Temple University Journal of Orthopaedic Surgery & Sports Medicine

Volume 4
Spring 2009

A John Lachman Society Publication

The New Temple University School of Medicine
(Under construction — to be completed in 2009.)

The John W. Lachman Auditorium — A work in progress.

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Table of Contents

Case Report

Review

Lectureships

Departmental News

Instructions to Authors

Dedication

Theodore “Ted” Quedenfeld

Theodore "Ted" Quedenfeld
November 1, 1934–March 24, 2001

Theodore "Ted" Quedenfeld, a 1960 graduate of Temple University, never left the school he loved. He spent his entire career, and a large part of his free time, caring for thousands of injured high school, college and professional athletes from throughout the Delaware Valley.

During his undergraduate years, Ted earned twelve varsity letters, as well as academic honors. He completed his graduate education with honors in 1962. Ted was appointed Head Trainer of the Department of Intercollegiate Athletics in 1960, a position he served with much distinction for 15 years, endearing himself to thousands of Temple students.

Ted was a charter member and co-founder of the Pennsylvania and Eastern Athletic Trainers Societies and was generally regarded as one of the most prominent and promising young athletic trainers in America. Ted's research interests in football cleats, head and neck injuries in football, as well as sports asthma helped promote advancements which changed the standard of care for athletes nationally.

In 1975, Ted took on a new challenge when he teamed with Dr. Joe Torg, creating the Temple University Sports Medicine Center; the first university based Sports Medicine Center in America, a concept that has since been established throughout the nation. He directed the Center for over 23 years and participated in the education of generations of orthopedic residents, medical students and athletic trainers throughout the university and health system. Ted's innovations in the delivery of orthopedic care, particularly the development of satellite clinical sites, secured the future of Temple's Orthopedic Department. His role in the establishment of educational programs, clinical trainers outreach services, and clinical research projects primarily dealing with injury prevention has ensured Temple a prominent place in the history of sports medicine, locally, regionally and nationally. Ted's national contribution was recognized in June, 2004 when he was elected to the National Athletic Trainers Association "Hall of Fame."

In addition to his administrative responsibilities, Ted was an Associate Professor at the Temple University School of Medicine. He was awarded the Benjamin Rush Award by the Philadelphia County Medical Society in 1972 for outstanding health service.

The diversity of Ted's admires was most notable, from university presidents to members of the physical plant, as well as athletes and patients. He treated all with equal respect and dignity. Ted's big picture included a vision to make Temple University Sports Medicine affordable and accessible to all athletes of the tri-state area. He shared a dream and pioneered the growth of sports medicine as we know it today. His peer recognition and Hall of Fame awards are too numerous to mention. Ted was a man of action, his work ethic and energy as well as his intensity became contagious to those around him. While serving as Administrative Director of Sports Medicine as well as Associate Professor in the School of Medicine, he never hesitated to answer the phones, make appointments, clean whirlpools or settle disputes, all with equal attention and humility. He built a team designed to serve patients and the physicians who cared for them.

After a short lived retirement, Ted was co-director of Temple University Sport Asthma Research Center as well as serving as consultant to the Temple Health System until his death.

Ted's contributions to Temple University and to the Department of Orthopedics were significant and lasting. Many of visions and innovations continue to guide and give direction to our department today.

James Rogers, MS, ATC

Temple University Journal of Orthopaedic Surgery and Sports Medicine

How to Reach Us

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Statement from the Chairman

The Department of Orthopaedic Surgery and Sports Medicine is proud to present this year's edition of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine.* In accordance with standards set by previous issues, we are pleased to present to you the research efforts of all of the sections of our department. Included are selected articles from our medical student research program, office of clinical trials, attending and resident research projects, and the basic science section. Since the inception of the "Journal" four years ago, the enthusiasm for research has become palpable within the Department and continues to grow in volume and quality.

The Department continues to play an important role at the institution in both the Medical School and the Health System, providing significant contributions to the missions of clinical excellence, resident and student education and research. On the Health System side, the transition to new space in the Boyer Pavilion, dedicated to musculoskeletal care, is underway and is providing a destination location to our region for clinical excellence. We wish to recognize the efforts of the administration of Temple University Health System and Temple University Hospital for their efforts in making this concept a reality.

On the Medical School side of the street, North Broad Street now has a new look with the final phases of construction of the new Temple University School of Medicine. The building's exterior is an architectural marvel and its interior is state of the art. Official opening is set for the 2009-2010 academic year. The Department of Orthopaedic Surgery and Sports Medicine will be featured proudly with the dedication of the John W. Lachman Auditorium early this fall. We wish to thank all of our orthopaedic alumni for their generous contributions which have made the Lachman Auditorium a reality.

Finally, I would like to acknowledge the Temple/Shriners Orthopaedic Alumni Association and the John Lachman Research Foundation for their continued support of resident education. I would like to express my gratitude to the faculty in making the "Journal" possible through their mentoring, clinical contribution, and editing efforts, specifically, Joseph Torg, MD, Saqib Rehman, MD, and Asif Ilyas, MD for keeping the process on schedule and the residents on track. And last but not least, a special thanks to senior resident Simon Chao, MD who has been an integral part of the success of the "Journal" since the first edition.

That being said, I respectfully submit to you Volume 4 of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine.*

Joseph J. Thoder, MD

Letter from the Editor-in-Chief

We are proud to present the fourth volume of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine.* In keeping up with the tradition of our past volumes, this year's *Journal* represents a culmination of research endeavors within Temple University pertaining to the field of Orthopaedic Surgery and Sports Medicine. It represents the tireless efforts and burgeoning research endeavors of our medical students, residents, faculty, and alumni.

In this edition, we include articles that encompass a broad spectrum of topics related to Orthopaedic Surgery and Sports Medicine. We have compiled research from within our department with contributions from the Department of Anatomy and Cell Biology and Department of Kinesiology of Temple University. Also, for the second year in a row, is a section in our *Journal* dedicated to research sponsored by our Office of Clinical Trials, which includes funded research by medical students during the academic year.

There have been many significant events within our department over the past year, which are chronicled in this year's *Journal.* We were proud as a Temple Family to have our Howard Steel Professor, Ray Moyer, MD, inducted into the Temple University Hall of Fame. Dr. Moyer has been, and remains, a great educator, mentor, and friend to a countless number of physicians, educators, and patients around the country. His life and work has benefited many people worldwide and will continue to inspire orthopaedic surgeons for many years to come. This volume of the *Journal* proudly honors this great man.

Also, this year's *Journal* is dedicated to the work and life of Ted Quedenfeld, who had an integral role in the formation of Temple University Center for Sports Medicine in 1974. We are proud of Ted's legacy as the "father of clinical athletic training," and are grateful for his invaluable service to the history of our Department of Orthopaedic Surgery and Sports Medicine.

Finally, the entire editorial staff would like to thank the authors and reviewers for their contributions to this year's publication. Each individual who has participated in this year's *Journal* has devoted valuable time and energy to this project that has resulted in the work which you now hold. We are grateful to the advertisers and to the John Lachman Society for the financial support of our project, and recognize that without their support, this endeavor would not be possible.

On behalf of the editorial staff of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine,* we hope you find this fourth volume a pleasure to read.

Sincerely,

Simon Chao, MD

LATCH IN HIS TEACHING MODE: Charlie Parsons' excellent drawing depicting "Latch in his teaching mode" has been adopted as the Society's logo. We are happy to inform that those who have accepted membership in the Society with a monetary commitment have received prints of Charlie's drawing autographed by Latch and suitable for framing.

Message from the John Lachman Society

The John Lachman Society was founded in 2004 to honor Dr. Lachman and propagate his principles of integrity, teaching, and excellent patient care. The Society also provides discretionary funds for the Department Chairman to promote and support the academic mission of the Department, including student and resident research. The mechanism to accomplish these goals is through the Society's support of the John Lachman Orthopedic Research Fund (JLORF), incorporated in Pennsylvania as a non-profit corporation. The Internal Revenue Service has determined that The John Lachman Orthopedic Research Fund is exempt from federal income tax under 501 (C) (3) of the Internal Revenue Code and that contributions to the fund are tax deductible.

The mission of The John Lachman Society is twofold: 1) to promote the Lachman principles of integrity, resident training, and quality patient care by various proactive means and programs; and 2) to provide discretionary funds for the Department Chairman to foster and support both the academic and research mission of the Department.

Those interested in membership to The John Lachman Society should contact the Chairman of the Membership Committee, Philip Alburger, MD, c/o The John Lachman Society, P.O. Box 7283, St. Davids, PA 19087.

THE JOHN LACHMAN SOCIETY MEMBERSHIP

The following are members of The John Lachman Society and have committed to supporting The John Lachman Orthopedic Research Fund:

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MICHAEL CLANCY, MD: John Kelly, IV, MD has recently submitted his resignation as President of The John Lachman Orthopedic Research Fund, effective September 1, 2008 and requested that he remain on the Board of Directors. The executive committee subsequently met and nominated Mike Clancy, MD, to succeed John as President. A vote of the Board was conducted and the nomination of Dr. Clancy was unanimously approved as well as Dr. Kelly's continuing on the Board.

Dr. Clancy was introduced to the Board at its last meeting and accepted his selection as President. He made special note of the fact that both the Temple University/Shriners' Alumni Society and the John Lachman Society shared mutual interests with regard to the promotion of the orthopedic department's educational, research and academic goals and committed himself to furthering of these efforts.

THE SUMMER MEDICAL STUDENT RESEARCH PROGRAM: Joe Torg, MD has reported on the success of the summer medical students' research program supported by The John Lachman Orthopedic Research Fund and supervised by the Department's Clinical Trials Desk. In 2007, there were twelve students participating in the program with a number of their projects resulting in manuscripts published in the *Temple University Journal of Orthopedic Surgery & Sports Medicine.* Of this group, four are currently under consideration for publication in major peer review journals. This past 2008 summer, there were seventeen students participating in the program with the anticipated production of between ten and seventeen manuscripts suitable for publication in our journal. Hopefully, a number of these will also be submitted to national peer review journals. The additional value of this program is that curriculum changes no longer require students to rotate through orthopedics on their surgical rotation. Those students interested in orthopedics have an opportunity to interface with our department between the freshman and sophomore years, and clearly the experience has been in keeping with Russell Conwell's concept of "acres of diamonds in your backyard."

RESIDENT ACADEMIC SUPPORT: Simon Chao has reported on resident travel to meetings supported by The John Lachman Orthopedic Research Fund. In the period 1-1-2008 through 10-25-2008, ten residents have attended either formal courses or national meetings with support from The John Lachman Orthopedic Research Fund.

WEBPAGE: The John Lachman Society web page can be entered at www.johnlachmansociety.org.

JOHN LACHMAN LECTURE: The Fifth Annual John Lachman Lecture was given in conjunction with the annual meeting of the Pennsylvania Orthopedic Society was presented by Linda Emanuel, MD, PhD. Dr. Emanuel is a Professor of Medicine at Northwestern University and a leader in the American Medical Association Professional Ethics Program. The topic of her presentation was "The Relationship of the Orthopedic Surgeon with Industry."

Dr. Emanuel pointed out that the Bayh-Dole Act of 1980, encouraged investigators to commercialize research conducted with government funds. She further pointed out that the primary interest of researchers was to discover generalizable knowledge. They also have secondary interests, i.e. publishing, income generation, political activism, etc. Thus, a conflict between the primary and secondary interests, in which the secondary interest may distort judgments relating to the individual's primary interests, can occur. A conflict of interest affecting one's judgment are common. The problems arise, however, when these conflicts are not recognized nor adequately dealt with. First, large financial interest related to financial support by members of the pharmaceutical industries and influence of research is greatest on interpretation and dissemination of data. Second, is the fact that disclosure is not a sufficient safeguard against financial conflicts. Dr. Emanuel further cited management principles and prohibitions as found in the American Academy of Orthopedic Surgeons Standards of Professionalism as required safeguards.

Although clearly controversial, Dr. Emanuel's lecture was well received and clearly in keeping with the Lachman principles of integrity, education and excellence in patient care.

TEMPLE UNIVERSITY JOURNAL OF ORTHOPAEDIC SURGERY AND SPORTS MEDICINE: A major accomplishment of the society was sponsorship of the third annual *Temple University Journal of Orthopaedic Surgery & Sports Medicine.* Thirty-five hundred copies of the Journal have been distributed to members of The John Lachman Society, Temple University medical faculty and key University administrators, members of the Pennsylvania Orthopaedic Society, Temple University School of Medicine alumni who trained elsewhere in orthopedic surgery, Chairman and Directors of orthopedic programs with residency training programs, selected members of the general orthopedic community including all members of the American Orthopedic Association, selected members of the National Athletic Trainers Association, and selected referring physicians. The Journal was well received and we believe clearly established the creditability of our academic program.

RESIDENTS LIBRARY SUPPORT: In keeping with the request of the Director of the residency program, The John Lachman Orthopedic Research Fund is committed to a $2,500 year expenditure for texts and other educational materials.

SYNTHES AWARD: Synthes has again for 2009 awarded The John Lachman Orthopedic Research Fund $20,000 to support the research and academic activities of the Department of Orthopedic Surgery.

FINANCIAL SUMMARY: Since its inception in 2005, the John Lachman Society has exceeded expectations in generating contributions to the John Lachman Orthopedic Research Fund sufficient to cover the Fund's operating expenses and has increased its endowment to over $225,000. Outstanding pledges in excess of an additional $200,000 bring the endowment to thirty-five percent of our goal of $1,000,000, which, conservatively invested, should yield enough money to carry our current level of annual expenses in perpetuity. This provides resources to the Department of Orthopedic Surgery at Temple University School of Medicine for research funding, resident education-related travel expenses, and publication of this Journal for the foreseeable future.

Joe Torg, MD
Secretary

Commentary

Modern Musculoskeletal Education: Alarming Changes

Asif M. Ilyas, MD

Department of Orthopaedic Surgery & Sports Medicine, Temple University School of Medicine, Philadelphia, PA

Modern medical school's emphasis, or de-emphasis, on musculoskeletal medicine is moving at a rapid rate. It is already well-established that today's medical students are alarmingly unprepared to examine and diagnose musculoskeletal ailments. Freedman & Bernstein showed us that 70% of new medical school graduates that matched in orthopaedic surgery residencies failed a validated musculoskeletal basic competency exam.[1] If medical students interested in musculoskeletal medicine fail to obtain the fundamentals in medical school where does that leave the rest? Matzkin et al. identified a failure of 79% among medical students and non-orthopaedic residents.[2] They did note however that subjects who had taken an orthopaedic rotation in medical school did score significantly higher.

In light of these striking facts, medical schools have further decreased, not increased, their emphasis on musculoskeletal education. As a case in point, Temple University School of Medicine has recently eliminated all surgical subspecialty rotations during the third-year of medical school. Instead, the 12-week surgical rotation has been shortened to eight weeks and consists entirely of General Surgery. This eliminates the opportunity of all medical students to obtain any exposure to the surgical sub-specialties including orthopaedic surgery and the clinical practice of musculoskeletal medicine prior to their fourth-year. The fourth-year as well, which is traditionally spent focusing on securing a residency position and passing Part 2 of the USMLE, has now been burdened with approximately six months of additional required rotations thereby further decreasing the opportunity a student might have to take a musculoskeletal rotation (i.e., Orthopaedic Surgery, Rheumatology, or Physical Medicine & Rehabilitation). The net effect of these changes is an overall decrease in the amount of exposure all medical students are obtaining to musculoskeletal medicine as well as a potential decrease in interest in the field of Orthopaedic Surgery.

To highlight these concerning changes, we undertook a study to identify the importance of musculoskeletal education in modern practice. We (Paterek & Ilyas) quantified the amount of time spent in musculoskeletal education during the clinical years at the Temple University School of Medicine and contrasted that to the percentage of surgical cases involving Orthopedic Surgery at Temple University Hospital to highlight the importance of musculoskeletal medicine in actual clinical practice. We identified a large disparity. While Orthopaedic Surgery represented 20% of all surgical cases performed at Temple University Hospital in 2007 (and General Surgery represented 32%), less than 20% of all students obtained at least a minimum of two weeks of a musculoskeletal rotation (including Orthopaedic Surgery, Rheumatology, or Physical Medicine and Rehabilitation), with more than 80% receiving none. Hence, while Orthopaedic Surgery represents a large portion of surgical cases relative to General Surgery at our institution, our medical students obtain a significantly disproportionate surgical education without adequate exposure to musculoskeletal medicine.

As leaders in the field of musculoskeletal medicine we need to take heed and respond to these changes. We know that the demand for musculoskeletal services are increasing as the population lives longer and leads a more active lifestyle, but this demand is not limited to only Orthopaedic Surgeons but to other medical specialties as well. As such, we need to become more cognizant of these troublesome changes in modern medical education and work towards increasing the quality and volume of musculoskeletal education in medical schools today.

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Commentary

The Iatrogenic Narcotic Addiction Syndrome: The E-Prescription Solution

Robert Miller, BS, Chris Williamson, BS, Joseph Torg, MD

Temple University School of Medicine, Philadelphia, PA

The iatrogenic narcotic addiction syndrome (INAS) can be defined as an addiction to a prescription agent due to the irresponsible action of a physician or the pharmaceutical industry, resulting in a dysfunctional lifestyle and possibly death. Once the individual becomes addicted to a prescription drug, his or her primary motivation is devoted to obtaining the narcotic for nonmedical reasons. The acquisition and use of narcotics for nonmedical reasons is called drug diversion. The National Survey of Drug Use and Health (NSDUH) reports that 20% of people over the age of twelve in the United States have used a narcotic drug for nonmedical reasons at least once. In addition, the NSDUH reports that seven million people *currently* use narcotics for recreational use.

It is clear that drug diversion is a major problem with regard to both opiate and non-narcotic prescription drug abuse. Two approaches have been proposed to eliminate many of the ways narcotic drugs are diverted into the hands of addicts. The first is to mandate that physicians use electronic prescriptions to prescribe potentially addictive agents. The second solution is to limit the spectrum of physicians who have the responsibility to prescribe these drugs, based on expertise in pain management.

Advancing technology in the form of electronic health records and electronic prescriptions will eventually replace the current paper-based systems used in health care. The DEA foresees that the nation will have complete electronic health capabilities within fifteen years. While the benefits of e-health record use are beyond the scope of our focus, electronic prescription for controlled narcotics is the method to make an immediate impact on the current problem of prescription drug diversion. Thus, it is strongly recommended to make prescriptions of controlled narcotics using electronic methods mandatory as soon as possible.

The DEA has recently reported that "a recent study of drug diversion and insurance fraud estimated that drug diversion costs health insurers $72 billion a year because of claims for fraudulent prescriptions and treating people for the effects of drug abuse." The problem includes people of all ages. The Partnership for a Drug Free America has found that 50% of teens say that prescription drugs are easy to obtain without a prescription, including over the internet. In 2004, 20% of teens admitted to using Vicodin without a prescription. Teens also said that 10% have used Oxycontin, Ritalin, or Adderall recreationally. The problem goes well beyond adolescents. 2005 data from the Drug Abuse Warning Network (DAWN) reported that in its thirty-two participating cities, there were 599,000 ER visits due to nonmedical use of prescription drugs, OTC drugs, and dietary supplements. This number was a 21% increase over ER visits in 2004. More than half of these visits were from patients over thirty-five years of age.

It is impossible to stop all of the methods through which prescription drugs are leaked to the streets. However, with the use of an e-prescription system, many of the ways controlled narcotics are diverted will be eliminated. For example, instances of stolen prescription pads and forged, legitimate paper prescriptions will be a thing of the past. In addition, doctor shopping, an important method of diversion in which an addict moves from doctor to doctor, looking for a physician to prescribe the narcotics he seeks, will be eliminated.

Currently, the most common form of e-prescription system works through three networks. First, the physician uses a program to write the prescriptions electronically. An example of the physician-accessed program is Allscripts' ePrescribe. The prescription is then sent electronically to an intermediary program, such as Surescripts, which recodes and reroutes the prescription to the pharmacy program. The pharmacist is then notified and fills the prescription.

There are many benefits to using an electronic program such as Allscripts, including delivery of prescriptions to the pharmacy in real-time, insurance formulary compliance checks, allergy checks, elimination of handwriting reading errors, notification of drug-drug contraindications, and simplification of the renewal process. Most pertinent to our goal of eliminating drug diversion is the feature of automatic population of the DEA drug history. In other words, the physician-accessed program lists the drugs previously prescribed to each patient — a list monitored and compiled by the DEA. This eliminates the prevalence of doctor shoppers, because a physician whom is suspicious of a patient attempting to obtain illicit narcotics will be able to see if that patient has been prescribed narcotics elsewhere.

Overall, e-prescription is more efficient, safe, and presumably will save millions of dollars when the system is completely implemented. Currently, only 2% of the 1.5 billion prescriptions written annually are submitted electronically. One reason is that it is not yet legal to prescribe Schedule II drugs, such as oxycodone, electronically.

The DEA has proposed a rule that will give the option to e-prescribe Schedule II controlled substances. Although the rule will certainly pass, it does not mandate the use of electronic technology. The DEA will offer e-prescription as an alternative. The DEA cites controlled substance diversion as the main reason to switch to e-prescription. However, it is extremely wary of the security measures needed to keep the e-prescription system as diversion-proof as possible. The result is an extremely dense document detailing the security measures needed to access the e-program and the what-ifs about illicit access of the e-systems in order to divert drugs. However, the e-services are currently as safe as e-banking. The industry is well on its way to answering the security questions the DEA has proposed.

Cost of implementation may be the largest deterrent to the adoption of health information technology. The average cost per doctor is $3,000 to establish e-prescription. Fortunately, there are many vendors and organizations now subsidizing the technology, to accelerate the use of e-prescription services. For example, the Highmark eHealth Collaborative has allotted $29 million to physicians in western and central Pennsylvania to establish electronic healthcare systems. There are groups like Highmark around the country subsidizing their physicians. The largest and most important program has been set up by a coalition of information technology companies, called the National ePrescribing Patient Safety Initiative (NEPSI). NEPSI offers free e-prescription services nationwide to any doctor who signs up.

The e-prescription program described earlier, Allscripts' ePrescribe, is the free program offered through NEPSI. It works through a variety of mediums, including laptops, desktops, and palm pilots.

The Federal Government has also provided incentives to switch to e-prescription. Congress recently passed a statute increasing reimbursements 2%, beginning in 2009, to physicians whom adopt the use of e-prescription systems when treating Medicare patients, with an additional increase in reimbursements in the following years.

As previously mentioned, it is our opinion that specialists knowledgeable in pain management should be the only physicians with the responsibility of prescribing opiates and other addictive agents. The goal is to stop the diversion of controlled substances. Use of the electronic method will help stop thieves and forgeries of paper scripts. However, limiting the number of physicians permitted to prescribe substances such as oxycodone will stop the problem at one of its sources. The "rogue internet pharmacy" is a very serious form of drug diversion. The DEA estimates that one hundred million dosage units of narcotics are diverted each year by rogue pharmacies.

Basically, a rogue internet pharmacy is a website that employs ignorant and/or unscrupulous physicians to supply the narcotics. The rogue internet pharmacies will largely disappear if only knowledgeable and reputable specialists are able to prescribe these drugs because most of the unscrupulous providers will be unable to prescribe substances prone to abuse. Also, physicians uncomfortable with prescribing addictive medications will be relieved of the duty, allowing them to focus on the areas of their expertise.

This proposed plan will not completely eliminate the problem of drug diversion, but it will take a major stride toward eliminating recreational use by decreasing the number of people who can readily obtain the prescription drugs, and decrease the number of those subsequently addicted. Millions of dollars will be saved by treating fewer addicts, lowering costs of drug enforcement, and curtailing violence associated with the drug trade.

When the DEA ratifies the proposed e-prescription rule for Schedule II narcotics, it will only be an option. It is imperative that physicians mandate it upon themselves to use this technology once they have the e-prescription services established in their practices. Electronic technology must dominate prescription services in order to maximize efficiency, safety, and to reduce healthcare costs. Most importantly, e-prescription will go great lengths to end prescription drug abuse.

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Commentary

How Children Drown — A Silent Death

Joseph Torg, MD

The tragic drowning of three-year-old Anthony Muniz in a neighbor's backyard pool, as reported by Bruce Lambert in *The New York Times* several years ago, clearly illustrated the common but poorly understood or recognized phenomenon of how children drown in a silent death. Whether in a pond or a pool, the drowning mechanism in toddlers is quite different from that of adults. Let me explain, for prevention of its occurrence is dependent on an understanding of what happens.

Every year in the United States, five hundred children five years old and younger drown in swimming pool mishaps. A local newspaper reports, "toddler drowns in swimming pool: a twenty-month-old child drowned yesterday afternoon after crawling out of his crib and going into a swimming pool at his home." Another relates, "an eight-year-old boy . . . was found face-down by other swimmers and a lifeguard . . . in a part of the pool where the water was four and one-half to five feet deep."

Whether the drowning involves an unattended child or one in a crowded pool, both scenarios present a preventable situation. Prevention, however, requires an understanding of the circumstances under which children drown.

Several years ago, my wife and I joined our daughter-in-law and our two grandchildren in a swimming pool outing. My grandson, an enthusiastic and somewhat impetuous three year old, was just learning to swim and was outfitted with inflated "water wings" worn on his arms for buoyancy. After several hours of vigorous and enthusiastic water activity, we had a poolside picnic preceded by removal of the flotation devices. Upon finishing his sandwich, chips, and soda, he decided to return to the pool sans "water wings." What happened next was both dramatic and enlightening. He jumped feet first into five feet of water and literally sank like a lead weight straight to the bottom. No cries for help, no flailing of arms, no nothing. His grandmother, a former competitive and synchronized swimmer immediately understood what was happening. Into the pool in a flash, she pulled him out, gasping for breath but very much alive.

Contrary to the old wives' tale describing the drowning person "coming up for the third time, flailing about and calling for help," children just sink and drown. It happens quickly, silently, and without notice. Once submerged, they become disoriented and oblivious to the change in environment.

A second incident involved the five-year-old son of a close friend and colleague. While attending a pool party, the boy, a non-swimmer, was allowed in the shallow end of a gradient depth large pool in which twenty adults and their children were swimming. His father, whose responsibility it was to "keep an eye on the youngster," lost track of him only to eventually find him lying on the bottom of the deep end of the pool. Attempts were made to resuscitate by the local paramedics, who had responded immediately to the 911 call. He was then air-evacuated to the University of Maryland Shock Trauma Unit where he was pronounced dead on arrival.

Drownings occur in crowded pools, even those with trained lifeguards in attendance. Unless a child is submerged in ice-cold water where a primitive reflex shunts all to the brain, he or she must be rescued and resuscitated within four to five minutes or irreversible brain damage and eventually death will occur.

A third drowning situation characteristically involves an older child, pre-adolescent, or adolescent attempting to swim in a stream or body of water with a tidal current. The individual is overcome by the force of the flow or current, panics, and is pulled under the water's surface. He or she may cry for help and place a companion or bystander at risk when they attempt to assist or rescue the victim.

Clearly, death by drowning involving toddlers and children, as well as pre-adolescents and adolescents, are preventable events. And prevention begins with an understanding of how these tragic events occur. Toddlers, children, and a swimming pool unsecured by a fence, gate, and/or pool cover are an invitation for disaster. Children swimming in pools of appreciable depth require continuous supervision. Non-swimmers should be restricted to wading pools or outfitted with a personal flotation device. As indicated, streams, rivers, and bodies with tidal currents present their peculiar risk factors and at a minimum should preclude non-swimmers and require swimmers to wear personal flotation devices, regardless of experience and age. Children should be able to swim by age five. Also, children should wear Coast Guard approved flotation devices when on docks or in boats. With regard to pools, streams, and rivers, the adage "an ounce of prevention is worth a pound of cure" is a gross understatement. With drowning, there is no cure.

Original Research

eXtreme Lateral Interbody Fusion (XLIF) for Adult Deformity: The Safety and Early Benefits and Results of a Novel Approach to the Spine

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Introduction

Deformity was one of the first indications for surgical fusion. Patient morbidity had traditionally been hard to quantify. Aside from the cosmetic issues, pain and cardiopulmonary concerns also play a role in surgical selection. Over 500,000 adults have curves greater than 30 degrees and 6% of individuals over 50 years old have some degree of scoliosis. Natural history studies show that scoliosis may progress in adulthood and that thoracic curves greater than 50 degrees increase at approximately one degree per year, thoracolumbar curves 0.5 degrees, and lumbar curves 0.25 degrees. While studies may show that the incidence of back pain in adults with deformity is no higher than those in the normal population, the back pain has been found to be more severe and persistent. Moreover, patients with deformity are at an increased risk of neurologic compressive lesions such as stenosis and nerve root impingement. While most patients may be treated without surgery, indications for complex spine reconstruction consisting of realignment and fusion include: curves greater than 50 or 60 degrees with associated pain, significant deformity unacceptable to the patient, curve progression with either sagittal or coronal imbalance, cardiopulmonary disorders attributable to the deformity, and nerve root or cord compression attributable to the curve.

Over the last few decades, a better understanding of spine anatomy and pathology coupled with an explosion of new technology has led to advances in the care of adults with spinal deformity. Obenchain, in 1991, described the first laparoscopic lumbar discectomy and in the ensuing 15 years, minimally invasive surgery (MIS) has been performed with increasing frequency. While the long-term results and advantages of MIS have not been clearly defined, many of the spine fusion operations are now being performed in this manner. Minimally invasive posterior decompressions, pedicle screw fixation, and fusions have become popular techniques for treating various disorders of the lumbar spine.

