis had accused his colleagues of the responsibility of their patients' deaths from postpartum sepsis, Codman knew that "Harvard was sensitive to ridicule...[he] sincerely believe[d]...

to presentation of facts." In 1916 he presented his infamous cartoon (8 feet long) to the local medical society. With it, he critically insulted his colleagues, the MGH Trustees, and the president and leaders at Harvard. An immediate uproar occurred in the medical and academic community. The local newspaper reported "Cartoon by Physician Makes Stir." As a consequence, Codman lost his Harvard faculty appointment. It has been stated that he "sometimes felt like a quixotic figure at best and, at worse, a failure."

Codman died of melanoma in 1940 at age 71, estranged from his profession, colleagues, and probably his wife. His obituary "omitted completely any mention…of his lifelong crusade to improve the quality of surgical care and…methods…to improve the work of hospitals." He is buried in an unmarked grave in the Mount Auburn Cemetery. This year, the MGH, together with the American College of Surgeons, the American Academy of Orthopaedic Surgeons and The Shoulder and Elbow Society have contributed to an engrave headstone for Dr. Codman. It is planned to be placed in the cemetery in June, 2013.

Both Semmelweis and Codman challenged the status quo in medical thinking. Both men were rejected by their colleagues. Both men became strident in their efforts to change and improve medical care. Both men died before seeing their major contributions to patient safety accepted by the medical profession. Pursuing improved quality of care, safety for all patients and minimalization of all surgical and medical errors today remains a quest for the ideal. But I still remain optimistic that the cultural changes that these two men strived for will be achieved with the current and next generation of active physicians and surgeons.

The Next Forty Years

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Over the 44 years since I completed my residency in orthopaedics in 1969, I've witnessed astounding changes in our specialty specifically and in medicine in general. In orthopaedics in the 1960s, we still had links to our bone-setter predecessors; fracture management was the most popular topic in the literature and our conferences. Treatment was in transition from an emphasis on closed reduction and non-operative measures to open reduction and internal fixation. Surgery was becoming more acceptable because we had begun to reduce operative infection rates and we had, for the first time, adequate intra-operative imaging.

Let me describe how we managed some common problems in the late 1960s—you'll readily understand how far we've travelled in just over four decades.

When I arrived on the orthopedic ward on White 5 at MGH in 1967, about half the patients with intertrochanteric hip fractures were treated with skeletal traction (an average of 12 weeks in a hospital bed for sufficient healing to support weight-bearing) and half were treated with surgery. Our fixation device was a Smith-Petersen nail coupled with a Thornton side-plate. (It had no telescoping capabilities.) During my last rotation on White 5 (1969), we treated all intertrochanteric fractures surgically (and usually inserted an early version of a telescoping device).

Tratment of ankle fractures was similarly evolving. In 1967, the standard of treatment for most was closed reduction and a plaster cast. The fracture clinic, unfortunately, saw too many patients with ankle fractures treated non-operatively who developed post-traumatic arthritis. By the early 1970s, the standard of care had changed. Most complex ankle fractures were treated surgically and outcomes improved considerably.

Care of severe arthritis of the hip was in flux in the late 1960s. The standard treatment was cup arthroplasty. There was a brief period of enthusiasm for trochanteric osteotomy, some patients had their hips fused, and total hip arthroplasty arrived from England as the decade was closing. By the early 1970s it became obvious total hip arthroplasty worked much better than its forerunner procedures.

Development of effective treatment for advanced arthritis of the knee lagged behind development of good treatment of the arthritic hip. In the 1960s we sometimes used the MGH distal femoral prosthesis but results were generally poor.

The principles of total knee arthroplasty were worked out in the 1970s and soon this procedure did as well as total hip arthroplasty.

Most traumatic knee injuries were a challenge. We usually made the diagnosis of a torn meniscus clinically because arthrography was not dependable (and MRI was to come years later). Surgery required arthrotomy, one to three days in the hospital, splint immobilization of the knee, two crutches for several days and then often physical therapy to mobilize the stiff joint. The advent of arthroscopy a few years later significantly improved treatment of meniscal tears in every important respect.