Such a minimally invasive technique, a direct lateral, retroperitoneal, trans-psoas approach which can be performed without an access surgeon, has been available for the last decade. This procedure, termed XLIF (eXtreme Lateral Interbody Fusion), takes advantage of MIS technology in order to perform the equivalent of an anterior lumbar interbody fusion (ALIF) with much less approach related morbidity and tissue disruption. Ozgur et al., published a technical report on how the procedure is performed; Diaz et al., have reported their results using this technique to treat degenerative scoliosis and have reported good results in terms of pain relief, function, and alignment. The goal of this article is to report the safety and early results of one cohort of patients who were treated for a variety of spinal disorders over a span of four years.

Materials and Methods

46 patients (79 levels) were treated with XLIF for a variety of spinal disorders over a four-year period. 27 patients (58 levels) were diagnosed with predominantly coronal deformities including AIS, degenerative scoliosis, or sagittal plane deformities including kyphosis and spondylolisthesis. The medical records were reviewed concentrating on intraoperative, perioperative, and short term (<6 month) complications. Blood loss, length of hospital stay, and VAS were

Figure 1. Pre-operative and post-operative AP radiographs of a 52-year-old male with degenerative scoliosis treated with L3-4 and L4-5 XLIF and posterior spinal fusion with instrumentation with improvement of coronal and rotational balance.

Figure 2. Pre-operative lateral radiograph and clinical picture of a 67-year-old female with focal kyphosis after laminectomy.

Figure 3. Post-operative lateral radiograph and clinical picture after a L2-3 XLIF and posterior spinal fusion with instrumentation with restoration of sagittal balance.

also documented. A subset of these patients treated for deformity were compared to those treated for degenerative disc disease to investigate how using XLIF for deformity differs from using XLIF for degenerative disease.

Results

Major complications including permanent neurologic deficit, major vessel injury, bowel injury, or venous thromboembolism (VTE) did not occur. There were two cases of prominent grafts in which the end of the polyaryletheretherketone cage protruded laterally greater than 5 mm. Only one of these patients experienced symptoms attributable to the graft and required anterior revision. This same patient experienced subsidence of the most caudal graft in a long fusion which also led to a revision posterior surgery to the pelvis. There were two cases of prolonged anterior thigh pain on the operative side which affected the patient's ability to ambulate. Both of these presumed neuropraxias resolved by three months time. Two patients developed ileus necessitating a two-day course of nasogastric tube placement. One patient developed recurrent pleural effusions after exposure to the spine required takedown of the diaphragm.

Blood loss from the entire cohort averaged 326 cc, however this data is skewed because many of the patients underwent combined anterior and posterior surgery where the blood loss was not separated in the operative note. In anterior-only cases and in the combined surgery where the estimated blood loss was divided by procedure, the blood loss averaged 51 cc with over 60% reporting minimal or less than 50 cc blood loss. Patients undergoing XLIF for DDD averaged 70cc of blood loss opposed to deformity patients who averaged 500 cc of blood loss which included various levels of posterior fusions.

The length of stay in the hospital averaged 6.14 days, again this data is skewed secondary to the number of staged surgeries in the deformity cohort. Average length of stay for patients undergoing XLIF only was 2.42 with a trend towards a two day hospital stay in those patients operated on within the last two years. The average length of stay for complex coronal deformity patients undergoing staged procedures was 12 days with an average of six days between the XLIF and posterior procedures. 9/12 of these patients were ambulatory to the bathroom and tolerating diets by POD#2. The other three patients necessitated prolonged intubation due to the complexity of their reconstruction Patients with complex sagittal deformity averaged seven days in the hospital, most of these included single stage reconstructions but one patient was stage over a two week period.

The VAS score was available for 18 of the patients all in the deformity group. Baseline VAS scores averaged seven and the most recent follow-up from three months to 48 months averaged 2.5.

Conclusions

The lateral approach to the spine is a safe and effective method to perform anterior discectomy and interbody fusion. No catastrophic events including neurologic, vascular or bowel injuries occurred. One patient did return to the operating room for revision surgery due to the XLIF procedure. Some minor complications occurred including two sensory neuropraxias lasting three months, one instance of asymptomatic graft prominence, and one case of recurrent pleural effusions after a thoracic XLIF was performed. The minimally invasive nature of the procedure involves minimal blood loss, short hospital stays and no major complications when used for degenerative disc disease. Similarly, when used for anterior reconstruction in complex deformity, tissue trauma is minimal with the majority of blood loss and morbidity coming from the posterior procedures. Length of stay in the hospital is also more closely correlated to the nature of the posterior surgery with the recovery from the XLIF portion of the case similar to those patients who receive a stand alone procedure. Complications specific to the deformity cohort in our series relates to the interbody graft prominence seen in two cases. This illustrates the point that in complex deformity, patient positioning and proper disc space preparation, which includes releasing the far annulus, is of utmost importance.

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Original Research

The Biceps Tendon as a Measure of Rotational Deformity in Residual Brachial Plexus Birth Palsy

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Abstract

Background: Children with residual brachial plexus birth palsy often develop internal rotation contractures with subsequent glenohumeral dysplasia seen on axial imaging. Coronal deformity (characterized by humeral head subluxation), and angular deformity (characterized by glenoid retroversion) have been defined. We hypothesize that the location of the biceps tendon characterizes rotational deformity.

Methods: A retrospective study was performed of 91 children (average age 3.2 ± 2.2 years) who lacked external rotation beyond neutral and who had MRI scans of bilateral shoulders performed at our institution between 2000 and 2007. Charts were reviewed for measurements of external rotation of the involved shoulder with the arm adducted and the scapula stabilized. The glenoscapular angle (glenoid version), the percentage of the humeral head anterior to the middle of the glenoid fossa (PHHA), and the angle of rotation of the biceps tendon (biceps angle) were measured on MRI scans of both shoulders. Statistical analysis was performed to compare these MRI measurements for the involved and uninvolved sides, and to identify correlations between them and the external rotation.

Results: The average biceps angle was 47.9° ± 15.2° on the uninvolved side and 26.2° ± 15.0° on the involved side. The average differences between the two shoulders in the biceps angle (21.7° ± 20.5°), the version (18.9° ± 15.0°), and the PHHA (19.8% ± 13.6%) were all significant ($p < 0.001$). Only the biceps angle correlated significantly with external rotation ($p < 0.001$). This correlation remained significant even when the version and the PHHA were held constant ($p = 0.004$).

Conclusion: The biceps angle is a measure of rotational deformity in patients with residual brachial plexus birth palsy, and correlates better with external rotation than either the glenoid version or the PHHA. The biceps angle may be a useful measure of rotational glenohumeral deformity before and after surgery.

Introduction

Several studies have reported deformities of the involved upper extremity in patients with residual upper brachial plexus palsy. Limb length inequality,[1, 2] scapula hypoplasia,[1, 3, 4] and rotator cuff atrophy[1, 5, 6] have been described. Irregularity of both the humeral head[1–4, 7–18] and the glenoid have noted,[1, 13, 14, 17–19] and humeral head subluxation and dislocation are common findings.[1, 8, 17]

Several radiographic measurements have been described to characterize glenohumeral deformity in residual brachial plexus palsy. Angular glenoid deformity is often characterized by the glenoscapular angle, a measure of glenoid version[4, 6, 14, 18–25] and coronal glenohumeral deformity by measures of humeral head subluxation.[4, 6, 14, 18, 21] Rotational deformity of the humeral head relative to the elbow has also been described.[4, 17, 23, 26, 27]

The purpose of this study was to determine whether clinical findings of an internal rotation contracture correlated with magnetic resonance imaging (MRI) findings of abnormal rotation of the humeral head at the glenohumeral joint. We hypothesized that rotational deformity could be characterized by the location of the biceps tendon on MRI.

Materials and Methods

Demographics

This is an IRB-approved retrospective case-control study of patients with brachial plexus birth palsy who underwent surgery at our institution. Between 8/16/00 and 11/28/07, 140 patients (aged five months to 10 years) underwent MRI of bilateral shoulders at our institution. The decision to perform MRI was guided by clinical examination: an MRI was typically performed for internal rotation contracture of the involved side. One patient was excluded from the study due to inadequate MRI. Of the remaining 139 patients, 23 had undergone prior procedures to the glenohumeral joint (including closed reduction, open reduction, shoulder release, or tendon transfer) and were also excluded from the study. The remaining 116 patients (average age 3.3 ± 2.2 years) were included in the study. Sixty-three patients were female, while 53 were male. The right side was involved in 66 patients, and the left in 50 patients.

Imaging

All imaging was performed on a 1.5 Tesla LX platform MRI unit (GE Medical Systems, Milwaukee, WI) with a GPFlex (GE Medical Systems) shoulder coil. Cartilage-sensitive axial images with a minimal interslice gap were used. The children were sedated and monitored by electrocardiography, oxygen-saturation measurements, and observation. MRI imaging was performed with the arms in resting position at the patient's side. As previously reported, standardized positioning of the shoulder has not been successfully accomplished due to the sedation, underlying contracture, and MRI unit.[21]

Previous criteria have been reported for standardizing the cross-sectional slice chosen for measuring the glenoscapula angle and the percentage of humeral head anterior to the middle of the glenoid fossa (PHHA).[21] The same cross-sectional slice that was used for these two measurements was also used for measuring the biceps angle to allow for simplicity of measuring all three values on the same image. The IMPAX for Orthopedics (Agfa-Gevaert Group, Mortsel, Belgium) software and analytical toolbar was used to calculate angles and measurements. Measurements of the glenoscapular angle, the PHHA, and the biceps angle (Figure 1) were all performed by a single observer on both the involved and the uninvolved glenohumeral joints. Rotational deformity of the glenohumeral joint was described by abnormal positioning of the humeral head relative to its geometric axis of rotation on the axial MRI image. The location of the biceps tendon was taken to indicate the rotational positioning of the humeral head, and the angle between the biceps tendon and a line perpendicular to the axis of the scapula was used to quantify the rotational deformity (Figure 2). A scapular line is drawn from the medial border of the scapula, along the axis of the scapula, and bisecting the glenoid fossa. The biceps angle is measured by first drawing a line passing through the geometric center of the humeral head that runs parallel to the scapular line. A line passing through the center of the humeral head that runs perpendicular to the scapular line is then drawn, and the intersection of these two lines denotes the origin (i.e., the geometric axis of rotation of the humeral head). A third line is drawn from the origin to the center of the biceps tendon at the point closest to the humeral head. The acute angle between the line from the origin to the biceps tendon and the line perpendicular to the scapular line is measured as the biceps angle. Decreasing values of the biceps angle indicated increasing internal rotation (relative to the axis of the scapula) of the location of the biceps tendon around the center of the humeral head.

Figure 1A. Axial MRI image demonstrating measurement of the glenoid version (–12°), PHHA (10.0/29.2 = 0.342), and biceps angle (60°) in a patient with 60° of passive external rotation with the scapula stabilized.

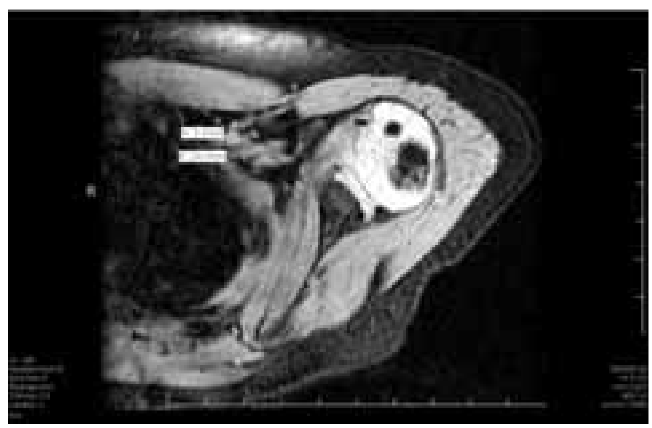

Figure 1B. Axial MRI image demonstrating measurement of the glenoid version (–17°), PHHA (8.8/24.6 = 0.358), and biceps angle (–12°) in a patient with –30 degrees of passive external rotation with the scapula stabilized.

Data

Charts were reviewed for clinical measurements performed at the office visit nearest in time to the MRI. The passive external rotation of the involved shoulder adducted to the patient's side with the scapula stabilized was recorded. All clinical measurements were performed by the senior orthopaedic surgeon or a licensed occupational therapist, and were taken relative to the neutral position. Increasingly positive values indicated increasing external rotation beyond neutral, while increasingly negative values indicated increasing lack of external rotation from neutral. Passive external rotation was not noted in the charts of three patients (none of whom had undergone a prior glenohumeral procedure), and these patients were excluded from the clinical analysis. Clinical and radiographic analyses were performed on the entire group of patients, and were repeated on a subgroup of patients who had external rotation to neutral or less, and on a second subgroup of patients who had external rotation beyond neutral.

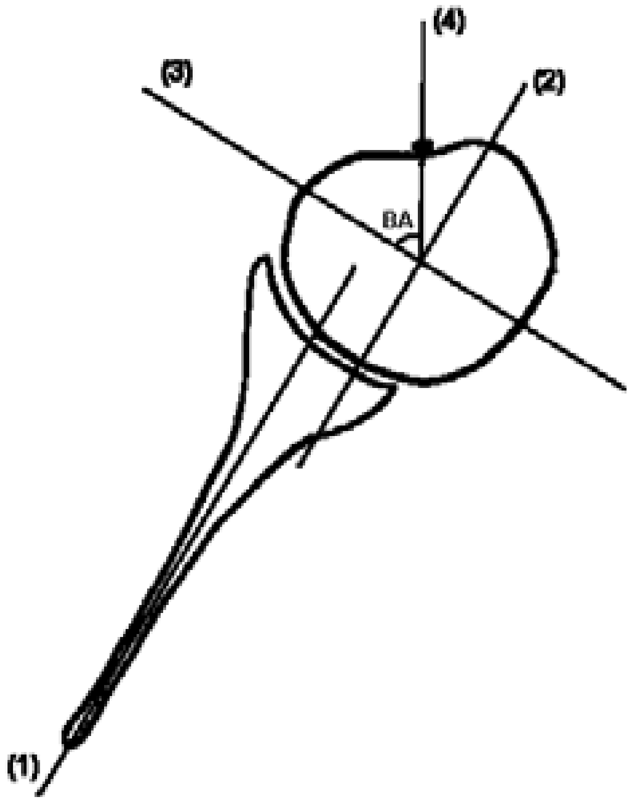

Figure 2. Measurement of the biceps angle. (1) A scapular line is drawn from the medial border of the scapula, along the axis of the scapula, and bisecting the glenoid fossa. (2) A line passing through the geometric center of the humeral head that runs parallel to the scapular line is drawn. (3) A line passing through the center of the humeral head that runs perpendicular to the scapular line is then drawn. The intersection of these two lines denotes the origin. (4) A line is drawn from the origin to the center of the biceps tendon at the point closest to the humeral head. The acute angle between line (3) and line (4) is measured as the biceps angle (BA).

Statistical Analysis

Statistical analysis was performed using SPSS Graduate Pack 12.0 for Windows (SPSS Inc., Chicago, IL). The distribution of the continuous imaging variables for both the involved and the uninvolved sides was tested for normality using the Kolmogorov-Smirnov statistic with a Lilliefors significance level, and were not found to be a good fit. Paired two-tailed Wilcoxon Signed Ranks tests were used to compare the values of glenoscapular angle, PHHA, and biceps angle for both sides. Spearman rank correlation coefficients were calculated for the involved side to identify the strength of the association between the external rotation and the glenoscapular angle, PHHA, and biceps angle. Partial correlation coefficients were calculated using Pearson's product correlation coefficient to identify correlation between the external rotation and each of the three measurements with the other two controlled. In order to evaluate the effect of changes in each of the three MRI measures on changes in the clinical external rotation, a standardized multiple regression analysis was performed with external rotation as the dependent variable and patient age, patient gender, affected side, glenoid version, PHHA, and biceps angle as the independent variables. All probability testing was completed in the null form, and significance was established at the $p = 0.05$ level of probability.

Results

There was a significant difference between the involved and uninvolved shoulders in the version, the PHHA, and the biceps angle (Table 1). A significant correlation was found between external rotation and each of the three measures for the involved side (Table 2). Evaluation of the partial correlation coefficients revealed that the correlation between external rotation and biceps angle remained significant when the other two measures were held constant. In contrast, there was no significant correlation between the external rotation and either the version or the PHHA when the other measures were held constant (Table 3). Of the three MRI measurements in the multiple regression model, the standardized coefficient of the biceps angle was the greatest and the only one that was significant (Table 4).

Table 1

	Uninvolved Mean ± std	Involved Mean ± std	Difference Mean ± std	p-value
All Patients (n = 116; Mean external rotation = –10.9° ± 22.0°)				
Version	–9.5 ± 5.9	–26.4 ± 14.3	–16.9 ± 14.3	<0.001
PHHA	0.45 ± 0.06	0.27 ± 0.13	–0.18 ± 0.13	<0.001
Biceps Angle	47.3 ± 15.4	28.2 ± 16.8	–19.1 ± 21.1	<0.001
Subgroup: External Rotation > neutral (n = 22)				
(Mean external rotation = –19.5° ± 12.1°)				
Version	–7.9 ± 6.1	–16.8 ± 7.8	8.9 ± 7.8	<0.001
PHHA	0.45 ± 0.06	0.36 ± 0.09	0.10 ± 0.09	<0.001
Biceps Angle	45.5 ± 16.7	38.1 ± 20.8	7.4 ± 22.2	0.07
Subgroup: External Rotation ≤ neutral (n = 91)				
(Mean external rotation = 24.9° ± 17.1°)				
Version	–10.0 ± 5.8	–28.9 ± 14.7	18.9 ± 15.0	<0.001
PHHA	0.45 ± 0.07	0.25 ± 0.13	0.20 ± 0.14	<0.001
Biceps Angle	47.9 ± 15.2	26.2 ± 15.0	21.7 ± 20.5	<0.001

Values of glenoid version, PHHA, and biceps angle for the entire population of 116 patients, and for subgroups by passive external rotation with the scapula stabilized.

Table 2

	Version	PHHA	Biceps Angle
All Patients (n = 113)			
PHHA	0.80**		
Biceps Angle	0.02	0.03	
External Rotation	0.29*	0.26*	0.39**
Subgroup: External Rotation > neutral (n = 22)			
PHHA	0.67**		
Biceps Angle	0.45*	0.39	
External Rotation	0.58*	0.20	0.43*
Subgroup: External Rotation ≤ neutral (n = 91)			
PHHA	0.79**		
Biceps Angle	–0.21*	–0.15	
External Rotation	0.03	0.03	0.34**

*$p < 0.05$
**$p < 0.001$
Spearman's correlation coefficients between the passive external rotation, the glenoid version, the PHHA, and the biceps angle for the entire patient population and for subgroups of patients.

Table 3

	Version	PHHA	Biceps Angle
All Patients	0.134	0.071	0.435**
External Rotation > Neutral	0.096	0.089	0.389
External Rotation ≤ Neutral	0.025	0.000	0.305*

*$p < 0.05$
**$p < 0.001$
Pearson's partial correlation coefficients between the passive external rotation and each of the glenoid version, the PHHA, and the biceps angle with the other two measurements controlled for subgroups of patients.

Table 4

	Standardized Coefficient
Age	–0.110
Side	0.112
Gender	0.185*
Version	0.197
PHHA	0.123
Biceps Angle	0.393**

*$p < 0.05$
**$p < 0.001$
Standardized coefficients for the multiple regression analysis ($R^2 = 0.324$).

Subgroup Analysis of Patients

Patients with Limited External Rotation. Ninety-one patients lacked passive external rotation beyond neutral with the scapula stabilized (range –60°–0°). There was a significant difference between the involved and uninvolved shoulders in the version, the PHHA, and the biceps angle (Table 1). The external rotation of the involved side correlated significantly with the biceps angle but not the version or the PHHA (Table 2). Evaluation of the partial correlation coefficients revealed that the correlation between the external rotation and the biceps angle remained significant when the version and the PHHA were held constant (Table 3).

Patients with External Rotation Greater than Neutral. Twenty-two patients had passive external rotation beyond neutral with the scapula stabilized (range 10°–80°). There was a significant difference between the involved and uninvolved shoulders in the version and the PHHA, but not in the biceps angle (Table 1). There was a significant positive correlation between the external rotation and the version as well as the biceps angle, but not for the PHHA (Table 2). A significant correlation was noted between the version and both the PHHA and the biceps angle (Table 2).

Discussion

Children with residual brachial plexus birth palsy often lack normal active and passive shoulder motion.[3, 4] Physical or occupational therapy has been recommended to maintain passive glenohumeral joint range of motion. Internal rotation contractures are common and lead to considerable glenohumeral joint deformity.[13, 14, 18] Lack of shoulder external rotation beyond neutral infers underlying glenohumeral joint deformity.[14, 28] Several imaging measurements have been used to define the glenohumeral deformity. The glenoscapular angle[4, 6, 14, 18–25] measures the version of the glenoid relative to the longitudinal axis of the scapula, with positive values indicating anteversion and negative values indicating retroversion. The PHHA[4, 6, 14, 18, 21] measures the percentage of the humeral head located anterior to the longitudinal axis of the scapula; decreasing values indicate increasing posterior subluxation of the humeral head on the glenoid. Posterior subluxation of the humeral head has also been quantified by the angle between the longitudinal axis of the glenoid and a line connecting the center of the glenoid to the center of the humeral head.[24, 27, 29] The humeral head version has also been determined by a variety of measurements.[23, 27] The reliability of various measures has been studied and the glenoid version has been found to be more reliable than the humeral head subluxation.[29]

The angular deformity of the glenoid is characterized by the glenoid version while translational deformity of the humeral head at the glenohumeral joint is measured by humeral head subluxation. The biceps angle describes a rotational deformity of the glenohumeral joint in terms of abnormal rotational positioning of the humeral head. Rotational positioning of the humeral head has previously been described in normal shoulders by the angle subtended by a line between the center of the humeral head and the intertubercular sulcus, and a line parallel to the plane of the glenoid cavity.[30, 31] Such a characterization is limited in children with residual brachial plexus palsy due to deformities of both the glenoid and the humeral head, as well as by hypoplasia and deformities of the tuberosities. The biceps tendon was chosen as a landmark because the tendon is clearly visualized on MRI. The biceps angle was described on the same axial slice used to measure glenoid version and PHHA to simplify and standardize the measurement process.

The glenoid version and PHHA characterize osseous and joint deformities, while the biceps angle depicts the soft tissue contracture that limits external rotation. External rotation must be examined with the scapula stabilized and can be difficult in children that are struggling and in shoulders with a concommitant glenohumeral abduction contracture. Furthermore, the biceps angle may be useful in patients with equivocal measurements of passive shoulder external rotation and when images studies are often reviewed in lieu of examination. The biceps angle is dependent on the position of the upper extremity during the MRI and standardized positioning is not possible in these patients. In generally, normal children lie supine with the elbow extended and tend to rotate their arms into external rotation. Children with glenohumeral joint contractures or osseous deformities are unable to position their arms into external rotation. The biceps angle may also be affected by the osseous deformity of the glenohumeral joint; changes in the morphology of the glenoid surface may affect the measurement of the biceps angle. The biceps angle, however, was described in relation to the geometric center of the humeral head in order to minimize the effect of factors extrinsic to the humeral head on the measurement of the angle.

The current study found significant differences in glenoid version, PHHA, and biceps angle between the involved and uninvolved sides in patients with residual brachial plexus deformity. Of the 116 patients in the study population, 91 patients (average age 3.2 ± 2.2 years) lacked external rotation beyond neutral. In this subgroup, only the biceps angle correlated significantly with external rotation, and this correlation remained significant when version and PHHA were held constant. No significant difference in the biceps angle was found between the involved and uninvolved shoulders in the subgroup of patients with external rotation beyond neutral. There was, however, a significant correlation between the biceps angle and the external rotation in this subgroup. These findings indicate that the biceps angle may be used to measure a component of radiographic rotational deformity in patients with residual brachial plexus palsy, especially those who lack external rotation beyond neutral. The resting position of the glenohumeral joint in patients who have external rotation beyond neutral may not be limited by soft-tissue contracture, and their arm rotation may be closer to normal during MR imaging. Inferences about the biceps angle in patients with external rotation beyond neutral are limited because this study examines a relatively small proportion of these patients. In particular, we do not image patients with residual brachial plexus palsy who have maintained reasonable external rotation with therapy and stretching.

Treatment recommendations for patients with brachial plexus birth palsy are often based on clinical evaluation, specifically external rotation. In particular, lack of passive shoulder external rotation beyond neutral is often an indication for operative intervention.[14, 28] The reliability of measuring passive shoulder external rotation with the scapula stabilized has not been clearly shown. The Mallet score gives an assessment of global shoulder rotation, not just external rotation. The biceps angle may be useful in patients with equivocal measurements of passive shoulder external rotation, such as struggling infants, patients with other concomitant shoulder contractures (for example, abduction contractures), and patients with external rotation near neutral. Furthermore, there may be certain circumstances in which a decision on a patient is based on imaging only (for example, when the patient is not available for clinical evaluation). The biceps angle also gives supportive evidence of glenohumeral changes in a previously undefined dimension that may be useful in research situations. Ultimately, the biceps angle provides a connection between clinical and radiographic parameters of external rotation.

In summary, the biceps angle is a measurement that differs significantly between the involved and uninvolved sides in brachial plexus and provides the best MRI indicator of internal rotation contracture. The biceps angle adds another dimension in assessing the complex multifactorial glenohumeral deformity of patients with residual brachial plexus palsy, and may be used in conjunction with the glenoid version and the PHHA. Further research is needed to evaluate its utility in preoperative evaluations and subsequent surgical outcomes.

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Original Research

A Comparison of the Bagby and Kuslich Cage and the Kerf Cut Cylinder for Anterior Spinal Arthrodesis: A Preliminary Study

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Abstract

Objectives: To compare two different techniques of anterior spinal arthrodesis in a sheep cohort with respect to fusion rates and biomechanics, and to evaluate these preliminary results in light of clinical experience in horses.

Methods: Sheep studies were carried out comparing a single Bagby and Kuslich (BAK) cage to the Kerf Cut Cylinder (KCC). Bone graft from the ilium was implanted into the BAK cage only and these were evaluated at autopsy. Specimens were subjected to biomechanical or histologic testing.

Results: The KCC group achieved a stiffer fusion faster than the BAK groups at four months.

Conclusions: This preliminary study suggests that the results of arthrodesis with the KCC in the sheep *in vitro* are consistent with clinical experience in the horse.

Introduction

The use of anterior column support in spinal arthrodesis has been widely studied.[1–22, 34, 35] Motion preservation techniques have been introduced as an alternative to fusion for axial pain syndromes.[23, 24] This, however, has limited applicability in cases of instability or neural compression. In veterinary, as well as in human medicine, fusion has been used to treat instability associated neurologic symptoms. Fusion has been used to treat the so-called Wobbler Syndrome — ataxia due to cervical stenosis — in horses. DeBowes studied the Bagby Bone Basket (BBB), an interbody device, in normal horses to evaluate the cage for arthrodesis.[10] Aside from histological data suggesting interbody fusion, facet atrophy was noted at the level of arthrodesis, further corroborating successful fusion (Figure 1).[25]

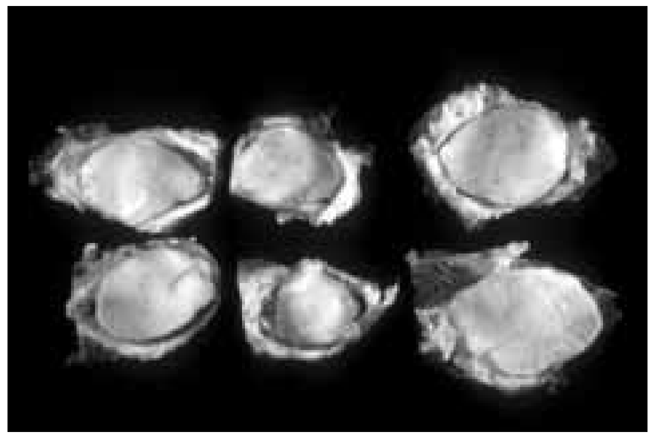

Figure 1A. This shows marked atrophy of both facet joints at the arthrodesis level compared to the adjacent ones caudad and cephalad in a normal horse C-spine of six months post-op at autopsy. (Reprinted with permission from R. DeBowes, *Am. J. Vet. Res.,* 45(1):191–199, 1984.)

Figure 1B. The picture on the left is a 60-year-old human observing bone spurs and atrophy of the cervical spine on the day of surgery (Dr. Cynthia Hahn). The picture on the right is eight months later after surgical arthrodesis, noting bone spur disappearance.

Conflict of Interest Statement: Dr. Bagby has gifted all of the patents to the Bagby LLC, of which he is not a member. Dr. Wagner has a financial interest in the processing of bringing the KCC to patient care after obtaining clearance by the Federal Food and Drug Administration (FDA). All of the other authors are not to receive funds from sales of the KCC implant.

Clinical experience has supported the hypothesis that arthrodesis alone, without subsequent posterior decompression, is sufficient to treat these animals. Currently, decompression surgery is not routinely done on ataxic "Wobbler horses." There appears to be two subgroups of "Wobblers;" unstable segments in young horses and degenerative stenosis in older horses. A celebrated example of the latter is the case of Seattle Slew, age 27 at the time of his surgery (Figure 4). Dr. Barrie Grant implanted 126 Kerf Cut Cylinders (KCC) implants from the year 2000 to 2003 (personal communication). Sixty per cent were able to be ridden again and 10% returned to the "breeding barn." Post-operatively, horse surgeries are not routinely evaluated by x-ray because general anesthesia is required. No donor bone graft was used.

In an effort to improve the implant and continue to obviate the need for autogenous graft harvest, the kerf cut technique was investigated. By definition, *kerf* means a space created by any sawing process (Figure 2). In the case of the KCC, a circular saw is utilized to create a kerf that would receive the cylinder implant. The leading portion of the implant is smooth and the following portion is threaded. The smooth leading end provides distraction and helps alignment into the kerf as well as avoiding trauma to the bone peninsula. The threads are designed to avoid traumatic torquing as the implant approaches the spinal canal. These are theoretical advantages over the BAK cage. It is the purpose of this study to compare these two devices in the sheep model.

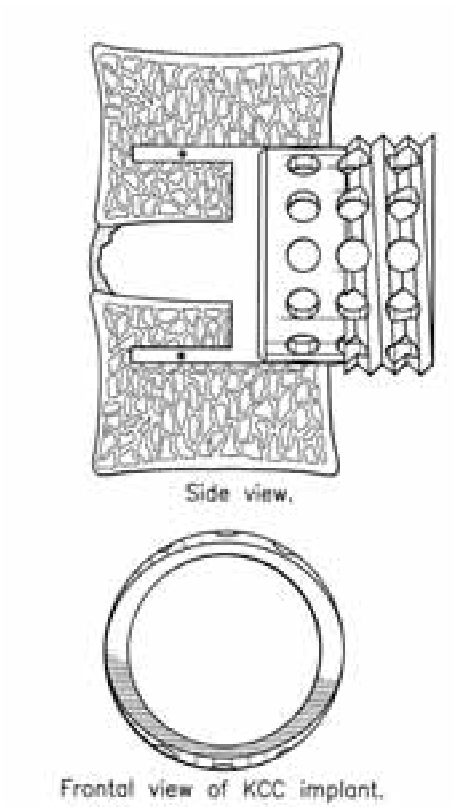

Figure 2. This demonstrates the kerf space * and the KCC being implanted on side view. Produced in 316 stainless steel or titanium (Wilson tool, Spokane Valley, WA, US Patent #6,447,545 B1, George W. Bagby Sept. 10, 2002). Note the peninsula of bone retained.

Materials and Methods

Sixteen sheep under went anterior spinal surgery via a lateral approach,[26] alternating placement of Bagby and Kuslich (BAK) cages and KCCs at L2-3 and L4-5 disc spaces (total of 32 disc spaces). 16 BAK cages (Zimmer Spine, Minneapolis, MN) and 16 KCCs were implanted. Animals were euthanized at two months and four months for motion studies and CT radiography plus histological studies. Autogenous iliac crest bone graft was used for the BAK. Bone graft obtained preparing the kerf bone bed was placed into the KCC after implantation.

Results

At two months postoperative, there were no bony unions across the disc space in either group. There was found to be new bone growth completely surrounding the fenestration walls in the KCC. This is in contrast to the BAK (Figure 3A, 3B). Furthermore, the motion studies showed less motion in the KCC levels in flexion, extension and lateral bending, but no difference in axial rotation.

At four months postoperative, the motion studies showed less motion on flexion and extension for the KCC group versus the BAK group. No difference was noted in stiffness in any deflection between groups.

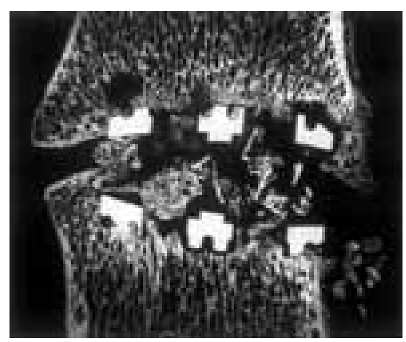

Figure 3A. BAK microradiography (two months post-op).

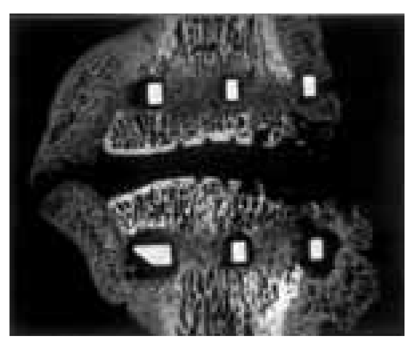

Figure 3B. KCC Microradiography Incomplete Discectomy (two months post-op).

In this preliminary study, the histological and microradiographic studies at four months showed minor advanced bony union crossing the disc space in the KCC when compared to the BAK. At first, in the KCC, we were not aggressively removing the disc and this interfered with bony union. Upon aggressively removing the disc for the KCC, there was significant improvement with bony trabeculae crossing the disc space at four months. This was not observed in the BAK group. The aggressive discectomies were done for the KCC on four additional sheep at eight levels (after the original 16 sheep) and were evaluated at 16 weeks. All eight levels progressed to arthrodesis as shown. No similar discectomies were done at eight weeks post-op (Figures 3C, 3D, 3F). In preparing the bone bed to receive the BAK, the disc is removed. The disc is not removed when cutting a circular kerf for the KCC. Motion studies were not carried out on the additional disc levels.

Several technical issues were identified in the course of the study. One was the need for aggressive disc removal in both groups that involved not only total removal but creating minimal surface bleeding mimicking a fracture hematoma*.[33] Second, the kerf cut is made only after the discectomy. This technique minimizes the likelihood of fracturing the peninsulas if the aggressive disc removal is done after the peninsulas are created.

Discussion

The Kerf Cut Cylinder (KCC) is referred to as the "Seattle Slew Implant" by veterinarians because of its continued use in the race horses. This has been a collaborative effort between specialties[26–29, 31, 34] (Figure 4). At this time, no investigative device exemption (IDE) exists for the KCC. While the design concept is attractive, certain modifications may be needed should human studies be pursued. In the current study, only one BAK was implanted per level; the investigators of the BAK recommend dual implants. Furthermore, the KCC has not been researched in direct comparison to the BAK cage with bone morphogenic protein. The figures showing the KCC with autogenous bone graft from the surgical site and the BAK with bone morphogenic protein are separate studies (Figure 3E). Histologically, they appear to be comparable.

The ideal implant for achieving anterior spinal arthrodesis remains to be defined. A stabilizing implant for arthrodesis that is perfect in perpetuity and avoids any loosening carries a potential shortfall because it avoids Wolff's law. In this atmosphere the implant is not stress shielded. With time the implant is prone to fatigue failure. The same stress is placed on it if arthrodesis does not occur. The fact that this study demonstrates new bone surrounding the walls of the fenestration caters to the "best of both worlds." It only prolongs the stabilization at eight weeks, adding to the tendency for arthrodesis to occur. With continued growth and remodeling the bony fusion "accepts" the stress, thereby taking the stress off of the surgical implant.

*ArthroCare: Articular coblation.

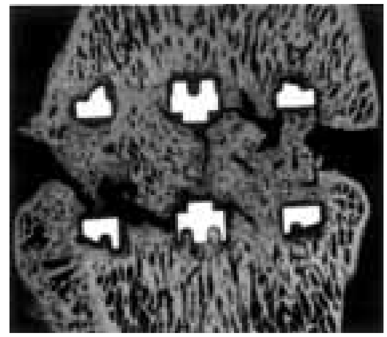

Figure 3C. BAK microradiography (four months post-op).

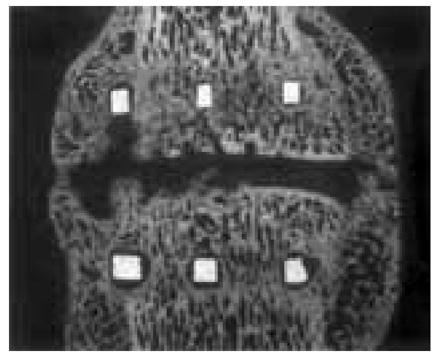

Figure 3D. KCC Microradiography (four months post-op). Incomplete discectomy.

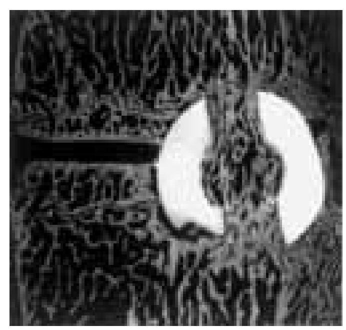

Figure 3E. Frontal view of the mid sagittal microradiograph, the so-called gold standard for documenting fusion. Sheep study at four months post operative with "Osteogenic Protein." (Reprinted with the permission from The Spine Editorial Office, DHMC Reference #36.)

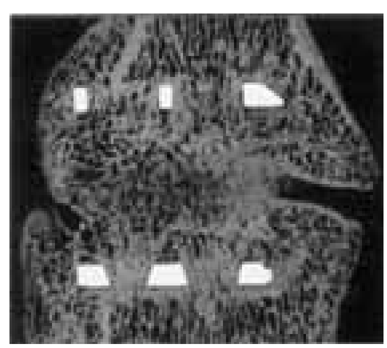

Figure 3F. Side view KCC microradiography (four months post-op) complete discectomy.

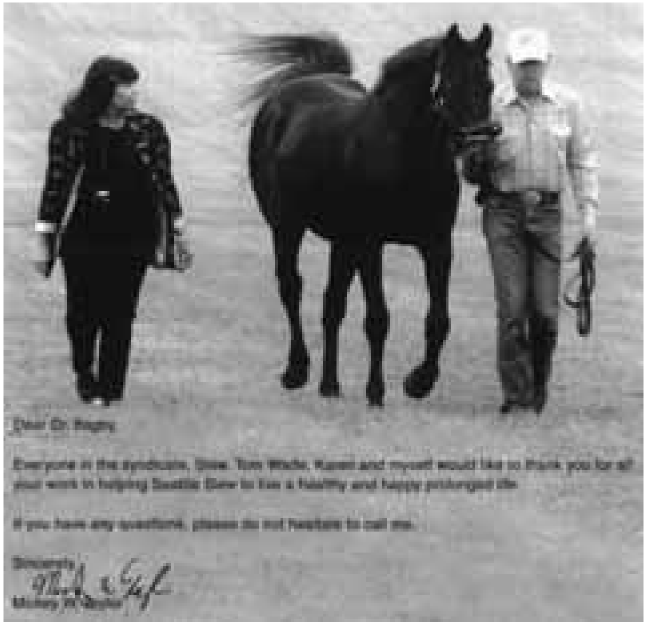

Figure 4. Seattle Slew (1974–2002) — 1977 Triple Crown Winner. Dr. Barrie Grant was the surgeon implanting the KCC to the cervical spine leading to arthrodesis for reversal of ataxia.

Conclusion

Based on these data, several advantages of the KCC are apparent. The KCC technique basically provides vascularized living bone as a substrate for arthrodesis via the peninsulas of bone inside the implant. No added surgery is required to bring the graft into place.[32] Whether or not this technique will be investigated in humans is unclear but the basic premises are intriguing.

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Original Research

A Novel Model for Inducing Joint Inflammation and Degeneration with a Pharmacological Intervention to Reduce Its Effects

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Introduction

Several animal models for osteoarthritis have been developed and their degenerative progression is similar to humans, but the initiating factors are not representative of the general population. An ideal model would involve the interaction between inflammation and biomechanical changes observed in humans without surgical trauma, targeted genetic manipulation, or chemical induction. This study assessed a voluntary high-repetition, high-force (HRHF) task in rats that required one limb to reach for, grasp, and pull a handle while the contralateral limb provides postural support. The high demand tasks lead to inflammation, fibrosis, and degenerative changes in nerve, muscle, tendons and bones.[1–3] However, the influence of this task on joints has not been assessed.

Ibuprofen, a common nonselective nonsteroidal anti-inflammatory drug, was used as a therapeutic intervention in this study. Ibuprofen's role in osteoarthritis is unclear. Its therapeutic effect should result in a chondroprotective effect but prior research has suggested that it induces catabolic changes. Additional research is needed to determine the role of ibuprofen in osteoarthritis. The purpose of this study was to evaluate the potential of a voluntary HRHF task to induce joint inflammation or degeneration and to determine the effect of ibuprofen on these outcomes.

Methods

A randomized controlled trial design was used. To address our goals, we used: (a) biochemical analyses to assess joint inflammation, (b) histological analyses to assess joint degeneration, and (c) biochemical analysis of a serum marker of collagen degradation — each with or without ibuprofen treatment.

83 young adult, female Sprague-Dawley rats were used. Animal care and use was monitored by the University Animal Care and Use Committee to assure compliance with Federal and NIH regulations. Experimental rats were trained to reach forward to pull a handle at a rate of 12 reaches/min at 60 ± 5% of maximum voluntary grip force for 2 hrs/day in 30 min sessions, 3 days/wk for up to 12 weeks. Both preferred reach and support limbs were analyzed. Animals were divided into 5 groups, including 2 experimental groups: 1) rats that performed a HRHF task without ibuprofen for 6 or 12 weeks (HRHF6 or HRHF12); 2) rats that performed a HRHF task for 6 or 12 weeks with ibuprofen treatment (HRHF6+IBU or HRHF12+IBU). Ibuprofen treatment was initiated at week 4 of task performance (liquid Motrin given daily in drinking water; 45 mg/kg body wt). Three groups did not perform the task and served as controls: trained controls without or with ibuprofen (TR CON or TR CON+IBU), and normal controls (NORM).

Biochemical analysis of joint inflammation was assessed in homogenized wrist joints and radioulnar diaphyses collected from HRHF6 (n = 5), HRHF12 (n = 6), HRHF6+IBU (n = 5), HRHF12+IBU (n = 6), and NORM (n = 9) rats. Three pro-inflammatory cytokines (Interleukin [IL]-1α, IL-1β, tumor necrosis factor [TNF]-α) and an anti-inflammatory cytokine (IL-10) were assayed by ELISA. Data were normalized to total protein concentrations.

Histopathological scores were assessed in paraffin embedded and sectioned joints stained with Safranin O and fast green in HRHF12 (n = 15), HRHF12+IBU (n = 10), TR CON (n = 8), TR CON+IBU (n = 9), and NORM (n = 4) rats. Osteoarthritic severity in the articular cartilage of the distal radius was assessed using the modified Mankin Scoring System,[4] which evaluates structure, cells, and saturation of safranin staining indicative of proteoglycan content in subscales. Immuno-histochemistry was performed to qualitatively assess the presence of ED1+ cells (e.g., macrophages, osteoclasts, and their progenitors) in NORM, TR CON, HRHF12, and HRHF12+IBU.

To validate the histological findings, serum levels of the C-terminus of peptide generated by cleavage of types I and II collagens by collagenases (C1,2C) via ELISA. C1,2C serum levels reflect degradation of tendon, bone, and articular cartilage. Serum was collected from HRHF6 (n = 5), HRHF12 (n = 6), HRHF6+IBU (n = 7), HRHF12+IBU (n = 6), TR CON+IBU (n = 6), and NORM (n = 6) rats.

Statistics: ANOVAs ($p \leq 0.05$) were performed and Bonferroni posthoc tests.

Results

All four cytokines were elevated in HRHF12 rats compared to the other groups regardless of limb or region. Also, IL-10 was significantly higher in HRHF12+IBU rats compared to NORM. Histopathological total scores of joint degeneration were significantly greater in HRHF12 rats (Fig. 1A). Histopathological total scores of joint degeneration were significantly greater in HRHF12 rats. The HRHF12 group had a greater loss of safranin staining in the epiphyseal plates than the two medicated groups. A reduction in safranin staining was also observed in the articular cartilage of HRHF12 rats compared to the other groups (Figs. 1B, C). Other cartilage changes in the HRHF 12 rats included irregular surface and chondrocyte proliferation (cloning), with a few also showing pannus and hypocellularity (cell loss). The highest scores were noted for the radial side of the radius in these rats. HRHF12 joints contained ED1+ cells, most likely osteoclast progenitor cells, in the subchondral bone of the distal radius and carpal bones. ED1+ macrophages were also increased in HRHF12 synovium. No ED1+ cells were seen in TR CON or HRHF12+IBU joints. C1,2C serum concentrations were significantly reduced in the ibuprofen treated groups than in the no ibuprofen groups.

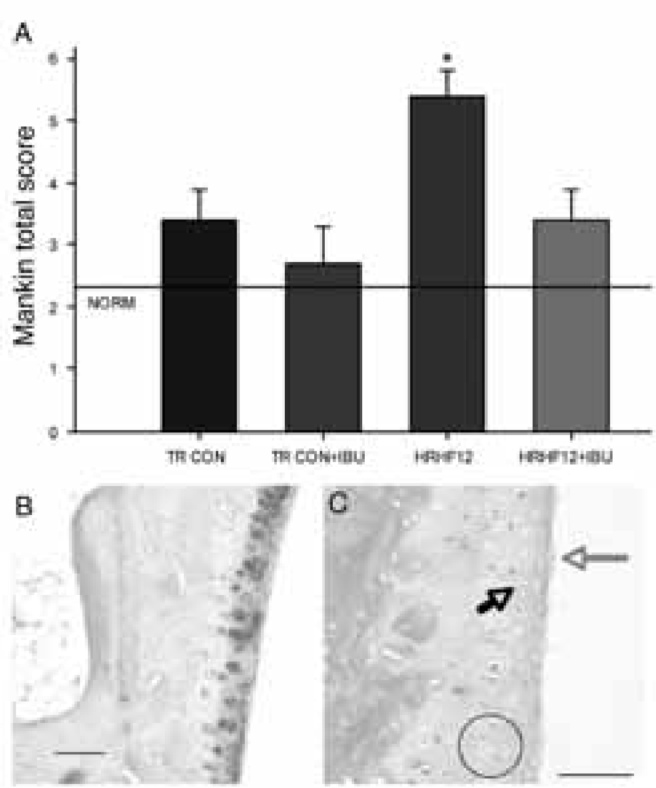

Fig 1. A) Modified Mankin histopathological score. *$p < 0.01$. **B)** Radial articular cartilage of a TR CON+IBU rat. **C)** Radial articular cartilage of a HRHF12 rat. Gray arrow = pannus; black arrow = cell clusters; circle = area with no safranin staining. Scale bar = 50 micrometers.

Discussion

The HRHF task induced joint inflammation and degeneration after 12 weeks. The histopathological articular cartilage were indicative of early joint degeneration (e.g., decreased proteoglycan staining with minimal structural changes; higher histological scores in the radial region). Ibuprofen had anti-inflammatory and chondroprotective effects. This rat model may be a successful model to assess early osteoarthritis and future disease modifying osteoarthritis drugs.

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Induction of CTGF by TGF-β1 in Osteoblasts: Independent Effects of Src and Erk on Smad Signaling

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Abstract

Connective tissue growth factor (CTGF/CCN2) is a cysteine rich, extracellular matrix protein that acts as an anabolic growth factor to regulate osteoblast differentiation and function. In osteoblasts, CTGF is induced by transforming growth factor beta 1 (TGF-β1) where it acts as a downstream mediator of TGF-β1 induced matrix production. The molecular mechanisms that control CTGF induction by TGF-β1 in osteoblasts are not understood. We have previously demonstrated the requirement of Src, Erk and Smad signaling for CTGF induction by TGF-β1 in primary osteoblasts, however the potential interaction among these signaling pathways in osteoblasts remains unknown. In this study, we demonstrate that TGF-β1 activates Src kinase in the rat osteosarcoma cell line (ROS17/2.8) and that treatment with the Src family kinase inhibitor, PP2, prevents Src activation and CTGF induction by TGF-β1. Additionally, the inhibition of Src prevents Erk activation by TGF-β1, as well as TGF-β1 induced Smad 2 & 3 activation and Smad nuclear translocation. These results demonstrate that Src is an essential upstream signaling partner of both Erk and Smads for TGF-β1 induction of CTGF in osteoblasts. MAPKs such as Erk can modulate the Smad pathway by directly mediating the phosphorylation of Smads or indirectly through activation/ inactivation of required nuclear co-activators that mediate Smad DNA binding. When we treated cells with the Erk inhibitor, PD98059, it blocked TGF-β1-induced CTGF protein expression but had no effect on Src activation, Smad activation or Smad nuclear translocation. Using electro-mobility shift assays, we show that treatment with PD98059 impaired transcriptional complex formation on the Smad binding element (SBE) of the CTGF promoter, demonstrating that Erk activation was required for SBE transactivation. Taken together these data demonstrate that Src is an essential upstream signaling transducer of TGF-β1 in osteoblasts for Erk and Smad signaling, and that while the Smad and Erk signaling cascades appear to function independent of one another, they are both essential for the formation of a transcriptionally active complex on the CTGF promoter.

Introduction

Osteoblasts are highly differentiated, biosynthetic cells that form bone through production and secretion of extracellular matrix (ECM) that becomes mineralized to form mature bone tissue.[1] Osteoblast growth, differentiation and biosynthetic activity are initiated and tightly regulated by systemic and locally-produced growth factors. Recently, connective tissue growth factor (CTGF/CCN2) has emerged as an important growth factor in osteogenesis. CTGF is produced and secreted by osteoblasts where it acts in an autocrine fashion as an anabolic growth factor to regulate osteoblast differentiation and function.[2, 3] In cultured osteoblasts, CTGF induces pro-osteogenic cellular activity including osteoblast proliferation, matrix production and terminal differentiation (mineralization).[2–6] Transforming growth factor-β1 (TGF-β1) is a potent, multifunctional, osteogenic growth factor that also regulates osteoblast differentiation and function.[7] One of TGF-β1 major effects on osteoblasts is its ability to stimulate the production and secretion of ECM,[8–11] however the mechanisms or downstream effector genes that facilitate this response are not understood. We recently demonstrated that in osteoblasts CTGF is stimulated by TGF-β1 and that CTGF is a downstream effector for TGF-β1 induced ECM synthesis.[6, 12, 13] The signaling pathways that mediate TGF-β1 induction of CTGF vary depending on the cell type being examined,[14] and we recently demonstrated that in osteoblasts CTGF up-regulation by TGF-β1 required Smads, the mitogen-activated protein kinase (MAPK) Erk and Src signaling.[15]

In general, TGF-β1 signals through a generic Smad mediated pathway involving Smads 2, 3 and 4.[16] Smads 2 and 3 are phosphorylated by active transmembrane serine/ threonine TGF-β1 receptors.[17] Following activation, Smad 2 and 3 form a trimeric complex with Smad 4, and this com-

This study was supported by the National Institutes of Health, grant numbers 2R01AR047432-06 (to SNP) and 1R03AR057193-01 (to JAA), by the State of Pennsylvania Department of Health (to XZ), by The Commonwealth Medical College (to JAA), and by Depuy Orthopaedics (to WGD).

plex subsequently translocates to the nucleus, where it binds to Smad binding elements (SBE) in promoters of TGF-β1-responsive genes.[16, 18] Transcriptional activation by Smads is not limited to the Smad-SBE interaction alone but requires additional association of Smads with other transcription factors and co-factors that together bind the SBE and adjacent cis-regulatory binding elements (DNA motifs).[19] Thus, Smad signaling is required, but in most cases it is not sufficient by itself to achieve target gene activation. The requisite additional transcription factors, co-factors and DNA motifs required for Smad transcriptional activation of the CTGF promoter are cell type dependent and have not been elucidated in osteoblasts. There are a number of studies to date that have shown there a considerable amount of crosstalk between Smads and other signaling pathways. TGF-β receptors activate Smad-independent signaling pathways that can regulate Smad activation and function.[18] MAPKs (Erk1/2, p38 and Jnk) represent one group of downstream signaling transducers of TGF-β1 that can regulate Smad activation and function.[18] MAPKs have been shown to directly regulate TGF-β1 induction of CTGF expression in some cell types.[20–26] We have recently demonstrated that Erk and not p38 or Jnk, are required for CTGF induction by TGF-β1 in osteoblasts.[15] Erk can potentiate the TGF-β1/Smad pathway via direct phosphorylation of Smads, or indirectly through activation/inactivation of co-activators/co-repressors that mediate Smad DNA binding.[27, 28] However, the potential interaction between Erk and Smads for CTGF induction in osteoblast remains unexplored and is the focus of this study.

We have also previously demonstrated that Src signaling is required for CTGF induction by TGF-β1 in osteoblasts, and that Src is activated upon TGF-β1 treatment.[15] Src activation following TGF-β1 treatment can occur as a direct result of TGF-β receptor activation.[29, 30] Studies have shown that Src can act as a downstream signaling effector for TGF-β1 and can function upstream of Erk in some cell types.[29–34] Although our previous studies have demonstrated that Smad, Erk and Src play important roles in TGF-β1 induction of CTGF expression in osteoblasts, their potential interactions with one another have not been investigated. It is not known whether Erk and Src cooperate with one another, function independent of each other, or how they regulate Smad signaling. Therefore, the focus of this study is to investigate these potential interactions between Src, Erk and Smad signaling in osteoblast.

Materials and Methods

Reagents

Transforming Growth Factor-β1 (rhTGF-β1) was purchased from Calbiochem (Gibbstown, NJ) and reconstituted as 2μg/ml in 4mM HCl with 1% bovine serum albumin. The Src family kinase inhibitor (PP2), an inactive analog of this inhibitor (PP3), and the anti-DAPI antibody were also purchased from Calbiochem. The MEK1/2 inhibitor (PD98059) and the anti-actin antibody were purchased from Sigma (St. Louis, MO). The anti-tyrosine 416 Src, anti-phospho-Smad2 (Ser465/467), anti-total Smad2/3, anti-phospho-Erk1/2 (Thr202/Tyr204), and anti-total Erk1/2 antibodies were purchased from Cell Signaling (Danvers, MA). The anti-phospho-Smad3 (Ser423/425) and anti-Smad4 antibodies were purchased from Abcam (Cambridge, MA). The anti-total Src antibody was purchased from Millipore (Billerica, MA). The anti-CTGF antibody was from Santa Cruz (Santa Cruz, CA). The horseradish peroxidase conjugated anti-rabbit and anti-mouse IgG antibodies were purchased from Pierce (Rockford, IL). The fluorescein conjugated anti-rabbit IgG antibody was purchased from Jackson ImmunoResearch Laboratories (West Grove, PA).

Cell Culture and Treatment

Rat osteosarcoma cells (ROS 17/2.8) were provided by Dr. Archana Sanjay (Temple University). Cells were cultured in α-MEM (Mediatech, Manassas, VA) supplemented with 10% heat-inactivated fetal calf serum (Biowest, France), 100 IU/ml penicillin, and 100μg/ml streptomycin (Gibco, Carlsbad, CA). The cells were maintained at 37°C with 5% CO_2 with change of media every three days until they reached ~80% confluency. Prior to any of the treatments, cells were serum-starved for 24 hours. Pre-treatment with the Src kinase inhibitor (PP2), the inactive analog of this inhibitor (PP3), the Erk inhibitor (PD98059) or diluent only (DMSO) occurred for 30 minutes prior to treatment with TGF-β1 (5ng/ml) for the appropriate length of time (as indicated for each experiment).

Protein Isolation and Western Blotting

2 x 10^6 cells/100mm culture dish were washed twice in PBS and harvested from culture dishes in protein extraction buffer (RIPA buffer) consisting of 50mM Tris-HCl (pH 7.5), 135 mM NaCl, 1% Triton X-100, 0.1% sodium deoxycholate, 2mM EDTA, 50mM NaF, 2mM sodium orthovanadate, 10μg/ml aprotinin, 10μg/ml leupeptin and 1mM PMSF. Cell lysates were agitated for 24 hours in 4°C and centrifuged at 14,000g for 10min at 4°C. The supernatant was stored in –80°C for later Western blot studies. The total protein concentration was measured using the BCA Protein Assay Reagent Kit (Pierce) according to the manufacturer's instructions. Twenty μg of protein from each sample were mixed with 2× Laemmli loading buffer and boiled at 100°C for five minutes. Samples were subjected to electrophoresis on 10% Tris-HCl ready gels (BioRad, Hercules, CA) and transferred to PVDF filters by electroblotting. After one hour blocking in 5% BSA or 3% dry milk/0.5% BSA (per antibody instructions) at room temperature, blots were incubated with one of the following primary antibodies: p-Erk (1:1000), p-Smad2 (1:1000), p-Smad3 (1:1000), p-Src (1:1000), total Erk (1:1000), total Smad2/3 (1:1000), total Src (1:1000), actin (1:5000), and CTGF (1:200), and then with the corresponding HRP-conjugated secondary antibody (1:10,000).

Antigens were detected using the Pierce supersignal west pico chemiluminescent substrate system.

Nuclear Protein Separation

The nuclear protein separation was carried out using the protocol described by Dignam et al.[35] Cells (3 x 10^6) were harvested and washed in PBS. After centrifugation, the cell pellet was resuspended in 50µl sucrose buffer containing 0.32 M Sucrose, 10mM Tris HCl (pH 8.0), 3mM $CaCl_2$, 2mM MgOAc, 0.1mM EDTA, 0.5% NP-40, 1mM DTT and 0.5mM PMSF. The lysates were centrifuged at 500g for 5 minutes at 4ºC. The nuclear pellet was washed in sucrose buffer without NP-40. After centrifugation, the nuclear pellets were resuspended in 15µl low salt buffer containing 20mM HEPES (pH 7.9), 1.5mM $MgCl_2$, 20mM KCl, 0.2mM EDTA, 25% glycerol, 1% NP-40, 0.5mM DTT, 0.5mM PMSF and in an equal volume (15µl) of high salt buffer containing 20mM HEPES (pH 7.9), 1.5mM $MgCl_2$, 800mM KCl, 0.2mM EDTA, 25% glycerol, 1% NP-40, 0.5mM DTT, 0.5mM PMSF, and 4µg/ml aprotinin. Lysates were incubated at 4ºC for 30min with agitation followed by centrifuge at 14,000g for 10min at 4ºC. The supernatants containing the nuclear protein lysate were then used for Western blot analysis and protein concentrations were determined using the Bradford protein assay.