We saw many patients with anterior cruciate ligament tears and could offer no effective treatment. The treatment standard then, strengthening of the thigh muscles, usually yielded inadequate results. The 1970s brought surgery for this injury, treat-

ment for which gradually became very effective.

Unfortunately, we have not made commensurate improvements with all our orthopaedic problems. In the late 1960s, I had the opportunity as a resident to attend an AAOS Annual Meeting in Chicago. I recall a seminar there on the lumbar spine in which a speaker said, "Low back pain is the weed in your orthopaedic garden and you must get rid of it." This weed remains in our garden today.

While in the late 1960s we were doing more surgery for fractures and obtaining better results, treatment for low back pain with or without sciatica was moving in the opposite direction. After Mixter and Barr announced in 1933 that the herniated lumbar disc was a cause of low back pain and/or sciatica, orthopaedic and neurosurgeons operated upon many discs in patients who subsequently did poorly. Consequently, by the 1960s, most orthopaedic staff members at the MGH had a decided bias against surgery for this diagnosis. Today we're aware there was then an incomplete understanding of what caused low back pain and sciatica (we know more about this today, but not enough). A personal recollection of what we didn't know in the late 1960s – the notebook I compiled during residency doesn't mention the diagnosis of spinal stenosis. Hiding in plain sight, this common entity awaited the 1970s to become known to most of the orthopaedic community. (Remember, myelography was the best we had for imaging the spinal canal in the 1960s. It was less sensitive than CT and MRI which came later.)

To the reader, these recollections must be as exciting as looking at an orthopaedic textbook from the 1960s. But there's a point here, and it relates to today's important national dialogue about health care costs. If one compares what we did 40-plus years ago to what we do today for most musculoskeletal problems, it's evident we do things better and our results are much improved. And these improvements haven't occurred just in orthopaedic surgery. Consider the important innovations developed in all of medicine between the 1960s and today that provide better treatment for heart disease, cancers, renal failure, eye and infectious diseases – the list is lengthy. Yet, society has chosen to reward all who directly provide health care to patients with decreasing compensation over the past 30-plus years in return for these superior services.

In a conversation during my residency years, a wise surgeon told me never to be concerned about the income I'd make from medicine. Practice good medicine, he said, and society will compensate you adequately. This unwritten compact prevailed until the 1980s when society began to change it. Today, it no longer exists and, accordingly, the viability of our traditional triple mission of patient care, teaching and research is now sorely threatened. (Orthopaedists' incomes have held up so far – this isn't a brief to improve them – but many of our medical colleagues are beleaguered.) Some factors that bear upon these changes warrant mention.

Health care costs in the United States increased from approximately 7% of gross domestic product in 1970 to 17.9% in 2011. Most newspaper articles and virtually all television discussions do not break down the responsibilities of different participants in the health care business for this rise in costs. These participants can be divided into two groups, one that delivers care directly to patients and one that doesn't.

Considering the group that doesn't treat patients, it's generally overlooked that an estimated 31% – much more than 40 years ago – of American health care dollars go to administrative costs, much of which are created by insurance companies and other intermediaries. Suffice to say, today much more money than in 1970 is spent on "health care costs" that have little to do with providing care directly to patients. And decision-makers on the Hills, Capitol and Beacon, who attempt to contain the rise in health care costs, continue to focus on further reductions of payments to direct caregivers while they leave unchallenged the profitability of many who have impaired efficiency of the healthcare

system and increased its costs. It's beyond the scope of this article – and my competence – to try to explain the reasons, certainly complex, for these actions. Perhaps economists from another part of the university understand why this is occurring.

It is within the scope of this article to express concern that if society's elected representatives continue in their current course, the provider sector in medicine may be so weakened that it will no longer be able to function as produc- tively as it has for generations. Mitch Rabkin, the astute former president of the Beth Israel Hospital, said in discussing hospital business, "No money, no mission." This applies as well to doctors and other direct care providers inside and outside of hospitals. If we don't convey this essential point to the public more effectively, there is a real risk the next 40-plus years will not bring advances in patient care as meaningful as what the last 40-plus years has provided.