Immunofluorescence Staining

Cells were plated at 5000/chamber in chamber slides (Nunc, Rochester, NY) in serum supplemented medium for 24 hours. Cells were then serum deprived for 24 hours prior to treatment. Some chambers were pretreated with 20µM PP2 (Src kinase inhibitor), 20µM PD98059 (Erk inhibitor), or equal volume of DMSO (diluent control) for 30 minutes prior to TGF-β1 treatment (5ng/ml) for an additional 30 minutes. Following treatment, cells were washed twice in PBS and fixed in 4% paraformaldehyde for 15 minutes at room temperature. The cells were washed again in PBS and permeabilized with 0.1% Triton X-100 in PBS for five minutes at room temperature. After three washes in PBS, slides were blocked using 1% BSA in PBS for one hour at room temperature. Cells were incubated with either anti-phospho Smad2 (1:100) and anti-phospho Smad3 (1:250) overnight at 4ºC. After three washes in PBS-0.1% Tween 20, cells were incubated with anti-DAPI antibody (1:1000; Calbiochem, Gibbstown, NJ) and fluorescein-conjugated secondary antibody (1:1000) for one hour at room temperature. The cells were washed again with PBS-T for three times, mounted using the mounting fluid (Light Diagnostics, Murray, Utah), and examined with a Nikon Eclipse E800 epifluorescent microscope. All images were captured using a Retiga EXi digital camera.

Cell Viability Assay

The CellTiter-Glo luminescent cell viability assay kit (Promega, Madison, WI) was used according to the manufacturer's directions. Briefly, cells in a 96 well microplate (4 x 10^4 cells/well) were treated with the Erk inhibitor, PD98059, or the Src inhibitor, PP2, under conditions used for corresponding experiments described above. After treatment the plate was equilibrated to RT for 30 minutes and subsequently lysed in CellTiter-Glo reagent for 10 minutes with mild agitation. The samples were then measured using a Wallac 1420 fluorometer, normalized to a blank reaction and graphed as relative luminescence being compared to the appropriate controls.

Electro-Mobility Shift Assay

Nuclear extracts from TGF-β1 treated cells with or without PD98059 pretreatment were prepared following the nuclear protein separation protocol described above. The electro-mobility shift assays and oligonucletide probes used in this study were prepared as previously described.[15] Briefly, probes were synthesized that were homologous to the native sequence found in the CTGF promoter and labeled with [γ-^{32}P] ATP (Amersham, Louisville, CO) and T4 polynucleotide kinase (NEB, Ipswich, MA). The binding reaction is composed of 5 µg of nuclear extract, 1× binding buffer [5× binding buffer: 50 mM Tris–HCL (pH8.0), 750 mM KCL, 2.5 mM EDTA, 0.5% Triton X-100, 62.5% glycerol and 1 mM DTT], poly-dldc (1 µg/ml), and 10,000 cpm of labeled probe. After incubating at RT for 30 min the entire sample was loaded on a 4% acrylamide, 60:1 acrylamide:bisacrylamide gel using 0.5× TBE.

Results

TGF-β1 Induces Src Kinase Activation in ROS Osteoblast-like Cells (Figure 1)

We have previously reported that TGF-β1 induction of CTGF protein expression in primary rat osteoblasts involves the activation of Smad, Erk and Src signaling. The purpose of this study was to examine the mechanisms by which Src and Erk influence Smad signaling to regulate CTGF expression in osteoblasts. One issue with utilizing primary osteo-

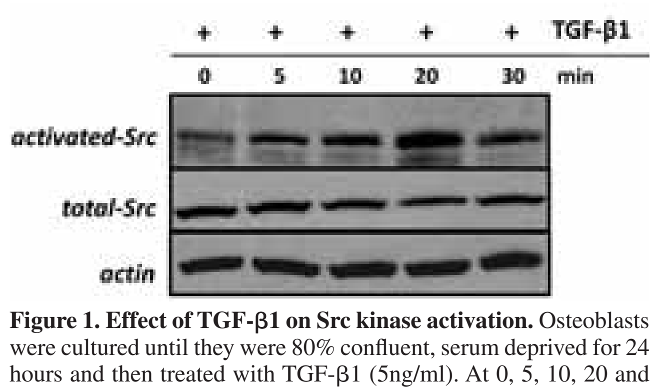

Figure 1. Effect of TGF-β1 on Src kinase activation. Osteoblasts were cultured until they were 80% confluent, serum deprived for 24 hours and then treated with TGF-β1 (5ng/ml). At 0, 5, 10, 20 and 30 minutes post-TGF-β1 treatment, cell lysates were harvested and assessed for Src activation by Western blot analysis. TGF-β1 treatment induced Src activation in a time dependent fashion with a maximal response occurring at 20 minutes post-treatment.

blast cultures for biochemical or molecular analyses is the heterogeneity of the cells in these cultures. For this reason, we chose to use the rat osteosarcoma cell line (ROS17/2.8) for our experiments. This cell line has been used extensively by other groups to study signaling and gene expression mechanisms in osteoblasts.[36, 37]

First we had to establish the time course for Src activation following TGF-β1 treatment in ROS osteoblast-like cells. Cells were treated with TGF-β1 (5ng/ml) for 0, 5, 10, 20 or 30 minutes. The TGF-β1 dose of 5ng/ml was used for this and all subsequent experiments since we had previously demonstrated that this was the minimal dose required for maximal induction of CTGF promoter activity and protein expression in osteoblasts.[15] Western blot analysis of cell lysates revealed a time dependent activation of Src with maximal activation occurring at 20 minutes post-treatment while total Src levels remained constant at all time points (Figure 1). Actin was used as a loading and transfer control.

Inhibition of Src Activation Causes a Dose-Dependent Inhibition of TGF-β1 Induced CTGF Expression (Figure 2)

In our next series of experiments, we used PP2, a Src family kinase inhibitor, to block TGF-β1 induction of Src activation. ROS cells were pre-treated for 30 minutes with 20μM of PP2 prior to TGF-β1 treatment for 20 minutes (maximal time for activation as determined in Figure 1). Western blot analysis of cell lysates demonstrated that this dose of PP2 completely blocked Src activation (Figure 2A). PP3, an inactive analog of PP2, and DMSO, the diluent for PP2 and PP3, were used as controls and had no effect on Src activation (Figure 2A). Next, we assessed the dose-dependent effect of PP2 on CTGF expression. Cells were pre-treated with the indicated doses of PP2 for 30 minutes, followed by eight hours treatment with TGF-β1. A time course experiment for CTGF induction by TGF-β1 in ROS osteoblasts demonstrated that CTGF reached maximal levels at eight hours post-treatment, and therefore this time point was chosen to evaluate CTGF protein expression in all subsequent experiments (data not shown). Western blot analysis demonstrated a dose-dependent inhibition of TGF-β1 stimulated CTGF expression with maximal effect at the 20μM dose (Figure 2B). This same dose of PP2 was used in all subsequent experiments.

Src is Upstream of Erk (Figure 3)

Next we wanted to determine whether Src can regulate the activation of Erk. In some signaling pathways, Src has been shown to be upstream of Erk (references). In these experiments, we pre-treated cells with the Src inhibitor, PP2, for 30 minutes and then stimulated them with TGF-β1 for an additional 30 minutes. Pilot studies revealed that 30 minutes post-TGF-β1 treatment caused maximal Erk activation in ROS osteoblasts (data not shown). Western blot analysis of cell lysates demonstrated that the activation of Erk was completely blocked following Src inhibition (Figure 3). The Erk inhibitor, PD98059, was used as a control, and effectively blocked Erk activation subsequent to TGF-β1 treatment (Figure 3). Total Erk levels were not affected by any of these treatments (Figure 3). These results demonstrate that Src functions upstream of Erk in ROS osteoblasts.

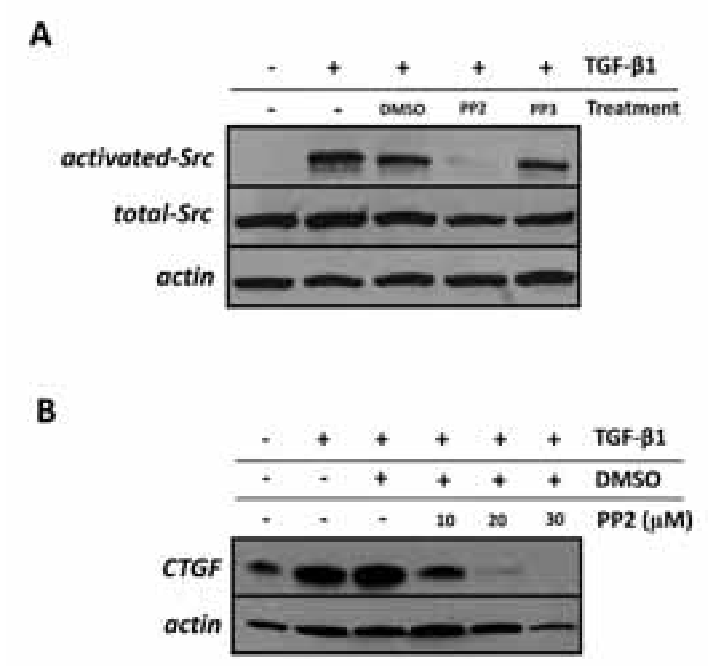

Figure 2. Effect of Src inhibition on CTGF induction by TGF-β1. Osteoblasts were cultured until they were 80% confluent and serum starved for 24 hours prior to any treatment. **(A)** Serum starved cells were pretreated with 20μM PP2 (Src kinase inhibitor) or PP3 (inactive analog, negative control) for 30 minutes and then treated with 5ng/ml of TGF-β1 for eight hours. Western blot analysis revealed that Src activation was inhibited by PP2 treatment, while PP3 had no effect. **(B)** Serum starved cells were pretreated with 10, 20 or 30μM of PP2, and then treated with TGF-β1 (5ng/ml) for eight hours. Western blot analysis demonstrated PP2 inhibited CTGF expression in a dose-dependent manner with maximal effect at the 20μM dose.

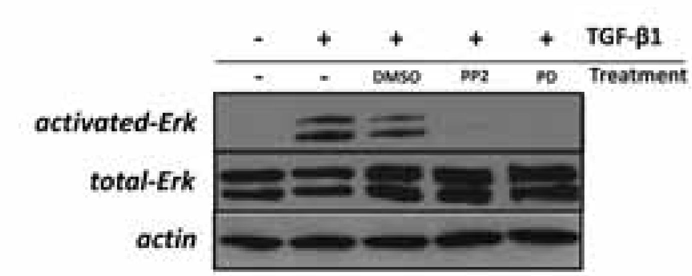

Figure 3. Effect of Src on Erk activation. Osteoblasts were cultured until they were 80% confluent and serum starved for 24 hours. Cells were pretreated with PP2 (20μM) or PD98059 (positive control, 20μM) for 30 minutes, and then treated with 5ng/ml TGF-β1 for 20 minutes. Western blot analysis of cell lysates showed that Src activation is required for the activation of Erk in osteoblasts.

Inhibition of Src, But Not Erk, Blocks Smad Activation and Nuclear Translocation (Figures 4 and 5)

The preceding experiments established that the signaling requirements for Src and Erk in TGF-β1-mediated induction of CTGF are identical in the ROS osteoblast cell line and primary osteoblasts.[15] Since Smad signaling is essential for TGF-β1 induction of CTGF in osteoblasts[15] and both Src and Erk have been shown to regulate Smad signaling in some cell types, we were interested in examining whether Src or Erk could affect Smad activation and/or nuclear translocation subsequent to TGF-β1 treatment in ROS osteoblasts. Cells were pre-treated with either the Src kinase (PP2) or Erk (PD98059) inhibitors prior to TGF-β1 treatment for 20 (whole cell lysates) or 30 (nuclear lysates) minutes. Western blot analysis of whole cell nuclear lysates showed that the inhibition of Src activation blocked the activation of Smads 2 and 3 as well as their nuclear translocation (Figures 4A and B). On the contrary, the inhibition of Erk activation had no demonstrable effect on the activation or nuclear translocation of Smads 2 and 3 (Figures 4A and B). None of the experimental conditions had an effect on total Smad 2/3 levels (Figure 4). For both whole cell and nuclear lysates, cells pre-treated with the diluent DMSO were used as a negative control (Figure 4). Subsequent immunofluorescent experiments were conducted to visualize the localization of activated Smad 3 following TGF-β1 treatment and to examine the effects of Src or Erk inhibition on Smad 3 localization. Cells treated with TGF-β1 for 30 minutes (positive control) showed an intense fluorescent signal for activated Smad 3 in their nuclei compared to negative controls in which the fluorescent signal for activated Smad 3 was undetectable or very weak (Figures 5 E and F). Nuclei were also stained with Dapi (blue) to correlate with the nuclear localization of activated Smad 3 (green) (Figures 5A, E and B, F). Cells pretreated with the Src kinase inhibitor did not exhibit a detectable fluorescent signal for activated Smad 3 (similar to negative control), while the Erk inhibitor had no effect on the nuclear localization of activated Smad 3 (similar to positive control). These results demonstrate that Smad activation and nuclear translocation is directly affected by the inhibition of Src but not Erk.

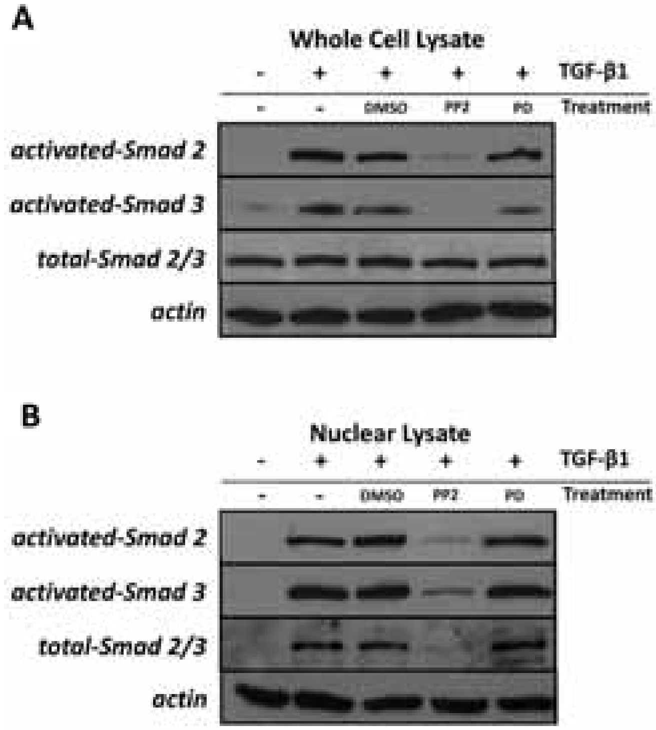

Figure 4. Effect of Src and Erk on TGF-β1 induced Smad activation and nuclear translocation. Subconfluent cultures of osteoblasts were serum starved for 24 hours, pretreated with the Src kinase inhibitor, PP2 (20μM), the Erk inhibitor, PD98059 (20μM), or diluent (DMSO) alone for 30 minutes followed by treatment with 5ng/ml TGF-β1 for 20 minutes (whole cell lysates) or 30 minutes (nuclear lysates). **(A)** Western blot analysis of whole cell lysates demonstrated that the activation of Smads 2 and 3 was inhibited by PP2, while the Erk inhibitor, PD98059, had no effect on Smad2 and Smad3 activation. **(B)** Western blot analysis of osteoblast nuclear lysates demonstrated that Src activation was required for TGF-β1 induced nuclear translocation of activated Smads 2 and 3, while Erk signaling does not affect the nuclear translocation of activated Smads 2 and 3.

Erk is Required for Transcriptional Complex Formation on the CTGF Promoter (Figure 6)

MAPKs, such as Erk, can modulate the TGF-β1/Smad pathway through activation/inactivation of required nuclear co-activators/co-repressors that mediate Smad DNA binding.[27] To determine how Erk signaling functions to potentiate CTGF induction by TGF-β1, we examined if Erk was required for transcriptional complex formation on the CTGF promoter in osteoblasts after TGF-β1 treatment. Previous studies have identified putative and functional regulatory motifs in the CTGF proximal promoter that are required to confer TGF-β1 responsiveness.[38, 39] We previously demonstrated that CTGF induction by TGF-β1 in osteoblasts is dependent on two proximal promoter elements, the TGF-β1 response element (TRE) and the Smad binding element (SBE).[15] For these studies, probes were generated that contained both the SBE and TRE (S-T), the TRE alone (T) or the SBE alone (S) (Figure 6A). To determine if Erk signaling was required to facilitate TGF-β1 induced complex formation/binding to the CTGF promoter, we used the Erk inhibitor, PD98059, to block the Erk signaling pathway. Nuclear lysates were prepared from osteoblasts treated with TGF-β1 that were either pretreated with the inhibitor (PD98059) or mock treated (DMSO). We assessed the ability of Erk inhibitor/TGF-β1 treated nuclear lysates versus TGF-β1 treated alone nuclear lysates to bind to each of the probes (Figure 6B). We found that blocking Erk signaling impaired the abil-

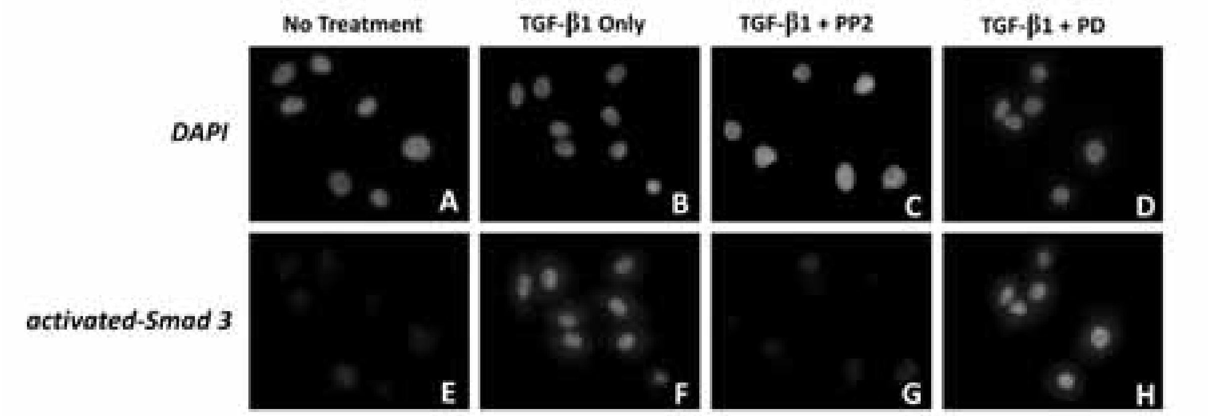

Figure 5. Immunofluorescent localization of activated Smad3. Osteoblasts were plated in serum supplemented media for 24hr and then serum starved for an additional 24 hr prior to treatment. All cells except for the negative controls **(A, E)** were treated with 5ng/ml TGF-β1 for 30 min; some were pre-treated for 30 min with PP2 **(C, G),** a Src Family kinase inhibitor, or with PD98059 **(D, H),** an Erk inhibitor. Following treatment, all cells were fixed, permeabilized and incubated anti-phospho-Smad3 (anti-p-Smad3) primary antibodies followed by anti-DAPI and a fluorescein conjugated secondary antibody specific for the anti-p-Smad3 antibody. Fields of cells with DAPI-stained nuclei are shown in A–D, while the corresponding fluorescein-stained (p-Smad3) cells are shown in E–H. There was intense nuclear staining for p-Smad3 in cells treated with TGF-β1 **(F)** while there was little to no staining in the negative controls (E). PP2, the Src kinase inhibitor, blocked the activation and nuclear translocation of Smad3 **(G),** while the Erk inhibitor, PD98059, had no demonstrable effect on Smad3 phosphorylation or its translocation to the nucleus.

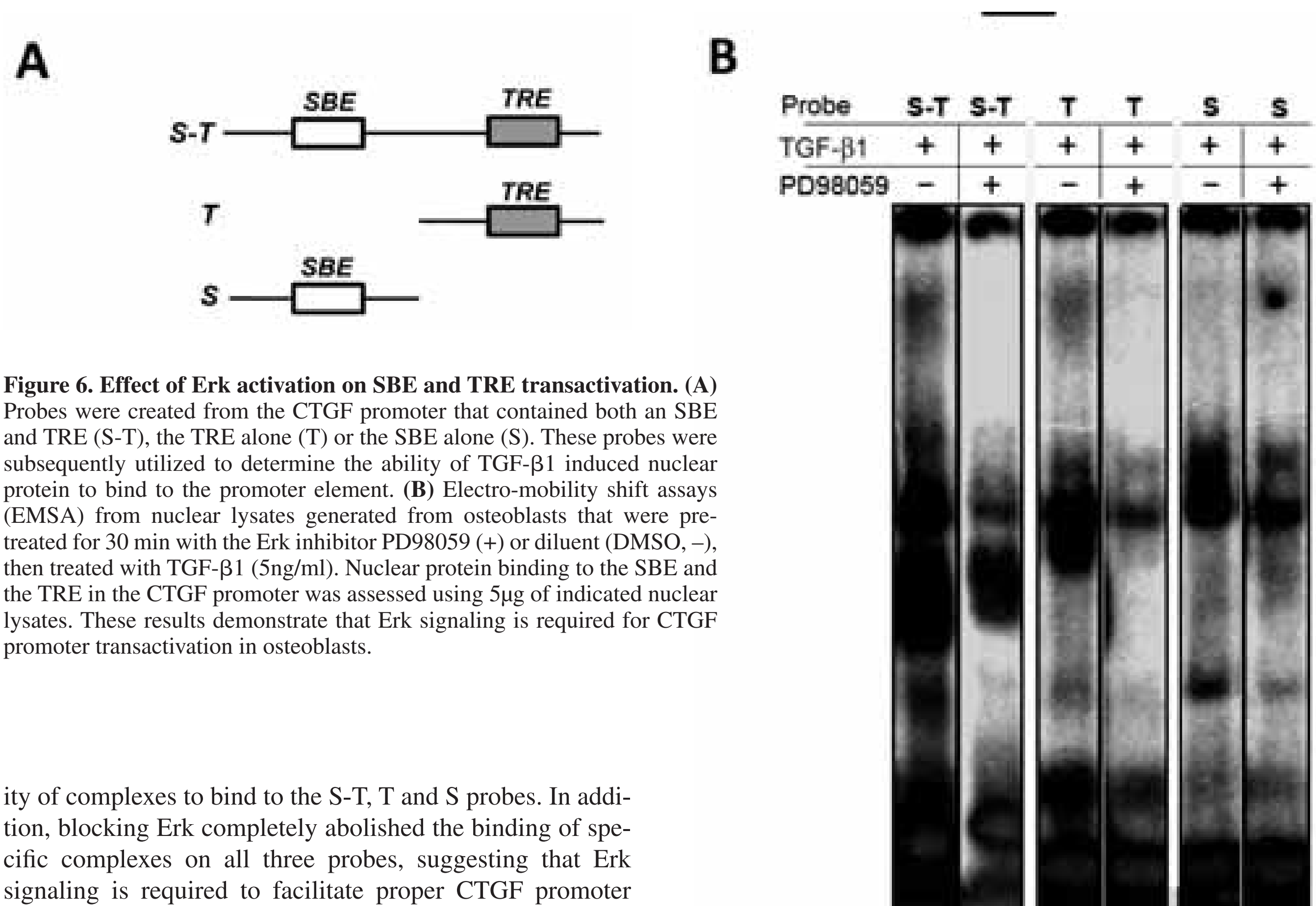

Figure 6. Effect of Erk activation on SBE and TRE transactivation. (A) Probes were created from the CTGF promoter that contained both an SBE and TRE (S-T), the TRE alone (T) or the SBE alone (S). These probes were subsequently utilized to determine the ability of TGF-β1 induced nuclear protein to bind to the promoter element. **(B)** Electro-mobility shift assays (EMSA) from nuclear lysates generated from osteoblasts that were pre-treated for 30 min with the Erk inhibitor PD98059 (+) or diluent (DMSO, –), then treated with TGF-β1 (5ng/ml). Nuclear protein binding to the SBE and the TRE in the CTGF promoter was assessed using 5μg of indicated nuclear lysates. These results demonstrate that Erk signaling is required for CTGF promoter transactivation in osteoblasts.

ity of complexes to bind to the S-T, T and S probes. In addition, blocking Erk completely abolished the binding of specific complexes on all three probes, suggesting that Erk signaling is required to facilitate proper CTGF promoter complex formation/binding resulting from TGF-β1 induction in osteoblasts.

Discussion

Connective tissue growth factor (CTGF/CCN2) is a cysteine rich, extracellular matrix protein that acts as an anabolic growth factor to regulate osteoblast differentiation and function. We have previously shown that in osteoblasts, CTGF is induced by TGF-β1 where it acts as a downstream mediator of TGF-β1 induced matrix production.[6] We recently tested the requirements of Smad and MAPK signaling for TGF-β1 induced CTGF promoter activity in osteoblasts, and demonstrated that Smads 3 and 4 (not Smad 2) and Erk (not p38 or Jnk) are required for CTGF induction by TGF-β1.[15] Interestingly in the same study, we also demonstrated that the non receptor tyrosine kinase, Src, was also an essential for CTGF induction by TGF-β1. Although these findings suggest that Erk and Src play an important role in TGF-β1 induction of CTGF expression in osteoblasts, it is not known whether Erk and Src function together or independent of each other, if they function to modulate Smad signaling or if they function in a Smad independent manner. In this study, we examined the interaction between Src and Erk for CTGF induction by TGF-β1 in osteoblasts and whether they regulate Smad signaling.

We characterized the role that Src plays in TGF-β1 induction of CTGF using the rat osteosarcoma cell line, ROS17/2.8. We found a time dependent activation of Src following TGF-β1 treatment in ROS osteoblast-like cells. The observation that TGF-β1 induces Src activation is consistent with other published reports that have also implicated the tyrosine kinase, Src, as a downstream signaling effector for TGF-β1 in certain cell types.[30–32, 40, 41] Importantly, when we treated our cells with the Src family kinase inhibitor, PP2, we were able to block Src activation and inhibit CTGF activation, demonstrating that Src is an essential signaling component of TGF-β1 induced CTGF expression in ROS osteoblast-like cells. This finding is consistent with studies in fibroblasts where Src activity is necessary for TGF-β1 induced CTGF expression.[66] Src activation following TGF-β1 treatment can occur as a direct result of TGF-β receptor activation[29, 30] or indirectly as a result of enhanced integrin-mediated cell attachment induced by TGF-β1.[31–34] In a study using mammary epithelial cells it was shown that PP1, and to a lesser extent, PP2, significantly inhibited TGF receptor kinase activity and blocked subsequent downstream signal transduction.[42] While our results demonstrating time dependent activation are suggestive of direct activation of Src by the TGF-β1 receptor, they do not rule out the possibility that other proteins are required. Future studies will address the interaction between Src and the TGF-β1 receptor, and the potential requirement of other proteins in this process.

Studies have shown that Src can function as an upstream signaling partner of Erk.[43, 44] A more recent study demonstrated that Src functions upstream of Erk in osteoblastic cell lines.[43] In this study, we demonstrated that activation of Src is required for TGF-β1 induced Erk activation, indicating that Src functions upstream of Erk with regard to TGF-β1 in osteoblasts. It is also important to note that inhibition of Erk activation using the MEK inhibitor, PD98059, had no effect on Src activation following TGF-β1 treatment in osteoblasts. The most interesting observation was the novel requirement of Src for Smad activation and nuclear translocation in osteoblasts (see Figure 7). Our results demonstrated that inhibition of Src activation completely blocked TGF-β1 induced activation of Smads 2 and 3 as well as their nuclear translocation. Such a role for Src in regulating Smad activation downstream of TGF-β1 has not been identified previously in any cell type. To date there has been one report demonstrating a role for Src mediated Smad 1/5 signaling downstream of BMP where Src complexed with Smad 1/5 to facilitate Smad nuclear translocation.[45] A more detailed investigation of the Smad-Src interaction in osteoblasts is warranted.

Our approach utilized the Src family kinase inhibitor, PP2, and this inhibitor blocks all Src family kinases. Although Src is the key functional family member in osteoblasts, other Src family kinases are also expressed including Yes, Fyn and Hck. In our previous study using primary rat osteoblasts, we used a dominant negative-kinase dead (DN-KD) construct to block Src activity and demonstrated specificity for Src in TGF-β1 induction of CTGF. However, we could not use this construct for this study since transfection efficiency in ROS cells was too low to effectively block Src activation. Instead we are currently using a Src siRNA to block Src in ROS osteoblast-like cells. This approach specifically blocks the expression of Src without affecting the expression of other Src family kinase members. We have also found that TGF-β1 induction of CTGF expression is completely blocked in cells transfected with the Src siRNA. While preliminary, these results confirm the specificity of Src as the only Src kinase family member responsible for regulating TGF-β1 mediated CTGF expression in ROS osteoblast-like cells. We will continue to utilize this approach to confirm the role of Src in regulating Smad activation and nuclear translocation.

Recent studies examining the interactions between MAPKs and Smad signaling demonstrated that TGF-β1 induced Smad signaling is regulated by MAPKs in osteoblasts and the cellular responses induced by TGF-β1 are determined by this interaction.[46, 47] MAPKs, such as Erk, can modulate the TGF-β1/Smad pathway through direct effects on the phosphorylation of Smads or indirectly through activation/inactivation of required nuclear co-activators/co-repressors that mediate Smad DNA binding.[27] In contrast to Src inhibition, this study demonstrated that the inhibition of Erk using the MEK inhibitor, PD98059, did not prevent activation (phosphorylation) of Smads 2 and 3 or the translocation of the activated Smad2/3/4 complex into the nucleus. To assess if Erk regulates Smad signaling indirectly through activation/inactivation of required nuclear co-activators/co-repressors to mediate Smad DNA binding, we employed electro-mobility shift assays. In these assays we demon-

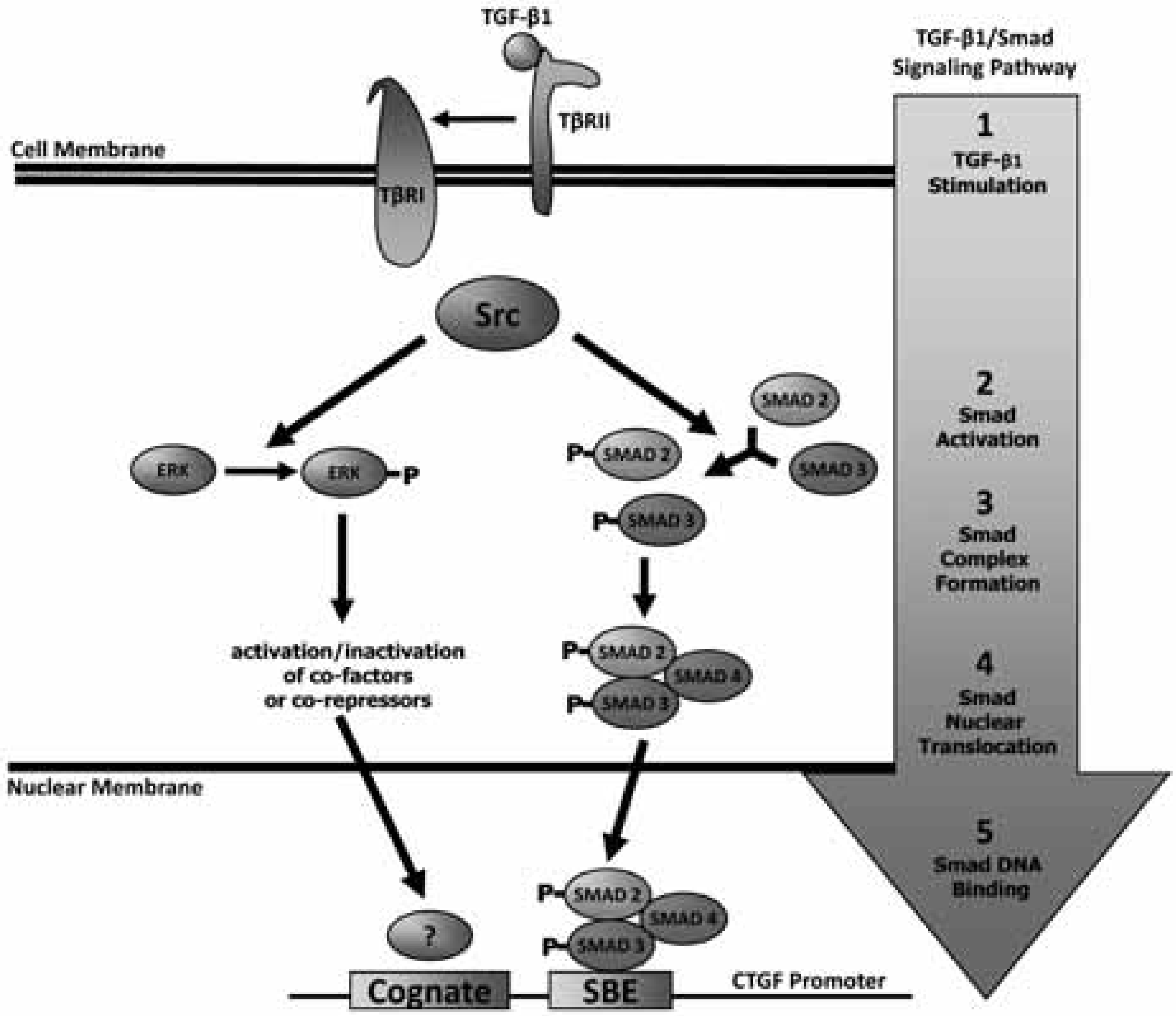

Figure 7. TGF-β1 and Src/Smad/Erk signaling in osteoblasts. TGF-β1 induction of CTGF in osteoblasts requires Src, Smad and Erk signaling. Based on our findings we propose that Src may play a central role in TGF-β1 signaling in osteoblasts by regulating the activation of both Erk and Smad 2 and 3.

strated that inhibition of Erk activation causes a significant reduction in the binding of trans-acting protein complexes to the TRE and/or SBE in the CTGF promoter. Previous studies have shown that activated Erk can translocate to the nucleus where it activates (phosphorylates) downstream transcription factors[48] that can form a transcriptionally active complex with Smad transcriptional co-activators such as p300 and CBP.[49, 50] Based on our results, we hypothesize that Erk mediates Smad signaling through activation of nuclear transcription factors that enhance Smad DNA binding and are necessary for transcriptional activation of the CTGF promoter (Figure 7). However, the identity of these nuclear transcription factors (proteins) through which Erk functions to regulate Smad binding remain unknown and are the focus of current investigation.

In this study, we examined the interaction between Src and Erk for CTGF induction by TGF-β1 in osteoblasts and whether they regulate Smad signaling. Our results demonstrate a new paradigm where Src plays a role as a major downstream signal transduction conduit for TGF-β1 signaling in osteoblasts in the context of CTGF regulation (Figure 7). Upon TGF-β1 stimulation, Src functions to distinctly regulate both Erk and Smad pathways. It appears from our results that these two pathways synergize at the promoter level and both pathways stimulate transcription factor binding for combinatorial CTGF promoter transactivation. Future studies will focus on the interaction between Src and the TGF-β1 receptor and identification of the transcription factors that function downstream of Erk and Smads that are required to achieve CTGF induction.

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Original Research

Spiral Fractures of the Femur in Ambulatory Toddlers: Another "Toddler's Fracture"?

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Background

Many ambulatory young children sustain femur fractures with fracture patterns and mechanisms similar to that of toddler fractures. This study was undertaken to identify the most common femur fracture patterns and their mechanisms of injury in the ambulatory toddler.

Methods

A retrospective review of all children under five years of age with a femur fracture during a five year period was performed. The mechanism of injury was classified as low-energy or high-energy and "suspicious for abuse" or "not suspicious for abuse," based on review of the records. All radiographs were reviewed in a blinded fashion to classify the fracture patterns as spiral, transverse, or oblique.

Results

Twenty-six fractures (74%) were classified as spiral, seven (20%) were transverse, and two (6%) were oblique. Of the spiral fractures, 25 of 26 were the result of reported low energy mechanisms. All of the transverse and oblique fractures resulted from reported high energy mechanisms. One child, with a spiral fracture, was found to be the victim of abuse.

Conclusions

Spiral fractures are the result of relatively low-energy torsional forces while transverse and oblique fractures are generally the result of higher energy direct forces applied to the bone. The toddler fracture of the tibia, the prototypical low-energy child's fracture, most commonly results from minor injury. This study documents that most femur fractures in ambulatory children are the result of low-energy spiral femur fractures. These injuries occur routinely from minor falls or tripping while upright, mechanisms that are frequently witnessed and reliably reported. Because of the similarity between the fracture patterns and mechanisms of injury, we believe that the ambulatory child's spiral femur fracture may be considered another "toddler fracture."

Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Digital Mapping of Arthroscopic Images

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Abstract

Purpose: To develop a reproducible technique to objectively measure, or digitally map, structures in arthroscopic images, and to describe how to apply these measurements to compare visualization methods.

Methods: A technique was developed to digitally map arthroscopic images using Adobe Photoshop. Step-by-step instructions on how to use this technique are included. Intra-rater and inter-rater variability were evaluated for this digital mapping method by having two raters map images of various normal and pathologic structures within the knee and the shoulder.

Results: Analysis of the coefficient of variation demonstrated all measurements were 0.09 or less, suggesting that this is a reproducible method.

Discussion: There are few orthopedic articles describing techniques to measure visualization of structures viewed arthroscopically. Presented is a novel technique to digitally map structures in arthroscopic images, and how to utilize this technique to investigate the adequacy of arthroscopic visualization. This technique allows for objective comparison of changes in the arthroscopic environment, such as comparing different portals for viewing a given structure, or changes in patient position to obtain better visualization. Variability testing was also performed to evaluate the reproducibility of this method.

Conclusions: By allowing *in vivo* comparison, this report adds much versatility to the one previously described *in vitro* method of comparing arthroscopic visualization.

Introduction

Arthroscopy is one of the most useful surgical modalities for both diagnosing and treating joint problems. There were over one million arthroscopic surgeries of the knee performed in the United States in 2007,[1] making it one of the most common orthopedic procedures. Arthroscopic surgery has also become the primary method to treat many types of shoulder pathology.[2]

Despite the popularity of this procedure, there are few objective techniques to compare the visualization of anatomic structures arthroscopically. Tolin et al.[3] mapped the arthroscopic field of view (FOV) of the posterior horn of the medial meniscus using spinal needles in cadaveric knees, followed by dissection of the knee. This method does not determine the arthroscopic FOV as seen in digital printouts, nor can it be utilized *in vivo*.

The purpose of this report is to describe a technique to objectively measure, or digitally map, structures in arthroscopic images, and includes a discussion of how to apply these measurements to compare visualization. This technique was developed utilizing Adobe Photoshop CS2 (Adobe Systems Incorporated, 345 Park Avenue, San Jose, CA 95110-2704, copyright 2005) and describes the steps involved in calculating the percent of the FOV occupied by a chondral defect in a medial femoral condyle as a model. The calculations obtained allow for objective comparison of changes in the arthroscopic environment, Also described are the steps involved in applying these measurements to compare visualization, such as comparing different portals for viewing a given structures, or changes in patient position to obtain better visualization. Using variability testing, this method has been shown to be reproducible.

Materials and Methods

Digital Mapping Technique

Although there are many ways to save arthroscopic images, as in printing hard copies, burn CDs or DVDs, or saving the files on a flash drive, directly saving the image as a digital file on a CD or a flash drive eliminates the time and loss of image quality when scanning hard copies. When using hard copies, a higher resolution scanner may increase the accuracy of the mapping, however, we used a low-resolution scanner for our variability testing, and found the images to be of sufficient quality. When scanning hard copies, images

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were saved on the computer in a JPEG or PDF format to allow for appropriate image manipulation in Photoshop.

For the purpose of this report, a medial femoral condyle chondral defect is digitally mapped in the following step-by-step guide:

1. Once the image is open in Photoshop, confirm Image Mode is set to *RGB Color* (Red-Green-Blue Color) to obtain accurate calculations using this technique.[4] RGB is typically the default image mode, so no action is usually required.
2. The first step is creating the FOV. The goal is to select a FOV that can be easily recreated on mapping serial images. Then, crop the individual image to be mapped, or zoom in on the desired image until a detailed view of the one image of interest is shown (Figure 1).
3. Once the desired image occupies the entire canvas (Photoshop's name for the work space), the edges of the FOV can more reliably be defined. As long as it is reproducible, the FOV can be a circle, square, or an irregularly shaped object within the image. The consistent method is to recreate a true circular FOV. By recreating a circular FOV, notches in the original FOV are removed, and this corrects for the loss of any parts of the FOV, as is seen at the top of Figure 1. Click and hold *Elliptical Marquee Tool*[5] with the left mouse button while over the dashed rectangle *(Rectangular Marquee Tool)* in the upper left corner of the tool bar (Figure 1). Start in the corner of the image using the Elliptical Marquee Tool to make a rough circular outline of the original arthroscope FOV. The selection area should be as congruent as possible with the circular FOV to ensure accurate calculation; right-clicking the mouse on the selection and choosing *Transform Selection* allows for fine adjustment of the circular selection, as seen in the lower right corner of Figure 1. When the circles overlap, the modified circular selection is accepted by clicking the checkbox at the upper portion of the Photoshop window.

Figure 1. New image with circular selection area using Photoshop "Elliptical Marquee Tool" to encompass a circular area that includes the original field of view (FOV). Also note the menu that opens when right-clicking the mouse, and the "Transform Selection" option is shown highlighted in gray.

4. Once the elliptical selection is made it is important that the entire circle is on the canvas. If the canvas is too small, the circle will be partially cut-off once the selection is made (upper edge of Figure 1). If the image is scanned and not cropped, the canvas is likely larger than the black margin of the arthroscopic image, so this step can be skipped. However, when directly importing a digital image or if the image is cropped at the black margin of the photo, the user will likely need to increase the canvas size. Click on the toolbar item *Image* (Figure 2, step 1) in the top menu, and select *Canvas Size* (Figure 2, step 2). In the canvas size window, the values displayed are those of the image. Add a few inches to the vertical or horizontal dimensions in the direction the ellipse is off of the image (Figure 2, step 3). The user will then have to remake the elliptical selection.

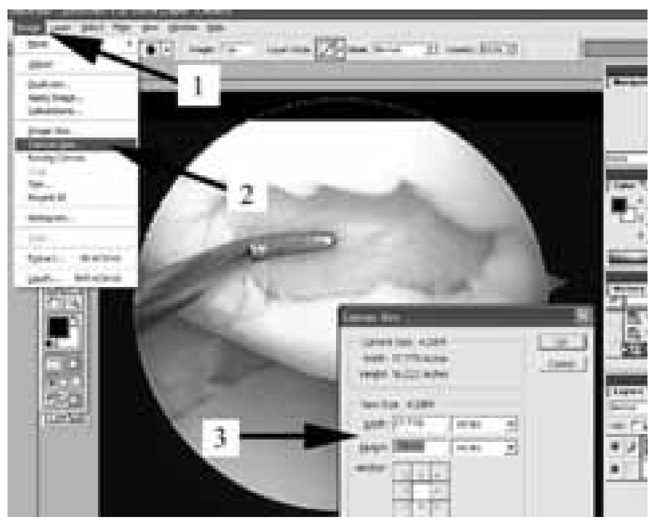

Figure 2. Steps involved in changing the canvas size to ensure the entire circle gets copied.

5. The new circular selection encompassing the FOV can be copied and pasted into a new Photoshop document (ctrl + N)[5,6] for further manipulation, thus eliminating the black surrounding the original arthroscope FOV (Figure 3).
6. Now that the FOV is within a new and independent image, a new layer can be created (ctrl + shift + N) in Photoshop.[5,6] This is a very important step for later calculation and cannot be skipped. When this new layer first appears, it will be transparent, so fill the new layer with white (ctrl + backspace). Once the new layer is filled in white, observe that it is a square placed overtop of the original circular FOV. At first it

might seem that the original image was lost, however, upon inspection of the *Layers* tab within Photoshop, one can see that there is a new white layer (*Layer 2* or some similar variant). *Layer 2* is on top of *Layer 1*. *Layer 1* may also be named *Background* or some similar variant (Figure 4).

7. Further inspection of the *Layers* tab within Photoshop, reveals an eyeball image next to each of the two layers of the current document (black arrow in Figure 4). By clicking on an appropriate eyeball in the *Layers* tab, it is possible to make any layer in the current document invisible.[4–6] When the white layer is invisible, it appears that the user is looking at the original circular FOV. (Note that the new white *Layer 2* is still there, but invisible).

Figure 3. FOV from Figure 2 copied and pasted into a new Photoshop document. Note, the checkered corners surrounding the circle are not part of the image, and inside the circle is the FOV used in the calculations.

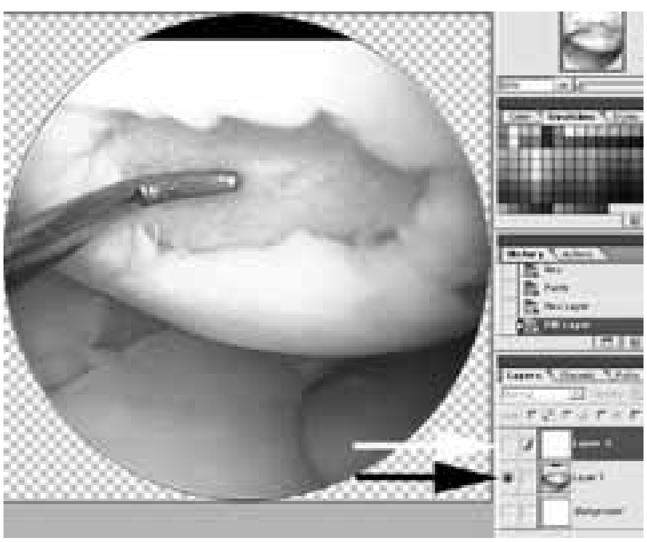

Figure 4. Two-layered Photoshop item with the new white layer, or "Layer 2," set to "Invisible." Note the white arrow pointing to an invisible *eyeball* next to "Layer 2," indicating that "Layer 2" is invisible. The black arrow shows the eyeball for "Layer 1" which should not be clicked, or else the circular FOV will temporarily disappear.

8. The next step involves the *Magnetic Lasso Tool* to outline the structure of interest. Before this can be accurately done, *Anti-aliasing* must be turned off.[5] Click on the lasso tool in the tool bar and then clicking on the *Anti-aliasing* check box that appears at the top of the window (Figure 5). *Anti-aliasing* will attempt to smooth out the selection made by the mouse using the lasso tool by graying-out pixels adjacent to the line of selection. If any gray area is in the new layer *(Layer 2)* that will be added in subsequent steps, the gray pixels will throw off the calculation of the percent of the FOV occupied by the structure of interest. This calculation is done based on the difference in the area occupied by black versus that occupied by white within the image. Gray areas will create inaccuracies in this calculation.

Figure 5. Steps to turn off anti-aliasing. Click on the lasso tool (black arrow) then uncheck the anti-aliasing box, which will appear at the top of the working window (white arrow).

9. When *Layer 2* is invisible, use the *Magnetic Lasso Tool*[5] to select that region of the image within the FOV that includes the anatomic structure(s) of interest. In this example we are interested in identifying the percent of the FOV occupied by the chondral defect. Given this assumption, the *Magnetic Lasso Tool* is used to select the appropriate region within the FOV (Figure 6).
10. Once the chondral defect or any anatomic structure of interest has been selected within the FOV while white *Layer 2* is invisible, make *Layer 2* visible again. The document will then appear as a completely white image with a selection area that represents the perimeter of the anatomic structure of interest (in this example, the chondral defect) (Figure 7).

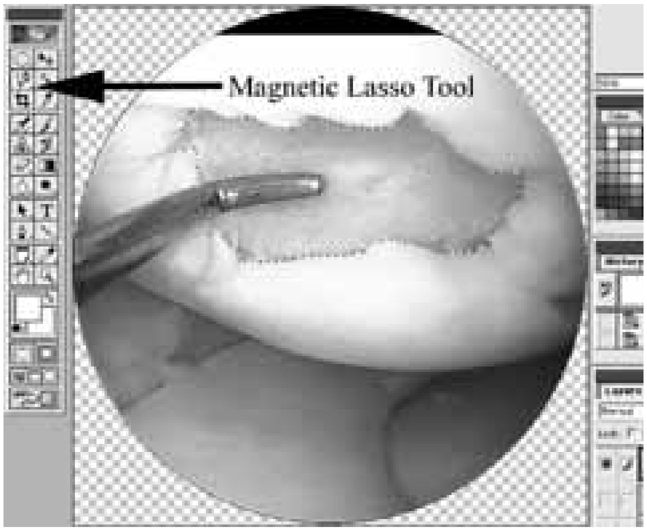

Figure 6. Chondral defect selected using Magnetic Lasso Tool within the circular FOV. Note that the white-filled "Layer 2" is invisible but the selection (dotted line) is actually in "layer 2."

Figure 7. The chondral defect selected as in Figure 6, but with white-filled "Layer 2" visible again.

11. With the document appearing as in Figure 7, the user should invert (ctrl + i) the selection's color. This should make the image appear as though the selection area is black surrounded by the white "Layer 2,"[4] similar to Figure 8.
12. Next, the user will de-select (ctrl + D) the current selection to make the calculation more accurate (Figure 8). If the selection area is not de-selected, the calculation given in the histogram will be based on only those colors included within the selection area. Since the entire selection area should appear black by the time that the selection area should be de-selected, such a calculation will be of no value. The goal is to calculate the percentage of the entire FOV (white) occupied by the newly outlined structure (black).

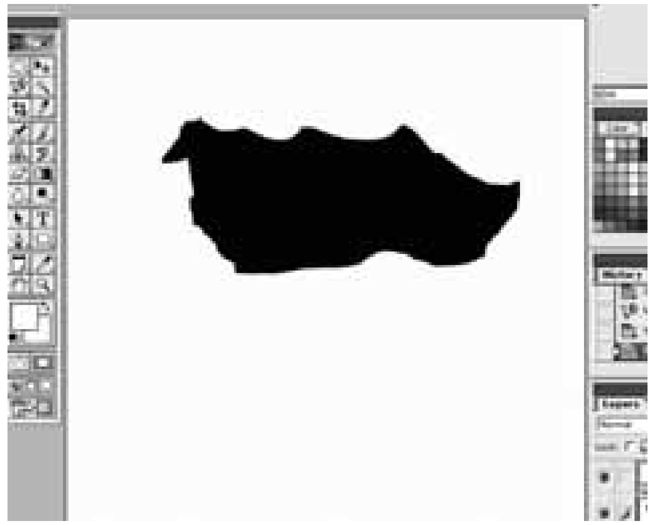

Figure 8. The FOV is now completely filled in with white, except for that area occupied by the anatomic structure of interest, which appears black.

13. To calculate the percent of the white, square-shaped *Layer 2* occupied by the structure of interest (in this case by the chondral defect), a Histogram of the image can be opened via the *Image* tab at the top of the Photoshop window: Image>Histogram.[6] The number next to *Percentile* shows the percentage of square-shaped *Layer 2* occupied by the black area. In this case, the chondral defect occupies 14.09 percent of *Layer 2*[6] (Figure 9). When reading the Percentile, the most accurate readings will be with the *Channel* set to *Red, Green,* or *Blue; Luminosity* will often give the same calculation, however it is a calculation based on

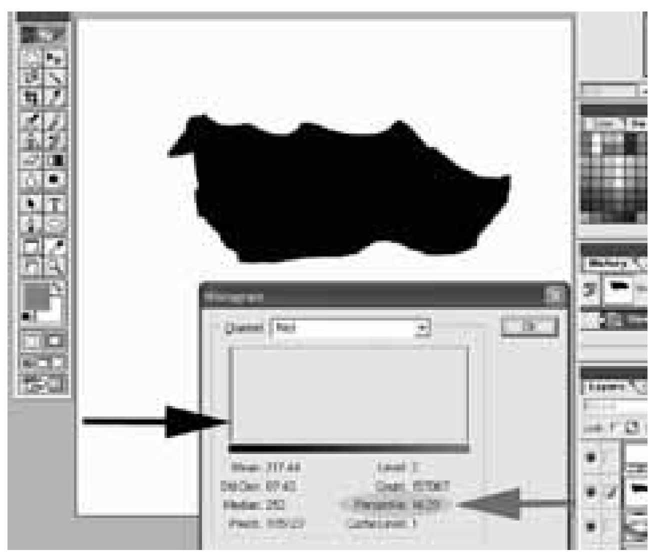

Figure 9. The selection area (black area) that represents the chondral defect occupies 14.09 percent of the square-shaped "Layer 2" as digitally calculated by Photoshop as calculated (gray arrow) within Photoshop's image-histogram. In order to obtain this value, the user may have to place the cursor on the vertical black line in the black region of the histogram (black arrow).

brightness rather than color. A comparison of the colors is the most accurate means of calculating the difference in black vs. white areas within the FOV, and thus *Luminosity* should be avoided for the histogram's channel.

Statistical Methods

Intra-rater and inter-rater variability have been evaluated for this digital mapping method. Two raters (ICD and IOP) were involved, and a meeting between them took place before measurements were done to ensure that each had a similar technique. They agreed on what they considered part of a particular structure, and each independently performed the digital mapping technique on a sample structure in front of the other rater.

After the meeting, each of the two raters mapped images of various structures within the knee and the shoulder. An effort was made to map both normal and abnormal structures. Structures mapped included the anterior cruciate ligament (ACL), inferior glenohumeral ligament (IGHL), middle glenohumeral ligament (MGHL), knee menisci, subscapularis tendon, long head of the biceps tendon, a Bankart lesion, a Type II SLAP lesion, divots within the humeral head and in the medical femoral condyle, and a calcific nodule in a reconstructed bovine ACL. The two raters measured each image three times, and the mean (average), standard deviation, and then coefficient of variation (COV) were calculated to give an indication of intra-rater variability. The COV is the standard deviation taken as a fraction of the mean. The COV was used, as it is the most applicable means of normalizing the standard deviation of each respective measurement with respect to its mean value. After this, the measurements obtained independently by each rater were compared, and COV between the mean measurements of the two raters gave an indication of inter-rater variability. It should be noted that a COV below 0.25 indicates low variability. Low variability demonstrates the measurements are consistently similar, which indicates they can be reproducibly measured.

Results

A summary of the data from each rater calculating the percentage of FOV three separate times on each of the 11 arthroscopic images follows. The COV comparisons are shown.

Intra-rater Variability

Each user had consistent results with low variability, demonstrated by *user-1* having a maximum COV of 0.0829 and *user-2* having a maximum COV of 0.0442 (Figure 10). All other measurements for each user had a COV well below these values, with 20 of the 22 measurements being under

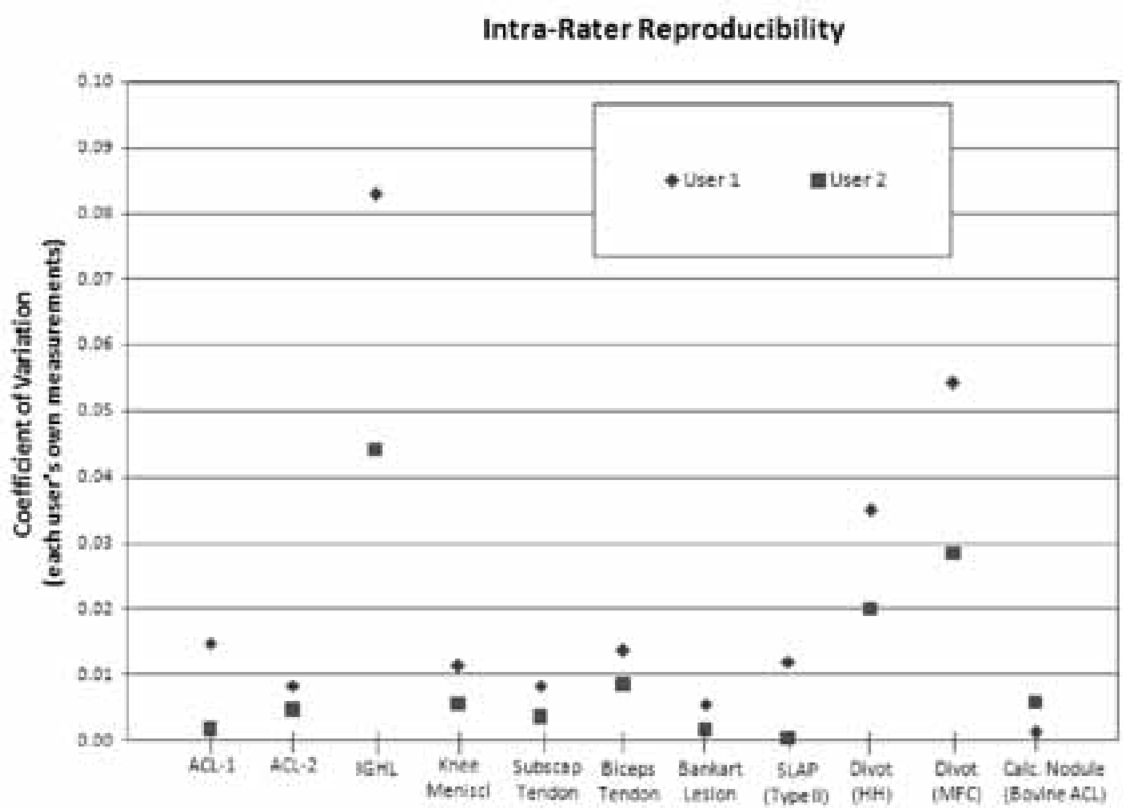

Figure 10. This figure represents intra-rater variability using the COV between measurements calculated by the same rater. One rater's measurements are designated by a square (ICD), the other rater (IOP) is designated by a diamond. Note that the variation is less than 0.09, indicating good reproducibility.

0.05, all below 0.09 and well below the 0.25 limit. This proves the data has low variability, which indicates a reproducible technique.

Inter-rater Variability

Comparing the variability between different users, the COV has an upper limit of 0.09, also well below the limit of 0.25 (Figure 11). This proves the data has low variability, which indicates a reproducible technique.

Discussion

There is a paucity of literature regarding a method to measure visualization during or after arthroscopy. The Tolin technique using spinal needles[3] has value, but also has many limitations, foremost of which it is limited to *in vitro* study.

A simple comparative study was designed to determine the variability of serial measurements by looking at both the intra-rater percentages, to confirm whether a given rater could reproduce consistent values, and inter-rater percentages, to confirm whether different raters could obtain similar values. During the analysis of data, the COV was utilized because it is a dimensionless number that allows comparison between data sets with significantly different means. Very different means were obtained from the different photos, so the COV was a more appropriate measure for comparing data than just using the standard deviation. The lower the COV, the less dispersion and the more similar the data, and 0.25 was used as the accepted cut-off for low variability, which suggests a reproducible method.

All values calculated were well under 0.25, and clearly demonstrate low variability for intra-rater and inter-rater values. For intra-rater variability, the COV was under 0.05 in 20 of the 22, and less than 0.09 in all, meaning that each of the three measurements the rater took for each photo were very similar, suggesting that this method is reproducible for a given rater. For our inter-rater variability, the COV was under 0.05 in 20 of the 24, and 0.09 or less in all, meaning that each of the three measurements taken by each rater were very similar to the other rater, suggesting that this method is reproducible between different raters. In summarizing the data, the technique outlined can be used to consistently calculate the percent of the FOV occupied by any given structure of interest contained within an arthroscopic image.

The primary disadvantage to this method is the difficulty in controlling the distance from the arthroscope to the

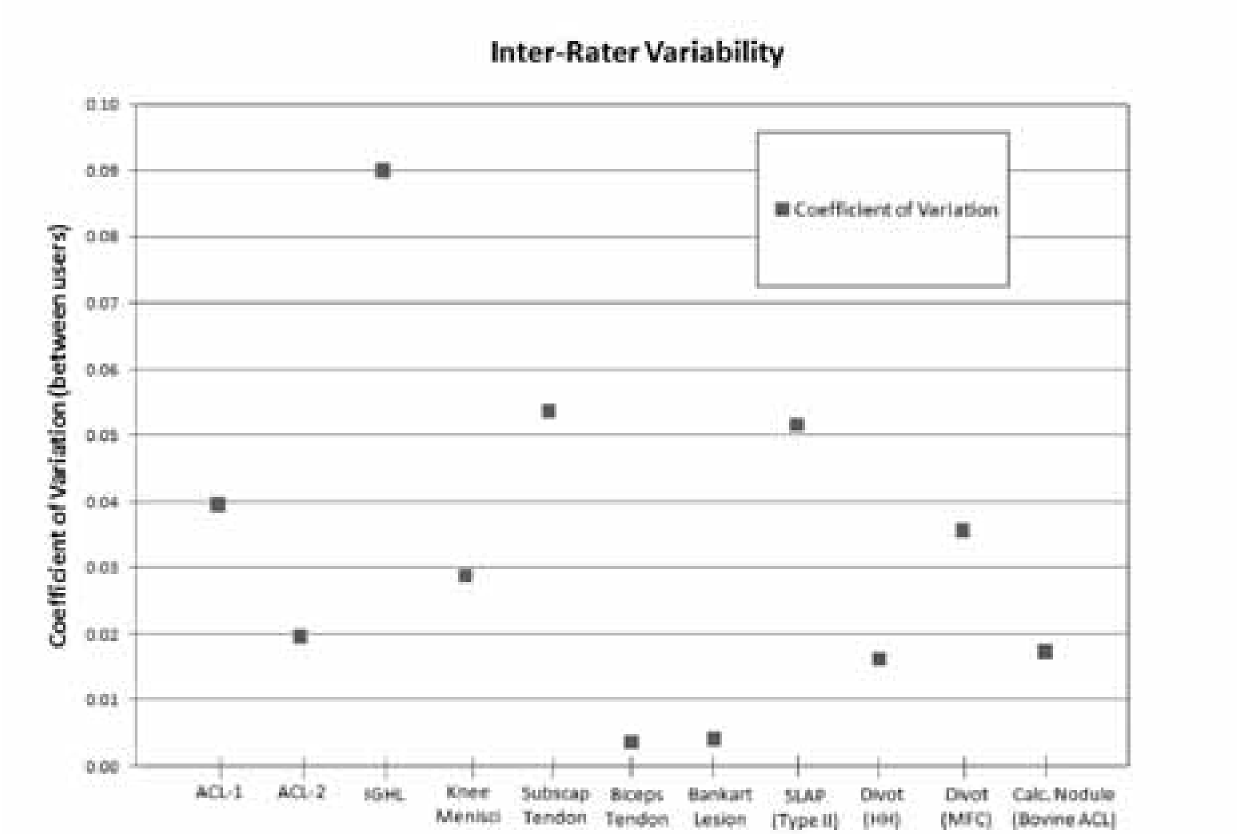

Figure 11. This figure represents inter-rater variability using the COV, represented by squares. Note that the variation is 0.09 or less, indicating good reproducibility.

structure(s) being photographed. It is clear that the percentage of a FOV occupied by a given structure is larger with the arthroscope positioned closer to that structure; the structure appears magnified within the FOV and the FOV represents a smaller region. While the distance the scope is inserted could be marked on the canula, stretching of the interposed soft tissues prevents this from being accurate. Instead, use a standard sized object in each photo, such as a probe tip, to compensate from changes in the percent FOV because of changes in the distance of the tip from the structure of interest. By including a standard sized object, a proportion using the percent of FOV a structure occupies can be multiplied by a ratio of the standard object's percent of FOV.

Conclusion

This method of digitally mapping structures within the FOV in an *in vivo* arthroscopic image has been shown to be highly reproducible with near negligible differences between one rater's own measurements, as well as between the measurements obtained by two independent raters. As long as a standard sized object is included, precise comparisons of structure visualization can be performed to evaluate any variable involved in arthroscopy. Using the technique to obtain percentages of FOV is the ideal means for comparing visualization between different arthroscopic images while variables are changed, such as patient or scope position.

This technique has numerous potential applications. It can be applied to both medical and non-medical image for practically any purpose, including comparing visualization. For example, pathologic structures could be digitally mapped and potentially could be correlated to outcomes.

Acknowledgements

We would like to acknowledge Milo Sewards, MD and Ray Moyer, MD for review of the manuscript and use of their arthroscopic images, and Eric Isele, Nick Deimler, and Jigar Patel for their help and extensive knowledge of Photoshop.

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Gunshot Injuries to the Hand and Upper Extremity: The Financial Burden of Treatment

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Abstract

Objective: To investigate the financial burden of treating patients who suffer gunshot injuries to the hand and upper extremity at an urban Level 1 academic trauma center.

Methods: All emergency room visits at our urban Level 1 trauma center from January 1 to December 31, 2006 involving a gunshot wound injury to the hand or upper extremity in patients between the ages of 18 and 89 were retrospectively reviewed. Information on age, sex, race, occupation, insurance coverage, diagnosis, inpatient treatment, and length of stay were collected for each patient. The financial burden was calculated as the difference between charges and reimbursement collected for treatment.

Results: Fifty-eight patients were identified that met the inclusion criteria for the study. Among this group, 88% were males, 89% were unemployed, and 69% were uninsured. The average age was 29. Among the patients that were tested for the presence of illicit drugs and/or alcohol at the time of admission 68% were found to be positive for at least one form of drug or alcohol use. After evaluation, 36 patients (62%) required admission with an average length of stay was 7.9 days. Fourteen patients (24%) required surgery, one case was emergent and the remaining thirteen were semi-elective but occurred during the hospital course. The average cost of treatment for each patient was $126,039, and the average reimbursement collected was $9,285. The average surgical fee was $6563, and the average reimbursement collected was $620.

Conclusion: There was a high burden of responsibility for the treatment of gunshot injuries to the upper extremity. The majority of these injuries required an admission with an average length of stay and daily care typically for greater than a week. For their care we received less than 10% reimbursement for the cost of the admission and surgical fees for the management of gunshot wounds to the upper extremity.

Introduction

Over the past few decades, injuries due to gunshot wounds have become increasingly common in the United States.[11] Today, an estimated 500,000 bullet injuries occur each year, and the total number of American deaths claimed by gunshot wounds is four times what it was in the 1950s.[1] This increase is significant not only because of the obvious implication in loss of life, but also the remarkable financial and social burdens associated with gunshot wound injuries.[1, 4, 11, 12]

The individual effect of a gunshot wound injury will vary depending on factors such as the location of injury and extent of soft tissue damage. While gunshot wounds to the chest and abdomen are typically associated with high rates of mortality, other less lethal injuries can produce their own unique spectrum of injury and prolonged treatment by the treating surgeon. Management of gunshot injuries to the hand and upper extremity are particularly difficult due to the complex anatomy of the afflicted area often requiring the time and expertise of hand surgeons.[13]

In addition to the complexity, there is also a formidable economic burden associated with gunshot injuries to the hand and upper extremity. The purpose of this study is to investigate the financial burden associated with treatment of patients at an urban academic medical center of patients who present with gunshot injuries to the hand and upper extremity.

Materials and Methods

After appropriate Institutional Review Board approval was obtained, all emergency room admissions to our urban Level 1 academic medical center that involved gunshot wound injuries from January 1, 2006 to December 31, 2006 were retrospectively reviewed. Among this sample, patients between the ages of 18 to 89 with a gunshot injury to the hand and/or upper extremity were selected for further review. The following data was collected on each patient: age, sex, race, occupation, insurance coverage, diagnosis, inpatient treatment, and length of stay.

Insurance information was obtained from patient charts and confirmed through the billing department. Insurance coverage was separated into four categories: private, medicare, medicaid, and none. Information pertaining to inpatient treatment included admission into the intensive care unit (ICU), surgeries, and length of stay. The financial burdens of treatment were determined from charges and reimbursements obtained through the billing department.

Results

A total of 58 patients were identified with gunshot injuries to the hand or upper extremity over the designated study period. The average age was 29. Males represented 88% of the patient population, with females representing the remaining 12%. Of the patients tested for the presence of drugs and/or alcohol at the time of admission, 68% were found to be under the influence.

The gunshots resulted in a variety of fractures and soft tissue injuries including: 34 patients with fractures and 11 patients with isolated soft tissue injuries. One patient presented with a forearm compartment syndrome.

All of the 58 patients were initially evaluated by the Trauma Surgery service and the consulting Orthopaedic Hand service in the emergency room. After this evaluation, 36 patients (62%) were admitted for treatment. The average length of stay for an admitted patient was 7.9 days (range 1–29 days). Among the admitted patients, 13 (22%) required management in the intensive care unit, but only two of these patients were admitted to the ICU specifically for their gunshot wound injuries to the upper extremity. The average ICU length of stay was 6.4 days (range 1–29 days).

Fourteen patients (24%) required surgical intervention. Surgeries included wound debridements, fracture management, and soft tissue repairs. There was one case of compartment syndrome requiring an emergent fasciotomy. The remaining surgeries were performed semi-electively during the inpatient stay.

Prior to their injury, 14% of the patients were employed and 86% were unemployed. Similarly, at the time of presentation, 69% of patients were uninsured, 24% had Medicaid, 3% had Medicare, and 3% had private insurance.

The overall average cost of treatment for all patients was $126,039 (range: $2,336–$1,664,935). The average amount collected for each patient was $9,285 (range: $0–$105,065). The overall collection rate was 7.4%. For 19 patients (32%), no payment was ever received.

Looking more closely at the 14 patients that required surgical intervention by the Orthopaedic Hand service, the average fee for surgical services was $6,563 (range $1,580–$16,890). The average amount collected was $620 (range $167–$1,982). The overall collection rate was 9.4%.

Discussion

Management of gunshot injuries to the hand and upper extremity are often complex injuries due to the mechanism of injury and the complexity of the underlying anatomy.

As treating physicians, we intentionally do not avail ourselves of the financial consequences in the treatment of these difficult injuries. Yet, the gunshot-injured patient poses a unique burden.

In our series, the average gunshot-injured patient was 29 years old, male (88%), unemployed (86%), and uninsured (69%). For those with insurance (31%), Medicaid was the leading payer; Medicare and private insurance were rare (only 3% of patients each). The majority of patients tested were also positive for the presence of drugs and/or alcohol at the time of admission (68%). These statistics correspond to current literature which sites young men as the victims of gunshot wounds in up to 83% or 93% of all cases[3, 4, 12] and correlates substance abuse with gunshot wound admissions in a majority of cases.[9]

Due to the long length of stay (average = 7.4 days) and emergent care gunshot victims require, the cost of treating these injuries was high. The average cost of treatment for a patient with a gunshot wound injury to the upper extremity in our study was $126,039 per admission and the total cost of care for all 58 patients was over seven million dollars. The average reimbursement collected per patient was $9,285, leaving over 90% of the healthcare costs uncovered. Specifically focusing on the fees for surgical treatment by our physicians, we experienced an overall collection rate of only 9.4%.

This generally poor reimbursement rate is astounding and can be discouraging for physicians responsible for caring for gunshot wound victims in urban centers such as our own. Typically, physicians caring for such injuries do not avail themselves to these disparities in reimbursements; yet, especially in today's challenging economic climate, the burden of treatment of these injuries are not irrelevant and should be taken into account when determining the allocation of resources.

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Risk Factors for Compartment Syndrome in Gunshot Fractures to the Extremities

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Abstract

Gunshot injuries resulting in fractures of long bones can lead to compartment syndrome. Since the degree of soft tissue injury is unknown, fracture pattern is often analyzed as a means to determine this. It is hypothesized that increasing fracture severity, vascular injury, low initial hemoglobin, and an intubated status are risk factors for the development of compartment syndrome in this patient group. This was investigated by performing a retrospective analysis of patients with gunshot long bone fractures with compartment syndrome over a period of five years at a level 1 trauma center. Study patients were compared with matched control patients with gunshot extremity fractures without compartment syndrome. Of 416 total patients, 24 study patients were identified (overall incidence of compartment syndrome was 5.7%) and compared with 100 controls. The most important risk factor was vascular injury ($P < 0.0001$); the risk for compartment syndrome was 14.6 times greater in these patients. In addition, patients with initial hemoglobin level below 13 mg/dl were four times more likely to develop compartment syndrome than those with higher hemoglobin levels ($p = 0.0046$). Also, patients who are intubated are at greater risk than those who are not ($P = 0.0094$). Fracture severity does not correlate to an increased risk. Although initial hemoglobin and an intubated status were significant risk factors on univariate analysis, they were not significant on multivariate analysis, meaning that they are indicative of severity of other injuries.

Introduction

Compartment syndrome is a devastating condition, which, if left untreated, can lead to muscle necrosis, irreversible nerve damage, and potentially lead to amputation.[1–3] Classically, compartment syndrome develops after a severe crush injury, causing soft tissue edema with subsequent increased pressure within a compartment contained by fascial planes. However, this syndrome is also seen in other types of injuries, such as penetrating traumas that cause long bone fractures.[4, 5] While it is believed that there is less soft tissue damage in such injuries, the development of compartment syndrome indicates that there are other factors to consider.

Diagnosing compartment syndrome by its classic signs and symptoms can be very difficult in patients presenting with multiple gunshot wounds, especially in those with compromised mental status[6, 7] and therefore, a high index of suspicion is necessary. Intracompartmental pressure measurements can provide definitive diagnosis with readings >30 mmHg,[4, 8, 9] However, impending compartment syndrome does not yet have elevated pressures and often the decision to perform fasciotomy is based on clinical judgment.[4, 6] Compartment syndrome is frequently associated with crush injury or severe soft tissue injuries, as is seen in high-energy fractures, particularly in the tibia. Low velocity gunshot injuries are not usually associated with severe soft tissue injury, though compartment syndrome can occur as a complication.[5, 10]

The purpose of this study was to determine risk factors associated with the development of compartment syndrome in patients with long bone fractures due to gunshot injuries. We hypothesized that fracture pattern as well as associated injuries, vascular compromise, and hemodynamic status play important roles in the development of compartment syndrome.

Materials and Methods

Medical records of patients presenting to our inner city level 1 trauma center over the past five years were searched with the following inclusion criteria: Age 12 and older with a gunshot injury to the extremities and an extremity fracture. Patients with high velocity (i.e., rifle) or shotgun injuries and those patients who had gunshot injuries with concomitant blunt extremity fractures were excluded.

Four hundred sixteen patients were identified to meet inclusion criteria. Two groups were identified from these 416 subjects: the study group comprised 24 subjects who either developed compartment syndrome or underwent fasciotomy (prophylactic or therapeutic) for impending compartment syndrome. The second group (control group) consisted of 100 (out of 392) age and gender-matched patients with similar injury patterns, who didn't develop compartment syndrome or undergo fasciotomy. Diagnosis of compartment syndrome was made either by history and physical examination or with compartment measurements of greater than 30mmHg using handheld Styker Intra-compartment Pressure Monitoring system (Stryker, Kalmazoo, MI).

Emergency room records, operative reports, radiographic image review, and inpatient medical records were used for data collection. Fractures were classified using the AO-OTA system to include the location as well as the severity of injury. Initial vital signs, hemoglobin level, as well as amount of resuscitative fluids and units of blood given during the initial resuscitation were collected as part of the initial hemodynamic status assessment. The extent of soft tissue damage (available in eight reports) was estimated from the operative report. Presence of vascular injury was confirmed by angiography or intra-operative findings. Intubation during any part of hospitalization was recorded and used as an assessment of overall severity of injury.

Each risk factor was analyzed using univariate logistic regression analysis to determine their relationship to development of compartment syndrome. Those factors found to have statistical significance ($p < 0.05$) in univariate analysis, were further studied using multivariate analysis to determine the effect of multiple risk factors in combination.

Results

The data shows the similar demographic distribution of the study and the control groups (Table 1). The large presence of young males in the study supports the fact that this is the subpopulation that is most vulnerable to gunshot wounds. The overall incidence of compartment syndrome in gunshot fractures was 5.7%.

Table 1

Demographics	Control Group	Study Group	Total
N	100	24	416
Males	96	23	
Female	4	1	
Age (avg)	M: 96%, F: 4%	M: 96%, F: 4%	
No. of gunshot wounds	259	56	315

The data identifies the potential risk factors for development of compartment syndrome in gunshot fractures (Tables 2–4). Initial hemodynamic parameters studied have shown statistical significance in initial level of hemoglobin drawn in the emergency department (13.5 g/dL vs. 11.7 g/dL), with increased likelihood of developing compartment syndrome in patients with lower levels (Table 2). Also, there was a trend towards lower diastolic blood pressure in this group, suggesting that they are more likely to have a delta P (diastolic BP – intracompartmental pressure) greater than 30 mmHg. Although the data demonstrates similar gunshot fracture location and pattern between the two groups, and there was a greater percentage of fractures with severe communition (AO-OTA classification C3) in both groups, this was not found to be associated with compartment syndrome (Table 3). The presence of vascular injury, severe soft tissue injury and intubation during any portion of hospitalization were found to be statistically more likely in the group that developed compartment syndrome (Table 4). Presence of vascular injury had the highest odds ratio (14.637, with 95% CI = 4.768–44.937).

Table 2. Assessement of Initial Hemodynamic Status as Potential Risk Factor

Hemodynamic Status	Control Group	Study Group	p (univ)	OR (95% CI)
Heart rate (beats/min)	91	94	0.187	
Systolic BP (mmHg)	130	121	0.453	
Diastolic BP (mmHg)	74	63	0.074	
Resuscitation fluids (mL)	1977	2357	0.312	
Packed RBCs (???)	119	160	0.727	
Initial Hgb (g/dL)	13.5	11.7	0.0005	0.682 (0.549–0.847)

Table 3. Gunshot Fracture Classification (AO-OTA) and Fracture Location as Potential Risk Factor

	Control Group	Study Group	p (univ)
Fx Pattern			
A1	0.26	0.25	0.993
A2	0.06	0.125	0.254
A3	0.09	0.083	0.964
B1	0.12	0.042	0.304
B2	0.08	0.042	0.551
B3	0	0.042	0.988
C1	0.07	0.125	0.347
C2	0.02	0	0.986
C3	0.37	0.5	0.409
Fx locations			
Arm	0.2	0.083	0.24
Forearm	0.18	0.292	0.187
Thigh	0.35	0.417	0.719
Leg	0.34	0.417	0.41

Table 4. Other Associated Injuries and Assessment of Injury Severity as Predictors of Development of Compartment Syndrome

	Control Group	Study Group	p (univ)	OR (95% CI)
Vascular injury	0.18	0.783	<.0001	14.637 (4.768–44.937)
Soft tissue injury	0.12	0.33	0.013	2.224 (1.182–4.183)
Intubation	0.09	0.292	0.009	4.424 (1.441–13.579)

The parameters that were found to have significant association with compartment syndrome from the univariate analysis were further studied using stepwise multivariate analysis. When adjusted for other factors, presence of severe soft tissue injury (p = 0.0347), and vascular injury (p = 0.0005), were associated with development of compartment syndrome (Table 5). However, there is strong association between soft tissue injury and vascular injury (1.3601, SE = 0.4967), meaning that the effect of soft tissue injury was different depending on the presence of the vascular injury (Table 6). Soft tissue injury had significant association with compartment syndrome only if no vascular injury was present (OR = 13.875 (2.010–95.798), p = 0.0076).

Table 5. Multivariate Analysis of Parameters Found to Be Statistically Significant from Univariate Analysis

Parameter	OR (95% CI)	Wald Chi-Sq	p Value
Intubation	1.610 (0.325–7.969)	0.3410	0.5592
Hgb	1.809 (0.190–3.445)	0.0818	0.7749
Soft tissue injury	2.314 (1.062–5.039)	4.4604	0.0347
Vascular injury	43.491 (5.178–365.293)	12.0718	0.0005

Table 6. Interaction of Vascular Injury and Soft Tissue Damage as Risk Factors in Development of Compartment Syndrome

	Estimate	Std Error	Wald Chi-Sq	p Value
Soft tissue and vascular injuries	1.3601	0.4967	7.4974	0.0062
	OR (95% CI)			p Value
Soft tissue with no vascular injury	13.875 (2.010–95.798)			0.0076
Soft tissue with vascular injury	1.591 (0.343–7.374)			0.5529

Discussion

Penetrating injuries are a major cause of trauma activation in inner city hospitals across the United States.[10] The difficulty in treating gunshot wounds is that the relatively small entry wound may not indicate of the extent of the injury. In this regard, there have been reports of compartment syndrome developing after gunshot fractures.[5, 11] In this study, we attempt to identify parameters that are associated with the development of compartment syndrome in gunshot fractures of long bones.

A five-year retrospective case control study of patients presenting to a level one inner city trauma center with gunshot fractures has identified 24 patients who subsequently developed compartment syndrome. Parameters, such as initial hemodynamic status, fracture pattern and location, as well as presence and severity of other injuries were studied. When these parameters were analyzed independently, it was noted that lower initial hemoglobin level, intubation at any day of hospitalization, presence of severe soft tissue injury and vascular injury were found to be associated with development of compartment syndrome. However, when adjusted for other factors, the presence of vascular injury was the overwhelming predictor of compartment syndrome. Seventy eight percent of patient in the study group had a vascular injury, compared to eighteen percent in the control group. Interestingly, presence of severe soft tissue damage seems to play a role in development of compartment syndrome only in the absence of vascular injury. These two findings are not surprising as they are widely reported in the literature as risk factors of compartment syndrome.[3, 7, 11–13]

Presence of vascular injury might be indicative of different pathophysiology in the development of compartment syndrome. First, it may indicate intracompartmental bleeding leading to increased pressure. Second, as we included patients who underwent both prophylactic and therapeutic fasciotomy, it may represent patients who had prolonged ischemia time prior to vascular repair. Third, it may represent significant external blood loss, leading to hemodynamic instability, potentially lowering systemic blood pressures, and increasing likelihood to have delta P less than 30 mmHg, which according to McQueen is a better diagnostic measurement than absolute intracompartmental pressure.[8, 9] This last mechanism is supported by the lower initial hemoglobin level observed in the study group (11.7 g/dL) vs. control group (13.5 g/dL). As these values are from blood drawn initially in the emergency department, they may represent a static point in the trend towards hemodynamic instability.

We included intubation as a parameter in order to measure the extent of the overall injury in patients with multiple gunshot wounds. Additionally, it is well known that increased suspicion for compartment syndrome is necessary in these patients as they cannot communicate any neurological changes.[8, 14] In this study, there was a four-fold increase in compartment syndrome in intubated patients (4.424, 95% CI = 1.441–13.579, p = 0.009). However, in a multivariate analysis adjusted for presence of vascular injury, no significant relationship was found. Therefore, although it is more likely for intubated patients to have compartment syndrome, it appears that this is because they are also more likely to have vascular injuries.

This is the first study to investigate the risk factors in the development of compartment syndrome in gunshot fractures. We do not propose a causative relationship to the parameters identified, but simply indicate increased statistical likelihood. Presence of vascular injury was the overwhelming predictor of compartment syndrome, whereas the severity of the fracture pattern, as classified by AO-OTA, was not a significant predictor. This classification is an alphanumeric fracture classification which for long bones represents an increase in fracture severity and comminution from A1 to C3. Since highly comminuted and segmental fractures are regarded to have a concomitant higher degree of bone and soft tissue injury, we hypothesized that a higher fracture type (i.e., C3) would correlate as a risk factor for compartment syndrome. However, this was shown to be incorrect. Therefore, in patients with gunshot fractures, it appears that it is the presence of other injuries, rather than the fracture itself that predisposes them to developing compartment syndrome.

Because the pathophysiology of compartment syndrome is multifactorial, when attempting to statistically isolate each of the parameters and then study them in combination, it is important to note that some parameters might be indicators of other risk factors, rather than independent contributors. Further study with greater sample size would be necessary for a more powerful statistical analysis and maybe identify other potential risk factors. The results of this study demonstrate that vascular injuries in patients with gunshot wounds and long bone fractures warrant a greater index of suspicion for compartment syndrome. Fracture severity was not found to be a risk factor. The predictive factors of low initial hemoglobin and endotracheal tube placement are most likely reflections of the severity of the vascular injuries, rather than independently predisposing factors to compartment syndrome. However, these other factors may be considered as markers to assist in gauging the presence and severity of vascular injury.

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Distal Biceps Tendon Rupture: Outcomes and Complications of a Two Incision Technique

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Abstract

Introduction: The modified two-incision technique has long been used as a method of treatment to repair traumatic distal biceps tendon ruptures. The complications most often associated with this approach are radioulnar synostosis and atypical radial nerve palsy. In the past decade, newer methods utilizing a single anterior approach with suture anchors or endobuttons for fixation have become popular. The purpose of this paper is to present our outcomes and complications with the modified two incision technique.

Methods: Forty-four patients were identified who underwent distal biceps tendon repair using a modified two-incision technique at our institution between 2002 and 2007. Of these 44 patients that were contacted, 10 (23%) agreed to participate in the study. A retrospective review was performed of these 10 patients. Complications were noted. Patients were also asked to complete DASH surveys and return to the office for a post-operative clinical exam to assess outcome. Post-operative exams were performed to assess strength and range of motion. Patient scores in the operative arm were compared with the non-operative arm.

Results: Of the ten patients who participated, none presented with radioulnar synostosis. No patients developed nerve palsies or paresthesias. No tendon re-ruptures were noted. The mean DASH score was 3.08, with seven (70%) patients having scores under 1.0. Of those seven patients, five (71%) had perfect scores of 0. The most common problems indicated by the DASH survey were difficulties with carrying objects over ten pounds, washing the back, and opening a tight jar. Patients also indicated difficulties with recreational activities in which some force and/or impact is required by the arm, and mild difficulty sleeping as a result of pain in the arm. All ten patients were able to return to their normal pre-operative activity levels.

Seventy percent of patients demonstrated equal supination and 100% of patients demonstrated equal pronation in the repaired arm compared to the uninjured arm. Eighty percent had equal extension and 100% had equal flexion in the repaired compared to the uninjured arm. Ninety percent of patients exhibited equal or greater grip strength in the repaired arm. All ten patients demonstrated equal pronation and supination strength when comparing the repaired to the uninjured arm.

Conclusion: Despite the fact that the modified two-incision technique has been associated with radioulnar synostosis and radial nerve palsy, none of our patients developed either of these complications. The outcomes in terms of range of motion and strength compare favorably with published outcomes using the single incision technique. We feel that this method of treatment remains a good option for repair of traumatic distal biceps tendon ruptures and is our preferred method of treatment.

Introduction

Distal biceps tendon rupture is a relatively uncommon injury that most often occurs in the dominant arm of males between 40 and 60 years of age.[5, 12] The rupture typically occurs at the attachment of the tendon to the radial tuberosity.[14] Injury results most commonly from a strong contraction against resistance.[14] Although the injury is relatively uncommon, more than one method of surgical repair has been developed. In 1956, Fischer and Shepanek described the one-incision technique in which a single anterior incision centered over the bicipital tuberosity is used to gain access to the bicipital tuberosity for anchoring of the ruptured biceps tendon.[11] In 1961, Boyd and Anderson described the two-incision technique that consisted of a primary incision in the antecubital fossa and a secondary incision in the proximal lateral forearm.[3, 11] The two-incision technique became the standard for surgical repair; however, within the past decade there has been a resurgence of the one-incision technique using new technologies that have been developed.[3]

Controversy has arisen over the use of both techniques due to post-operative complications. The single-incision technique requires extensive anterior exposure to reattach the distal biceps tendon to the radial tuberosity and has been associated with radial and median nerve palsies.[3, 8] The single limited-incision technique seeks to minimize the aforementioned risks by directly repairing the tendon with the use of a suture anchor; however, concerns remain regarding the strength and durability of this modified approach. Furthermore, the use of suture anchors is technically difficult and greatly increases the cost of surgery.[8, 11] The two-incision technique described by Boyd and Anderson is also not without complications. This technique has been reported to result in radial nerve palsies, radioulnar synostosis, and soft-tissue calcification that can limit elbow range of motion.[8, 11, 12]

A modified two-incision technique was developed to avoid elevation of the anconeus muscle from the proximal ulna, which was thought to be a risk factor for radioulnar synostosis. A review of current literature, however, shows that radioulnar synostosis is still reported as a complication following the repair of the distal biceps tendon using the modified two-incision technique.[3, 8] Ideal repair of the distal biceps tendon, regardless of the method used, needs to provide strong fixation to allow early range of motion. The operative goal is restoration of elbow flexion and supination, motion, strength, and endurance.[5, 12] Neither surgical approach is without complications but each has been shown to provide the desired results.[3, 4, 8]

The purpose of this study is to evaluate the clinical outcomes and complications associated with distal biceps repair using the two-incision technique.

Materials and Methods

Approval for this study was first obtained from the Temple University Institutional Review Board. From February 2002 to February 2007, a total of 44 patients underwent surgical repair of the distal biceps tendon at Temple University Orthopaedics and Sports Medicine by the senior author (J.T.) using the modified two-incision technique. The 44 patients who where identified who underwent repair of the distal biceps tendon were first sent letters describing the project and later contacted by phone to ask for their participation. Of those 44 patients contacted who had undergone surgical repair, 10 (23%) agreed to participate in the study. Patients were required to be seen for an interview and post-operative clinical exam to assess outcome. Informed consent was obtained before participation in the study was initiated.

The patient information that was recorded included age, gender, hand dominance, side of injury, mechanism of injury, date of repair, the time between injury and repair, the need for a graft; and length of follow-up. This information was collected via chart review and inquiries during the physical examination. Ages were recorded as at the time of surgical repair.

The participants were required to return to the office for a post-operative examination that was performed by the senior author (J.T.). Data collected during this examination included a subjective questionnaire regarding patient satisfaction and a Disabilities of the Arm, Shoulder, and Hand (DASH) survey filled out by the patient. DASH scores were obtained through the approved scoring system (www.dash.iwh.on.ca). Furthermore, strength and range of motion exams of both the operative and non-operative arms were performed. Supination and pronation were scored from 0–90 degrees and extension and flexion were scored from 0 to 140 degrees. Strength of supination and pronation was scored from 0 to 5, using manual muscle testing. Finally, grip strength of both arms was measured at three different settings.

Surgical Technique

The procedure is performed with the patient in the supine position under general anesthesia. A sterile tourniquet is applied. A 3 cm transverse incision is made in the antecubital crease. The antecubital fascia is incised and any hematoma is evacuated. Digital exploration proximally delivers the distal end of the avulsed tendon into the wound. The tendon end is then debrided of any fibrinous adhesions and secured with a #2 ethibond suture in a Krakow fashion. The path of the biceps tendon to the radial tuberosity is then developed by blunt dissection. The radial tuberosity is palpated with the forearm fully supinated and a hemostat is passed along the path to contact the tuberosity on the midline side of the radius. The forearm is then flexed and fully pronated as the hemostat is advanced toward the lateral aspect of the proximal forearm. The tip can be palpated on the lateral aspect of the forearm and a longitudinal incision is placed in this location. The interval between the extensor digitorum and the extensor carpi ulnaris is developed to expose the supinator muscle. The supinator is then split in line with its fibers to expose the tip of the long hemostat and the radial tuberosity. Maintaining the forearm in full pronation and elbow flexion, the tuberosity is debrided and a trap door is developed to accept the tendon. Two drill holes are fashioned in the radius just lateral to the trap door and the medullary bone within the trough is removed with a curette. A 14-gauge catheter is then passed retrograde using the long hemostat and delivered into the anterior wound. The sutures securing the biceps tendon are then passed around the radius and into the lateral incision. The sutures are passed into the trough and out the drill holes with the aid of a wire loop. The tendon is pulled until it is seated within the trough and secured.

Results

All ten patients who participated in the study where males who ranged in age from 39 years old to 66 years old (mean age of 51.7 years). All of the patients were right hand dominant. Time between injury and repair ranged from four days to 91 days (mean of 28 days).

Eight (80%) of those patients injured the dominant arm, while only two (20%) injured the non-dominant arm. Eight (80%) patients described their mechanism of injury as resulting from strenuous activity, six of whom had been performing lifting activities against strong amounts of resistance.

One patient described the injury as a result of a swinging motion, while another patient described the injury as a result of performing pull-ups. Four (40%) of the patients underwent surgical repair within seven days of the injury, while six (60%) underwent repair greater than seven days after the injury. The two patients who had the longest time between injury and repair (90 and 91 days) had this delay in treatment because of a late initial presentation to our office. The average length of follow-up was 42.2 months, with the minimum being 18 months and the maximum being 72 months.

Table 1 shows the results of the DASH scores. The mean DASH score was 3.08, with seven (70%) patients having scores under 1.0. Of those seven patients, five (71%) had perfect scores of 0.0. The most common problems indicated by the DASH survey results were difficulties with carrying objects over ten pounds, washing the back, and opening a tight jar. Patients also indicated difficulties with recreational activities in which some force or impact is required by the arm and mild difficulty sleeping as a result of pain in the arm. When patients were subjectively asked if they were to injure the healthy arm in the same way, would they have the surgery performed again, all patients expressed satisfaction and would undergo repair again. All ten patients were able to return to their normal pre-operative activity levels.

Table 2 shows the results of the strength and range of motion examinations. The patient's injured arm was compared with the uninjured arm. 70% of patients showed equal or better supination and 100% of patients showed equal or better pronation in the repaired compared to the healthy arm. 80% of the participating patients showed equal or better extension and 100% of patients showed equal or better flexion in the repaired compared to the healthy arm. Furthermore, 80% of patients exhibited equal or greater grip strength at the lowest setting. Of the two patients that did not display equal or better grip strength, one injured his non-dominant arm which accounts for the healthy arm showing greater grip strength and the other patient had since undergone additional surgery in the operative arm for an unrelated issue. 90% of patients exhibited equal or greater grip strength at the intermediate setting compared to the healthy arm. Finally, 90% of patients exhibited equal or greater grip strength at the highest setting compared to the healthy arm. All ten patients exhibited equal pronation and supination strength compared to the healthy arm.

Table 1

Patient #	Age	Gender	Hand Dominance	Arm/Mechanism of Injury	Time Between Injury and Repair (Days)	Graft ?	Follow-up (Months)	DASH Score	Patient Satisfaction
1	47	male	right	R, strenuous work	90	no	40	7.5	yes
2	39	male	right	L, heavy lifting	14	no	30	0.0	yes
3	46	male	right	R, swinging motion	91	no	60	0.0	yes
4	50	male	right	R, strenuous activity	5	no	72	0.0	yes
5	63	male	right	L, heavy lifting	4	no	28	0.0	yes
6	66	male	right	R, heavy lifting	12	no	36	0.0	yes
7	59	male	right	R, heavy lifting	7	no	18	5.0	yes
8	50	male	right	R, heavy lifting	28	no	30	0.8	yes
9	54	male	right	R, heavy lifting	4	no	48	0.8	yes
10	43	male	right	R, pull-ups	28	no	60	16.7	yes

Table 2

Patient #	Supination (Control)	Supination (Operative Arm)	Pronation (Control)	Pronation (Operative Arm)	Flexion (Control)	Flexion (Operative Arm)	Extension (Control)	Extension (Operative Arm)	Grip I (Control)
1	75	75	90	90	140	140	0	0	60
2	90	90	90	90	140	140	0	0	100
3	90	85	90	90	140	140	5	10	60
4	85	85	90	90	140	140	0	0	90
5	75	75	85	85	130	135	10	0	70
6	85	70	85	85	140	140	0	10	40
7	85	85	85	85	140	140	0	0	40
8	85	85	85	85	140	140	0	0	55
9	85	85	85	85	140	140	0	0	80
10	85	80	85	85	140	140	0	0	90

Of the ten patients who participated, none presented with radioulnar synostosis. Also, no patients developed any nerve palsies or paresthesias. No tendon re-ruptures occurred.

Discussion

Ruptures of the distal biceps tendon most often occur in the dominant arm of middle aged men.[11] Surgical repair offers the best recovery results; however, the modified two-incision technique has been associated with radioulnar synostosis and radial nerve palsy.[8, 12] On the other hand, the one-incision technique has been associated with complications such as radial and median nerve palsies.[9, 15] In this study, all ten patients underwent repair using the two-incision technique. Our study has sought to prove that the results of the two-incision technique are no worse if not better than those associated with the one-incision technique.

In the study done by McKee et al., the mean DASH score for the one-incision technique was 8.2, while the mean DASH score for the ten patients participating in this study was 3.08, which is better than the mean for the population (mean score is 6.2).[11] The mean flexion and extension for our patients was 139.5° and 2.0°, respectively, which shows normal range of motion in the repaired arm. In the McKee study, the mean flexion was 137.0° and the mean extension was 2.0°.[11] Thus, our results for post-operative range of motion are similar to those in the McKee study where a one-incision technique was used.

Heterotopic ossification has been associated with the two incision technique in the past and is thought to be a result of subperiosteal exposure of the ulna with the second incision.[4] None of the patients who participated in our study presented with heterotopic ossification and only one patient presented with significantly lower supination (70°) in the repaired arm compared to the healthy arm (85°). In the study by El-Hawary, one of nine patient developed heterotopic ossification with the use of a single anterior incision technique while no patients in their study of the ten who underwent the two incision technique developed heterotopic ossification.[4] In the study by John where a single incision repair with use of suture anchors was used to treat acute distal biceps ruptures, two of 53 patients developed heterotopic ossification that resulted in some loss of forearm rotation and mild pain.[6]

The modified Boyd and Anderson approach for repair has also been documented in the literature to result in occasional radioulnar synostosis which would lead to a decrease in range of motion.[14] None of our patients developed radioulnar synostosis. On the other hand, posterior interosseous nerve palsies have been associated with the one incision technique.[14] In our study, no patients developed post-operative nerve palsies with the two incision technique. In the study by El-Hawary, three of nine patients in the one incision group developed cases of lateral antebrachial cutaneous nerve parestheias which resolved without intervention and one patient out of ten in the two incision group developed a transient superficial radial nerve paresthesia likely due to post operative splint pressure.[4] In the study by John, one patient of fifty-three developed a temporary radial nerve palsy after repair using a one incision technique.[6]

All patients in our study expressed satisfaction in the outcome of the surgical repair. When asked if the same circumstances arose again in which they ruptured their distal biceps tendon, all responded that they would undergo the same surgery again. We believe the modified Boyd and Anderson two-incision method of repair remains a good alternative to the one incision technique in that complications have been minor and return to post-operative function is at least as good as the one incision technique.

Table 2 ***(Continued)***

Grip I (Operative Arm)	Grip III (Control)	Grip III (Operative Arm)	Grip V (Control)	Grip V (Operative Arm)	Supination Strength (Control)	Supination Strength (Operative Arm)	Pronation Strength (Control)	Pronation Strength (Operative Arm)
60	110	110	50	80	5	5	5	5
100	150	150	110	115	5	5	5	5
60	140	140	120	100	5	5	5	5
95	130	130	80	100	5	5	5	5
65	120	120	60	90	5	5	5	5
60	85	85	70	75	5	5	5	5
60	100	100	70	80	5	5	5	5
55	117	117	75	85	5	5	5	5
95	125	125	85	90	5	5	5	5
85	130	130	90	110	5	5	5	5

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Community Acquired Methicillin-Resistant *Staphylococcus aureus* Infections of the Hand: Prevalence and Timeliness of Treatment

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Abstract

Purpose: The prevalence of community-acquired Methicillin-Resistant Staphylococcus aureus (ca-MRSA) appears to be increasing, but the timeliness of appropriate antibiotic administration is often delayed. We retrospectively reviewed the prevalence of ca-MRSA infections in an urban setting and evaluated the effectiveness of implementation of a formal hand infection treatment algorithm in improving the timeliness of appropriate antibiotic delivery and reduction of length of stay.

Methods: We retrospectively reviewed all visits for a hand infection to the emergency room of an urban academic medical center over a 12 month period. A formal hand infection algorithm was used in the treatment of each patient. All patients with culture-positive hand infections were included for evaluation. Infections determined to be nosocomial or not community-acquired were excluded.

Results: 85 patients (65% male, 35% female) with an average age of 39 years met the inclusion criteria. The overall prevalence rate of ca-MRSA hand infections was 55%. With implementation of our algorithm, the average delay to appropriate antibiotic delivery for ca-MRSA infection was 0.49 days, versus 0.11 days for non-MRSA infections ($p > 0.05$). The average length of stay was 4.0 days for ca-MRSA infections and 3.5 days for non-MRSA infections ($p > 0.05$).

Conclusions: ca-MRSA infections of the hand continue to increase in urban settings. By implementing a formal hand infection treatment algorithm, the delay to appropriate antibiotic treatment, length of stay, and the associated costs of treatment can be reduced.

Introduction

Community acquired methicillin-resistant *Staphylococcus aureus* (ca-MRSA) has become an increasingly more prevalent pathogen in soft tissue infections (Figure 1).[1] Much has changed since Karanas et al. and Connolly et al. published case reports in 2000 describing uncommon ca-MRSA infections of the hand.[2, 3] More recent reports have documented alarmingly high rates of ca-MRSA infections of the hand within the general population.[4–7]

The high prevalence of MRSA infections within the community has important implications on empiric antibiotic use and surgical treatment.[9] Given the growing prevalence of ca-MRSA infections, we instituted a formal hand infection treatment algorithm in order to improve the treatment of hand infections. The goal of this study was to determine the current prevalence of ca-MRSA infections of the hand at our urban academic medical center and examine the timeliness of appropriate antibiotic treatment with use of our treatment algorithm in order to maximize outcomes and minimize treatment delays and length of stay.

Figure 1. ca-MRSA infection of the hand.

Materials and Methods

A formal hand infection treatment algorithm was introduced in 2006 and was used in the management of all hand infections seen in the emergency room of our urban academic medical center in 2007 and onward (Figure 2).[5] All patient visits to the emergency room were retrospectively examined for a 12-month period, January 1–December 31, 2007. Institutional review board approval was obtained prior to beginning the study. All patients with International Classification of Disease (9th revision) codes relevant to hand infections during the 12 months were collected. These included the following ICD-9 diagnoses: cellulitis/abscess, septic tenosynovitis, and open wounds of the finger, hands or wrist. Over 500 patients were identified.

The inclusion criteria was any hand infection patient seen in our emergency room during the review period who was an (1) adult between the ages of 18 and 89 and had (2) a "culture-proven" hand infection, (3) was admitted for treatment, (4) did not have a history of a previous MRSA infection, and (5) did not have a possible nosocomial source (i.e., a history of a surgical procedure, dialysis treatments, any catheterizations, or hospitalization including nursing home stays within the past year).

Results

A total of 85 culture-proven community-acquired hand infections were identified over the 12-month period that met our inclusion criteria. Forty-seven, or 55%, were found to be ca-MRSA hand infections. Thirty-eight, or 45%, were found to be non-MRSA infections. The non-MRSA infections included: 15 MSSA, 8 coagulase-negative Staphylococcus aureus, three Streptococcus species, and 12 other infectious organisms.

Of the 85 patients, 55 were male (65%) and 30 were female (35%). The average age was 37 in the ca-MRSA group and 42 in the non-MRSA group. Univariate Analysis assessing individual risk factors such as age, sex, occupation and their association with MRSA did not show that any specific diagnosis was predictive of MRSA. Interestingly however, it appears that an open wound may be protective against MRSA

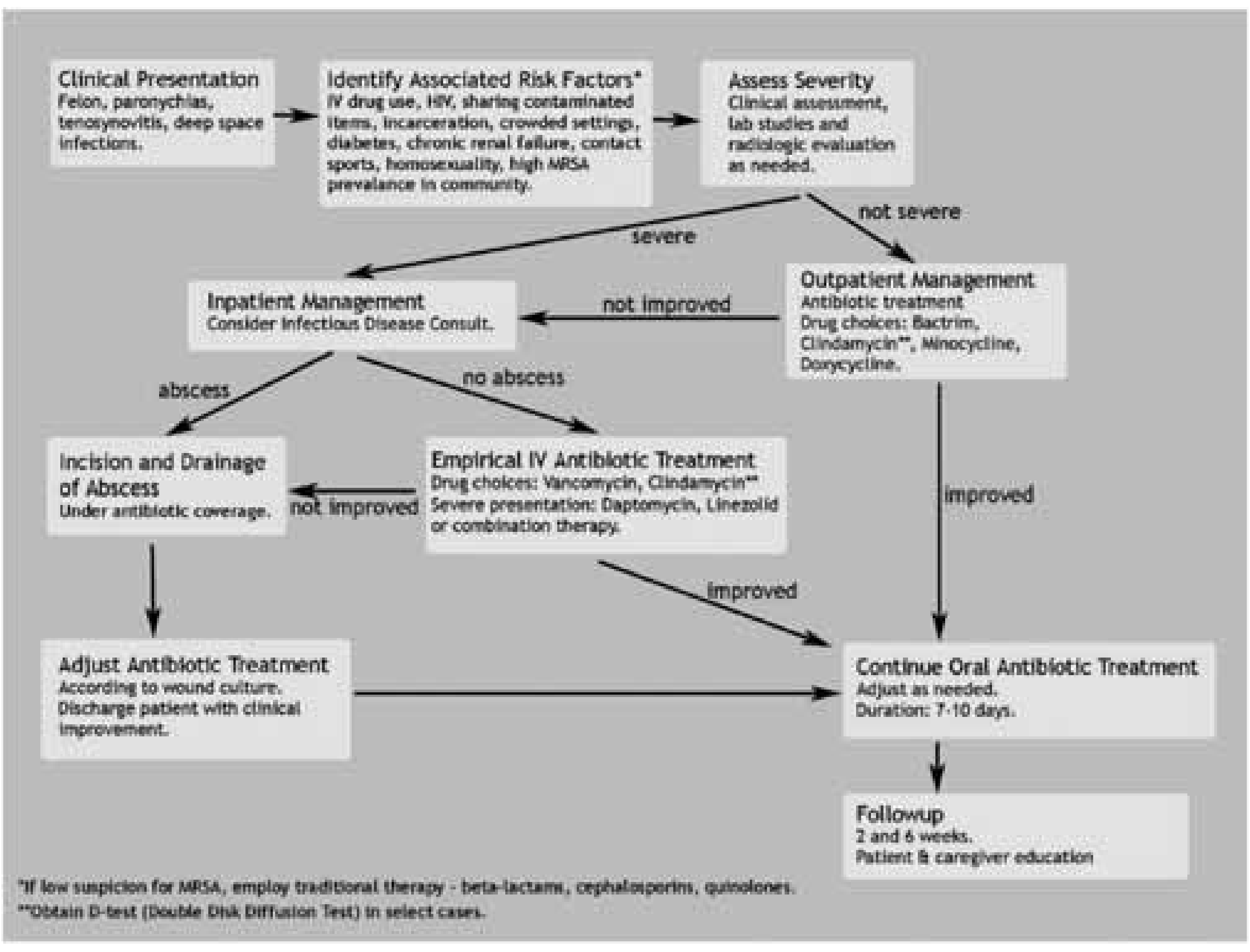

Figure 2. Hand infection treatment algorithm (adapted from Kiran et al. *Plast Reconstr Surg.* 2006;118(1):164).

with a relative risk reduction of 81%. The most common mechanisms of injury were laceration (19%), puncture (14%), and human/fight bite (11%). There was no significant association between mechanisms of injury and subsequent infection with MRSA. The average length of stay was 4.0 days for the ca-MRSA group and 3.5 days for the non-MRSA group ($p > 0.05$).

By following our hand infection algorithm, 41 of the 47 patients with ca-MRSA infections (87%) were treated with empiric antibiotics sensitive to the cultured organism. In comparison, 37 of 38 patients with non-MRSA infections (97%) were treated with empiric antibiotics ultimately found to be sensitive for the cultured organism. The days until proper treatment were significantly different between the two groups. The mean days until appropriate antibiotic treatment for the non-MRSA group was 0.11 days, while the mean days for treatment of the ca-MRSA group was 0.49 days ($p > 0.05$).

Discussion

Methicillin resistance first appeared as noscomial staphylococcus aureus infections in 1961, just one year after the introduction of the semi-synthetic penicillin class that included methicillin.[11] Over the last decade, MRSA has emerged in the community in otherwise young and healthy individuals with no healthcare associated risk factors.

Carriers of ca-MRSA have an increased risk of developing infections, but can remain asymptomatic and act as a reservoir for transmission of the organism.[10] Risk factors for ca-MRSA include: antibiotic use within the previous year; close and crowded living conditions; compromised skin integrity; contaminated surfaces, frequent skin-skin contact, shared items (towels, whirlpools, sports equipment); and inadequate cleanliness.[14] At-risk groups for ca-MRSA infections include: athletes in contact sports, military recruits, children in day care, homeless persons, IV drug users, men who have sex with men, prison inmates, and minorities.[14]

As the prevalence of ca-MRSA in soft tissue infections has grown so has its involvement in the hand, and perhaps even to a greater extent. Literature on ca-MRSA of the hand is limited, but recent reports confirm an increasing prevalence.[4–7] Kiran et al. performed a retrospective review of 343 hand infections at our institution from 2003–2005.[5] The incidence of ca-MRSA infections in 2003 was 14% and climbed to over 40% in 2005. Furthermore, they noted that by dividing their series into 7-month intervals that there was an increased prevalence with each interval with the largest increase in prevalence occurring in the beginning of late 2004 into 2005. Similarly, Bach et al. performed a prospective review of hand infections at their institution from March to December 2005 and identified a prevalence of 73.1% for ca-MRSA in culture-proven hand infections.[7] A recent retrospective study from LeBlanc et al. retrospectively reviewed charts from 2001–2003 on finger and hand abscesses.[6] The group identified 761 patients with 436 cultures. They identified an increasing incidence of MRSA infections from 34% in 2001, 46% in 2002, and eventually 61% in 2003. After retrospective review of all culture-proven community-acquired hand infection cases in the year 2007 at our institution we identified a prevalence of 55% for ca-MRSA infections. This represents a continued increase in ca-MRSA hand infections from 18% in 2003 and 41% in 2004 from the same institution.[5]

Based upon our study, there is an increasing prevalence of ca-MRSA in our urban community with a prevalence of 55% in 2007. Also, while using the same inclusion criteria as Kiran et al., we identified 47 ca-MRSA hand infections over 12 months in 2007 versus 75 ca-MRSA over 21 months from 2003–4 in the Kiran et al. series.[5] This continues to support the high prevalence of ca-MRSA hand infections identified recently in most urban community series studying infections of the hand.[5–7]

In light of the growing prevalence, associated morbidity, and high cost of treatment we implemented a formal hand infection treatment algorithm to improve the care of these infections and reduce the associated costs. The algorithm was introduced by Kiran et al.[5] The algorithm was made in consultation with our Infectious Disease specialists and analyzed the known prevalence and local antibiotic sensitivities to ca-MRSA infections. The algorithm emphasized three points: (1) that the prevalence of ca-MRSA hand infections will be high since risk factors are common in urban communities, (2) empiric antibiotics must be tailored to expected sensitivities to ca-MRSA infections of the hand, and (3) hand infections must be treated aggressively with both appropriate empiric antibiotics and early surgical incision and drainage. Upon admission to the emergency room the infection is assessed and labs are drawn. An incision and drainage is performed whenever possible in the emergency room prior to the administration of antibiotics. Empiric antibiotic treatment is initiated with either intravenous Vancomycin or Clindamycin (alternative includes Daptomycin). If the infection is deemed appropriate for outpatient management then the antibiotics are switched to oral Clindamycin or Bactrim (alternative includes Minocycline).

To the best of our knowledge, only the study by Downs et al. examined time to appropriate antibiotic delivery for ca-MRSA infections of the hand.[4] They retrospectively identified 32 patients with culture proven hand infections who received antibiotics for treatment over a three-year period. Cultures confirmed MRSA infections in 34% of patients and appropriate antibiotic treatment was found to be delayed with statistical significance. The non-MRSA hand infections received appropriate antibiotics at an average of 0.4 days, but MRSA infections required 2.2 days until antibiotics with appropriate sensitivity were administered.[4]

Our data was retrospectively drawn after implementation of our hand infection algorithm and we observed improvement in appropriate early antibiotic delivery. In the ca-MRSA group the delay to appropriate antibiotic delivery was 0.49

days, as compared to 0.11 days in the non-MRSA groups. Similarly, our length of stay in the ca-MRSA group was 4.0 days, as compared to 3.5 days in the non-MRSA group.

This study has several limitations. First, it is retrospective. Second, despite diligent chart review some nosocomial cases may have been misclassified as community-acquired, or vice-versa. In addition, the accuracy and technique by which cultures are drawn are operator-dependent and it is possible that in some cases the index cultures were taken by members of the emergency department. But the strength of this study is its illustration of how a formal hand infection treatment algorithm that takes into account local antibiotic sensitivities can improve early appropriate antibiotic delivery and avoid prolonged length of stay.

In conclusion, there is a continued high prevalence of ca-MRSA hand infections in urban settings. Risk factors for ca-MRSA hand infections include IVDA and a WBC > 8.7 at presentation. By implementing a formal hand infection treatment algorithm we were able to decrease the delay to appropriate antibiotic treatment, improve our length of hospital stay, and improve the overall quality of care for infections of the hand. We recommend an aggressive approach to hand infections and the institution of treatment algorithms that takes into consideration the local prevalence of ca-MRSA infections. Further work is necessary to validate our algorithm and improve the quality of care for ca-MRSA infections of the hand.

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Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

The Incidence of Radiocarpal Dislocations

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Abstract

Introduction: Radiocarpal dislocations are uncommon injuries but their incidence is not well established. We retrospectively reviewed all distal radius fractures and wrist dislocations over a five-year period to define the overall incidence.

Methods: The radiographs of all patients presenting to the emergency department of a level 1 academic trauma center with a diagnosis of a distal radius fracture (ICD-9 code 813) or wrist dislocation (ICD-9 code 833) over a consecutive five-year period, from 2003–2007 were reviewed. A radiocarpal dislocation was defined as a dislocation or subluxation of the entire carpus of the hand relative to the distal radius.

Results: Over the five-year study period a total of 12 radiocarpal dislocations were identified. All were the result of high-energy injuries. The annual incidence for each of the five years was: 5.7%, 1.2%, 1.4%, 2.9%, and 2.2%. A fracture was identified in 10 cases while two were strictly soft tissue injuries. A dorsal-directed dislocation was identified in 83% of cases.

Conclusions: The five-year incidence of radiocarpal dislocations was 2.7%. The average annual incidence was 2.5%. These injuries occur most often in young males from high-energy mechanisms of injury. Dorsal was the most common direction of displacement. An associated fracture was identified in 83% of cases.

Introduction

Radiocarpal dislocations are wrist injuries defined as a dislocation of the radiocarpal joint, with or without associated fractures of the distal radius. The radiocarpal joint is composed of the radius and the three proximal row carpal bones — the scaphoid, lunate, and triquetrum. The dislocation of the carpus relative to the radius may occur in either a dorsal or volar direction and may represent solely a soft tissue injury or it can be associated with fractures of the distal radial cortical rim, radial styloid, or ulnar styloid.[1] Prior to Pouteau and Colles, dislocations were considered the preeminent wrist injury.[2] However, a review of the literature reveals that radiocarpal dislocations are rare injuries, estimated by Dunn to be as uncommon as 0.2% of all dislocations.[3] Not many large series exist and the reports found in the literature review consist primarily of case reports.[4–15] To the best of our knowledge no recent series has examined the modern incidence of radiocarpal dislocations.

The purpose of this study is to investigate the incidence of radiocarpal dislocations at an urban academic medical center and to examine associated patient demographics and risk factors.

Materials and Methods

After appropriate Institutional Review Board approval was obtained, a retrospective review of all radiographs of patients, between the ages of 18 to 89, presenting with a diagnosis of a "distal radius fracture" (ICD9 code 813) and "wrist dislocation" (ICD9 code 833) to the emergency room of our urban academic medical center over a five-year period (January 1, 2003 to December 31, 2007) was performed. Only initial and/or pre-reduction radiographs were examined.

Radiocarpal dislocations were defined as a dislocation or subluxation of the entire proximal carpal row relative to the distal radius. The dislocation was noted as Type 1 if there were no associated fractures (Figure 1). The dislocation was noted as Type 2 if associated with a fracture (Figure 2). All radiographs were examined by the senior author (AI) for determination of the presence of a radiocarpal dislocation. In addition, patients determined to have a radiocarpal dislocation had their charts examined for associated demographic information, mechanism of injury, and associated injuries.

Results

During the five-year study period, 12 radiocarpal fracture dislocations were identified (Table 1). These cases were identified from a total of 438 patients that presented with a diagnosis of a distal radius fracture or wrist dislocation resulting in an overall incidence of 2.7%. The annual incidence was 5.7% in 2003, 1.2% in 2004, 1.4% in 2005, 2.9% in 2006, and 2.2% in 2007, resulting in an overall annual incidence of 2.5%.

Figure 1. A Type 1 Radiocarpal Fracture-Dislocation depicting a dislocation without a fracture.

Figure 2. A Type 2 Radiocarpal Fracture-Dislocation depicting the dislocation with a fracture.

Table 1. Yearly Incidence of Radiocarpal Dislocations at TUH

	Year				
	2003	**2004**	**2005**	**2006**	**2007**
Incidence	5.7% (5/88)	1.2% (1/85)	1.4% (1/71)	2.9% (3/105)	2.2% (2/89)

There were two Type 1 dislocations and 10 Type 2 dislocations. Among the Type 2 dislocations, there were three fractures of the ulnar styloid, four of the radial styloid, and six involving the marginal rim of the radius. Three patients experienced a combined injury with both a radial styloid and ulnar styloid fracture.

The injury was more common in males (11 of 12 dislocations; 91.7%) and most prevalent in the 20–40 age group (10 of 12; 83.3%). The incidence of dorsal dislocations was also more common than volar (10 of 12; 83.3%). The mechanisms of injury included four motor vehicle accidents (MVA), four motorcycle accidents (MCA), one fall from a height, and 1 assault.

Discussion

Radiocarpal dislocations represent a high-energy shear and rotational injury to the wrist with or without an associated fracture. These injuries must be differentiated from Barton's fractures of the distal radius. Barton's fractures are compression injuries where the articular surface of the involved radius remains in continuity with the proximal carpal row by the intact volar radiocarpal ligaments.[1] In contrast, fractures associated with radiocarpal dislocations are typically smaller cortical rim and/or styloid fractures.

We identified an overall incidence of 2.7% of radiocarpal dislocations among all distal radius fractures and wrist dislocations over a five-year period. Although still an overall uncommon injury pattern, an incidence of 2.7% was higher than the 0.2% often noted by Dunn.[3] We would suggest two possibilities for our difference in incidence. The first is a matter of definition. The definition and subsequent diagnosis of a radiocarpal dislocation can be easily confused with a "high" or "very distal" distal radius fracture and/or Barton's fracture of the radius. Similarly, we recognized during the review of our series that associated radial and ulnar styloid fractures required particular scrutiny to evaluate the possibility of these fractures representing avulsion injuries due to the shear mechanism with resultant radiocarpal subluxation. The second possibility to explain our difference in incidence is the denominator. Dunn identified an overall incidence of 0.2% but used all dislocations of the hand and wrist as the denominator.[3] However, the paper did not include sufficient data to allow for the incidence to be recalculated according to our formula. His data did, however, show that dislocations of the entire carpus did account for 15% (6 of 40) of carpal dislocations in his study. It was the third most common behind "transnavicular perilunate dislocations" (27.5%) and dislocations of the lunate (17.5%).[3]

In short, we identified an overall incidence of 2.7% for radiocarpal fracture-dislocations. This is much higher than what has previously been reported in the literature. Associated fractures of the marginal rim, ulnar, or radial styloid are common. This injury is most often seen in young men involved in high-energy trauma and most often results in a dorsal dislocation of the carpus.

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Musculoskeletal Medicine: The Disparity Between Education and Practice

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Abstract

Introduction: Despite the growing prevalence of musculoskeletal problems in the general population our medical students appear to receive inadequate musculoskeletal medical education. The purpose of this study is to quantify the amount of time spent on musculoskeletal education at our institution during the pre-clinical and clinical years and contrast it to the time in terms of volume that musculoskeletal medicine represents to general medical and surgical services in actual clinical practice in order to better understand the disparity and guide future curriculum improvements.

Methods: During the 2007–2008 all required musculoskeletal pathology coursework during the pre-clinical years and required musculoskeletal rotations in the clinical years was measured in order to evaluate the standard musculoskeletal education. Similarly, musculoskeletal demands of a general medical practice was examined and measured by the number of referrals given for Orthopaedic Surgery specialists by the Internal Medicine and Family Practice department. In addition, the orthopaedic surgical volume was measured and compared against the overall surgical volume.

Results: During the pre-clinical years, 6% of the time was spent studying musculoskeletal conditions. During the clinical years, There were no required rotations specifically in Orthopaedic Surgery, Physical Medicine and Rehabilitation or Rheumatology. Yet, in terms of clinical volume, General Surgery represented 36% of inpatient and 26% of outpatient surgical cases while Orthopaedic Surgery represented 20% of inpatient and 22% of outpatient cases.

Conclusion: The disparity between musculoskeletal education in medical schools and the actual practice of musculoskeletal medicine in clinical practice is high. This disparity warrants a re-evaluation of our medical school curriculum to better prepare our future physicians in the management of the musculoskeletal medicine that they will be required to treat.

Introduction

Despite the prevalence of musculoskeletal problems in the general population, graduating allopathic physicians are unprepared to diagnose and treat these conditions.[4, 11, 14] Musculoskeletal conditions are common in all age groups. In the geriatric population, joint diseases make up half of all chronic conditions.[10] Within the general population, musculoskeletal complaints are the primary reason for outpatient visits.[2] Studies have found that among the pediatric population, ages 3–14, musculoskeletal examinations made up 6% of overall visits, making them one of the most common causes of non-routine visits. Non-routine visits accounted for only 30% of total pediatric visits. This increases in importance as the population ages.[5, 6] Fundamental knowledge of musculoskeletal medicine is essential for most practicing physicians despite their specialty.

Studies have shown that graduating medical students and residents are not well prepared to handle musculoskeletal ailments. When given examinations approved by internal medicine and orthopedics residency directors, the majority of participants failed.[4, 8, 9,11, 13] The pass rates ranged from 18 to 26%. Students that received more required musculoskeletal education or participated in additional musculoskeletal electives performed better.[11, 14] Students of osteopathic schools, which tend to have a greater focus on the study of the musculoskeletal system, were more confident than their allopathic counterparts in their ability to diagnose and treat common musculoskeletal ailments.[3]

While there is a significant amount of time spent handling musculoskeletal ailments in the general practice, few medical schools have required pre-clinical courses or clinical rotations in musculoskeletal medicine.[7] The purpose of this study is to quantify the amount of time spent on musculoskeletal education at our institution during the pre-clinical and clinical years and contrast it to the time in terms of volume that musculoskeletal medicine represents to general medical and surgical services in actual clinical practice in order to better understand the disparity and guide future curriculum improvements.

Materials and Methods

After appropriate Institutional Review Board approval was obtained, the medical school curriculum and clinical practice in musculoskeletal medicine was examined over a one year period, July 1, 2007 to June 30, 2008, at our academic medical center. Specifically, the required musculoskeletal pathology coursework during the pre-clinical years and required musculoskeletal rotations in the clinical years was measured in order to evaluate the standard musculoskeletal education. Similarly, musculoskeletal demands of a general medical practice was examined and measured by the number of referrals given for Orthopaedic Surgery specialists by the Internal Medicine and Family Practice department. In addition, the orthopaedic surgical volume was measured and compared against the overall surgical volume.

In order to quantify the time spent learning musculoskeletal related topics in the Temple University School of Medicine's (TUSM) pre-clinical curriculum, the second year Pathology course curriculum was examined. TUSM uses a block system. Pathology is spread out over several blocks during the second year with one block specifically focusing on the musculoskeletal and nervous systems. In the musculoskeletal and nervous systems block, the hours designated to musculoskeletal topics were counted. We also looked at the time devoted to other major topics within the musculoskeletal and nervous systems block. Similarly, all second year course blocks were evaluated and the total number of teaching hours per discipline determined. Hours that were not related to pathology topics were not included in the data. The course information was based on the 2007–2008 curriculum and was obtained from the curriculum department.

For quantification of the clinical hours spent in musculoskeletal medicine at TUSM, only mandatory clerkships during third and fourth year were considered. All information from third and fourth year was combined into one set of data due to the related nature of the coursework. Elective rotations and sub-internships are not reflective of the education of the entire student population as a whole and were excluded from the data. The number of weeks spent on required musculoskeletal rotations, including Orthopaedic Surgery, Physical Medicine and Rehabilitation, and Rheumatology, was compared to the number of hours spent in other required rotations. The percentage of fourth year TUSM students that participated in Rheumatology, Physical Medicine and Rehabilitation and Orthopedic Surgery electives in the 2007–08 school year were included in order to evaluate the exposure to musculoskeletal medicine in the clinical years.

Overall volume of musculoskeletal medicine within a general clinical practice setting was determined via several variables. First, the total number of referrals given by the Temple University Hospital's (TUH) Internal Medicine and Family Practice department to the Orthopedic Surgery department was measured. This information was drawn from the department's referral database of all of their managed care patients. Second, the total number of inpatient and outpatient surgical procedures performed at TUH was measured. These figures were obtained from TUH Surgical Services.

The values for educational and clinical exposure were expressed as percentages and raw values. We used descriptive statistics in order to make comparisons between time spent in each category.

Results

During the pre-clinical education, musculoskeletal medicine was taught in the "musculoskeletal and nervous systems" block. This was a six week course consisting of a total of 100 teaching hours designated to specific topics. Specifically, 28 hours were spent studying musculoskeletal conditions. The rest of the course focused on psychiatric and neurological disorders, for 33 and 22 hours respectively. Seventeen hours were spent on topics that did not fit either categories. The additional clinical disciplines and associated teaching hours are outlined in Figure 1.

Immunology/Virology was the largest pre-clinical discipline, encompassing 23% the preclinical curriculum. Other major block topics included cardiology and pulmonary medicine, hematology and oncology, gastrointestinal, renal and endocrine systems. All of these components received a greater number of curricular hours than musculoskeletal medicine, but we did not find a statistical significance ($p > 0.05$) in the number of hours allotted for each discipline, except for immunology/virology ($p < 0.05$). There were also a total of 44 hours that did not fit into any of the broad categories. This was included as "Other" in Figure 1. It encompassed anesthesia, analgesics, chromosomal disorders, genetic disorders of metabolism, heavy metal and environmental toxicities, herbal medicine, pediatric and geriatric pharmacology, diseases of childhood and infancy, forensic pathology, diseases of the male genitourinary tract and prostate, dermatopathology and pathology reviews. Introductions, lab testing information and pharmacology reviews that were not disease oriented were excluded.

During the clinical years, required clinical rotations included Internal Medicine, General Surgery, Family Medicine, Obstetrics and Gynecology, Pediatrics, Psychiatry, Radiology, Anesthesia, Intensive Care, and Emergency Medicine. The total time in weeks, shown as a percentage of all required rotations, spent on each rotation is illustrated in Figure 2. The rotations ranged from 1–12 weeks in length with Internal Medicine being the longest at 12 weeks and Anesthesiology being the shortest at one week. Psychiatry, Pediatrics, Obstetrics/Gynecology and Family Medicine were each six weeks in length. Radiology, Emergency Medicine and Neurology were each four weeks in length. Intensive Care was three weeks in length. The General Surgery rotation was eight weeks long and did not include time on Orthopaedic Surgery. There was a required four-week surgi-

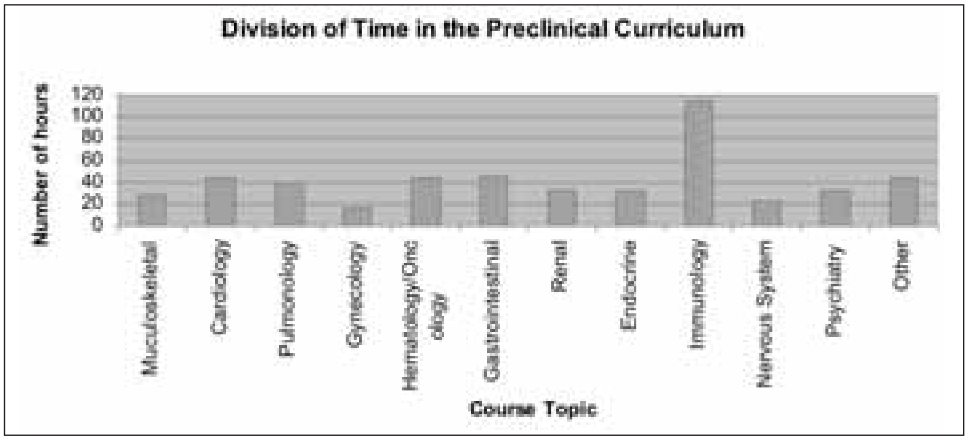

Figure 1. Division of time in teaching hours spent on all pre-clinical discipline.

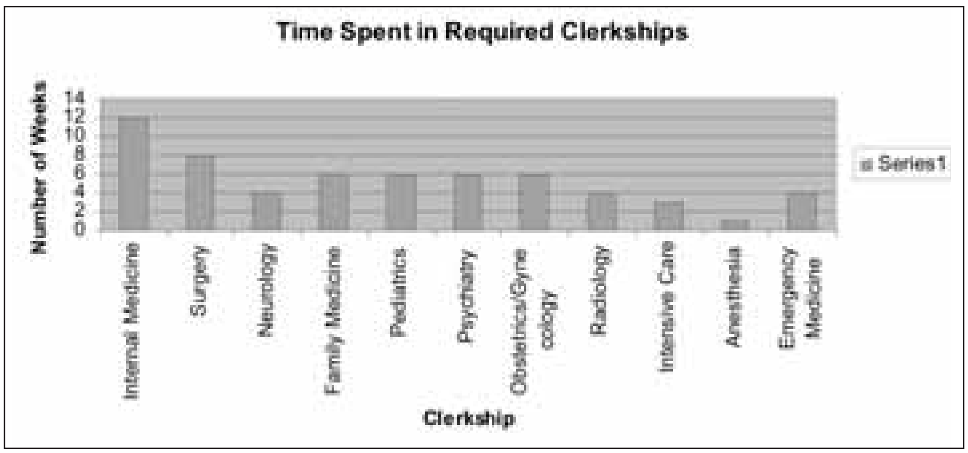

Figure 2. Number of required rotations in weeks spent on clinical rotations.

cal subspecialty rotation during the fourth year. During this rotation students could elect to spend four weeks on either Orthopaedic Surgery, Neurosurgery, Urology, Plastic Surgery, Otorhinolaryngology, or Ophthalmology. Or, students pursuing a surgical residency could fulfill this requirement by performing a four-week surgical sub-internship. There were no required rotations specifically in Orthopaedic Surgery, Physical Medicine and Rehabilitation or Rheumatology.

There were also 24 weeks of remaining elective rotation time with each elective rotation lasting 4 weeks. On average, 8.6% of students chose Orthopaedic Surgery, 7.4% of students chose to do Rheumatology, and 5.7% chose to do Physical Medicine and Rehabilitation. Several students chose to take multiple musculoskeletal electives but over 80% of medical students did not take any musculoskeletal clinical electives. Eight weeks of vacation were also incorporated into the schedule.

In terms of clinical volume of musculoskeletal medicine from a general medicine point of view, there were 480 out of a total of 8,321 referrals, 5.8%, to Orthopaedic Surgery. From a surgical point of view, a total of 10,234 surgeries were performed over the study period.

The total number of surgeries based on specialty is illustrated in Figure 3. General Surgery also included the subspecialties of surgical trauma, vascular surgery, breast surgery, and bariatric surgery. General Surgery and Orthopaedic Surgery represented the largest and second largest percentage of cases, respectively. Of these, 32% were designated General Surgery and 20% Orthopaedic Surgery. When broken down for inpatient and outpatient surgeries, General Surgery represented 36% of inpatient and 26% of outpatient cases while Orthopaedic Surgery represented 20% of inpatient and 22% of outpatient cases.

Discussion

Musculoskeletal issues have a major impact in the general population. In the geriatric population, musculoskeletal conditions are very common. Half of all chronic conditions has been estimated to involve various joints of the body.[10] It has been estimated that musculoskeletal conditions account for 15–30% of visits to primary care doctors.[12] In the pediatric population, 6% of the primary care visits were for musculoskeletal complaints.[5, 6] This number climbs as children age,

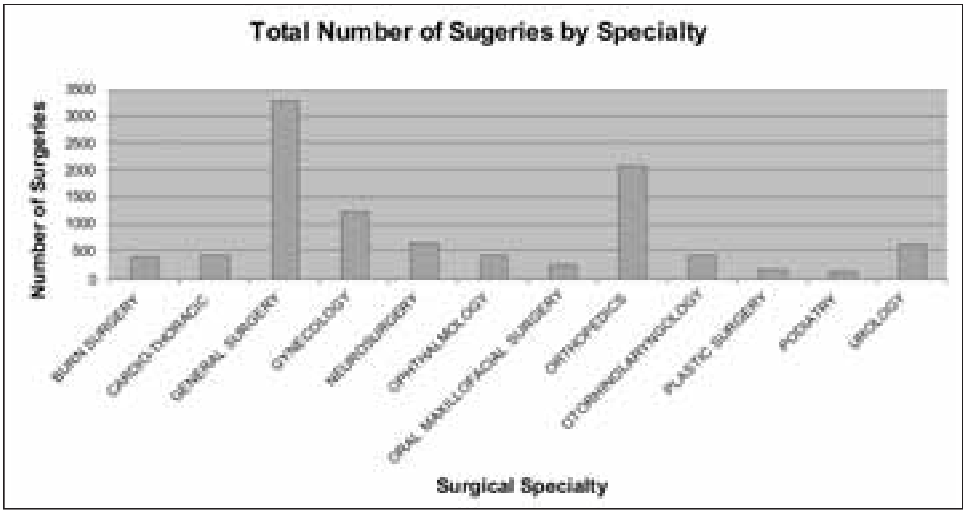

Figure 3. Total number of surgeries in hours by surgical specialty.

to more than 10% for adolescents ages 11–14.[6] Subsequently, musculoskeletal complaints remain one of the most common reasons for urgent pediatric visits.[5, 6]

Numerous studies have shown that recent medical school graduates are unable to adequately diagnose and treat common musculoskeletal conditions; however, increased education has been shown to improve competency and confidence. Freedman and Bernstein administered a musculoskeletal medicine proficiency test to 85 medical and surgical residents during their first postgraduate year. The majority of students, 82%, failed the examination.[8, 9] In contrast, studies have shown that participants who had taken a musculoskeletal medicine elective as a medical student tended to score higher and pass proficiency tests more often.[4, 11, 14] Moreover, students that had required clinical orthopedic rotations seem to do better than their counterparts without a similar requirement.[11, 14] Similarly, in looking at confidence in performing maneuvers and diagnosing conditions, Clawson found that osteopathic students felt better prepared than their allopathic counterparts.[3] This suggests that regardless of intended specialty, it was possible to have most students feel confident in their abilities provided the school makes musculoskeletal medicine a larger focus.

We identified a large disparity between musculoskeletal education and the prevalence of musculoskeletal medicine in clinical practice as determined by specialty referrals and surgical volume. Although Orthopaedic Surgery constituted 5.8% of all specialty referrals and 20% of total surgical volume, musculoskeletal medicine education constituted 6% of the pre-clinical medical school education and has no requirement in the clinical education at TUSM. Moreover, all exposure to musculoskeletal medicine obtained during their clinical education was strictly in the form of fourth-year electives and, more importantly, these electives were no required, highly variable, and therefore not equally experienced by all fourth-year students.

In terms of pre-clinical education, we felt that 6% of time spent on musculoskeletal medicine is appropriate relative to the other disciplines, this was reinforced by the lack of statistical significance between them, excluding Immunology. From a clinical education perspective, however, Orthopaedic Surgery warrants greater emphasis. General surgery had the largest total case volume, with 32% of all surgeries, and receives the second longest required clinical rotation, eight weeks, which accounted for 13% of all required clinical rotations (Figure 2). In contrast, Orthopaedic Surgery had the second highest case volume, constituting 20% of all surgeries, but received no required clinical rotation. In contrast, a lower volume specialty, Obstetrics and Gynecology, was given required clinical time while it represented only 12% of the total surgical volume. It received a six-week clerkship, which represented 10% of the required clinical hours. Similarly, students also receive exposure to Obstetrics and Gynecology during their six-week required Family Practice rotations as well. The other surgical specialties without required clerkships (Neurosurgery, Urology, Plastic and Burn Surgery, Otorhinolaryngology, and Ophthalmology) all had statistically significant lower caseloads than Orthopedic Surgery, accounting for between 3–6% of the overall surgical volume (Figure 3). Also, while there was a mandatory surgical sub-specialty clerkship during the fourth year, only 8.6% of the fourth-year class chose to rotate on Orthopaedic Surgery. Overall, less than 20% of fourth-year students chose to take any musculoskeletal clinical electives.

It was made clear by DiCaprio et al. that the majority of medical schools do not have a significant musculoskeletal requirement.[7] We felt that it would be interesting to examine the significance of musculoskeletal medicine from a clinical practice perspective and contrast it to medical school education. The disparity is evident. While it may be argued that no topic receives full coverage and some topics require a disproportionate number of hours, we believe that based on the high prevalence of musculoskeletal medical issues in general medicine and the high failure rates in competency examinations of musculoskeletal illnesses that a greater emphasis on musculoskeletal medicine is warranted in curriculums. A clerkship in any musculoskeletal specialty would aid in overall ability to diagnose and treat musculoskeletal conditions. Similarly, while a clerkship in Orthopedic Surgery might focus too much on the surgical aspects of musculoskeletal medicine, alternative or hybrid options with Physical Medicine and Rehabilitation or Rheumatology could provide education in non-operative management of musculoskeletal conditions as well as further experience with musculoskeletal examinations.

There were multiple weaknesses in our study. We did not examine the adequacy of education in the other major fields of medicine for comparison. It is possible that all fields suffer similar competency issues due to the volume of information that must be taught during medical school. However, we found that a large disparity between demands of clinical practice and the education provided for musculoskeletal medicine. Also, the clinical orthopaedic volume that an urban academic medical center sees may be different than one in a different location. Similarly, we employed a clinical experience rationale to argue that greater musculoskeletal education is warranted but a medical school likely considers other variables in deciding allocation of clinical time; such as the distribution of questions on the United States Medical Licensing Exams.

In conclusion, the disparity between musculoskeletal education in medical schools and the actual practice of musculoskeletal medicine in clinical practice is high. This disparity warrants a re-evaluation of our medical school curriculum to better prepare our future physicians in the management of the musculoskeletal medicine that they will be required to treat. We would recommend a re-evaluation of current required rotations and incorporation of a formal required musculoskeletal rotation with a combination of specialties such as Orthopaedic Surgery, Physical Medicine & Rehabilitation, and Rheumatology.

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Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Epidemiology of Orthopaedic Injuries with Falls from Ladders at a Level 1 Trauma Center

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Abstract

Nonoccupational ladder falls have been recognized as a public health concern and often occur in middle-aged rather than younger adults. The prevalence, epidemiology, and spectrum of ladder falls at an urban level 1 trauma center were investigated retrospectively. Using an orthopaedic database to identify patients, 51 medical records were reviewed revealing 38 patients who sustained ladder falls and orthopaedic injuries over a four year period. The mean age of patients was 50 years and a full spectrum of orthopaedic injuries were identified. Lower extremity injuries were more common, particularly with falls greater than ten feet.

Introduction

More than 2.1 million individuals were treated in U.S. emergency departments for ladder-related injuries from 1990–2005.[1] Recent studies have made three important findings related to ladder falls: the increasing incidence of ladder injury-related hospitalizations from 1990 through 2005, the predominance of ladder injuries in non-occupational settings, and the prevalence of injuries among the elderly population.[1–9] The aim of this study was to determine the prevalence, epidemiology, and spectrum of orthopaedic injuries seen with ladder injuries admitted to an urban level 1 trauma center.

Materials and Methods

Approval from the Institutional Review Board (IRB) for a retrospective case study was obtained to perform this retrospective review of medical records. An orthopaedic inpatient database for all orthopaedic patients admitted from 2004–2008 was utilized for identifying subjects. Data was entered into the database only when the orthopaedic service either admitted or was consulted on a patient being admitted to Temple University Hospital, an urban level 1 trauma center in Philadelphia, PA. Data is entered manually by orthopaedic surgery residents. The entry fields included injury mechanism, injury diagnoses, and treatment. This database was searched with the term "ladder" for the injury mechanism field. Patient records were excluded if the screening indicated that the injuries were not in fact from a ladder injury. From the remaining database records, actual inpatient medical records were then reviewed to collect the following data: from the charts: age, sex, mechanism of injury, location of orthopaedic injury, associated non-orthopaedic injury, height of ladder, occupation, and treatment.

Results

51 patients were identified from the initial database search. 13 patients were excluded after the initial database search, all due to the lack of an actual fall from a ladder in the history. 38 patients were therefore eligible for this retrospective study. There were 33 males (86.8%) and 5 females (13.2%) with an age range of 29–74 years and a mean age of 50. The ladder injuries resulted in 26 lower extremity injuries, 18 upper extremity injuries, and five axial-skeletal injuries, demonstrated in Figures 1 and 2. Nine patients (23.6%) had multiple injuries. There was only one reported case of loss of consciousness. There were no deaths related to ladder injuries among the study population. Out of the five females involved in the study, four suffered lower extremity injuries and one had an axial skeletal injury; there were no upper extremity injuries among the female population. Of the 38

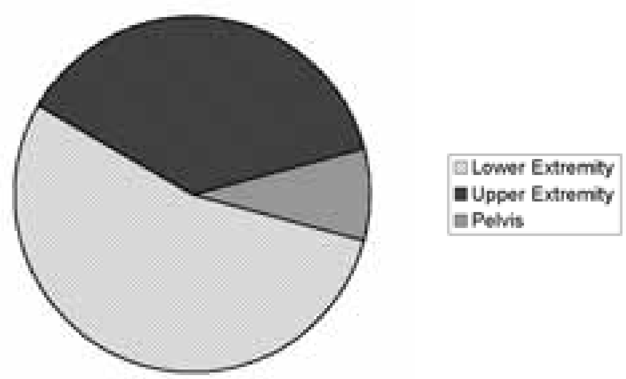

Figure 1. Distribution of orthopaedic injuries from falls from ladders (age range 29–74).

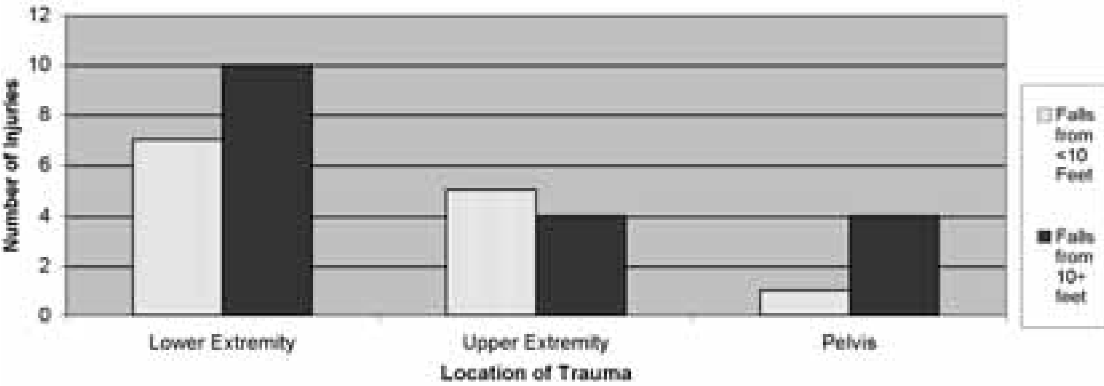

Figure 2. Distribution of orthopaedic injuries as related to fall height from ladders.

patient records reviewed, 29 (76.4%) detailed the specific height at which the patient fell from the ladder. Of those individuals who fell at a distance of less than 10 feet, there were five cases of upper extremity injury, seven cases of lower extremity injury, and one case of axial skeletal injury. Of those who fell at a distance of 10 feet or greater, there were four cases of axial skeletal, four cases of upper extremity, and 10 cases of lower extremity injury. Seven patients (18.4%) indicated their professions on their hospital admissions forms; only two of these individuals indicated that they were trained to use ladders. Seven patients (18.4%) reported that they were influenced by one of the following factors during their injury: alcohol, substance abuse, or depression. With regards to treatment, nine cases (23.7%) were treated with nonoperative management such as cast treatment or with external fixation. 21 patients (55.3%) were treated with surgery for their orthopaedic injuries.

Discussion

In a 16-year study period ending in 2005, ladder-related injuries in the United States saw a 50% increase, with 97% of these occurring outside of the workplace, in homes and nonoccupational activity.[1] The primary finding of this study is that individuals who suffered ladder-related traumas were almost entirely between the ages of 40 and 60 years old (mean age of 50 years). Their results indicate that only two of the ladder-related injuries (5.3%) occurred in the workplace. Another significant finding in our study was the diversity of injuries as a result of ladder falls. Figure 1 demonstrates the spectrum of both upper and lower extremity injuries incurred from these falls. Only two patients indicated that they were trained to be on ladders, although this may not have been asked of all the subjects given the retrospective nature of this study. This finding, however, concurs with another study, which found that a majority of the patient population, 60%, who suffered ladder-related injuries had them occur in non-occupational settings as well.[1] This indicates a necessity for education and training for recreational ladder use. Interestingly, one of the two individuals in the study population who used a ladder professionally sustained an injury unique from the other patients (subscapularis tendon rupture). It could be speculated that perhaps this was due to the individual's training to avoid a fracture. Another significant factor among our study population was the finding that seven patients (18.4%) reported having accidents while influenced by alcohol, substance abuse, or depression. The mean age of our patients was 50 years old, which is nearly identical to three other studies, whose study populations had mean ages of 45.6, 50, 48 years.[1, 8, 9] In addition, our finding of males predominating over females by 87% was also consistent with other studies. Although cost was not a factor in our research, in another study, the average duration of hospital admission as a result of ladder-related injuries was 18.4 days.[1] Fractures were the most common type of injury, and were 5.7 times more likely to result in hospital admission.[1] Orthopaedic surgeons should be most concerned with the surgery-related outcomes of this study, with a finding that 55.3% were treated surgically, most using open reduction and internal fixation techniques.

There are several limiting factors to our study, mostly dealing with sparsely detailed patient charts. Patients who were enrolled in the TUHS Orthopaedic database with keywords relating to "ladder" were included in the study, and lack of adding this detail at the time of admission would immediately eliminate this patient from the study population. Patient occupation was absent or marked as "unknown" in 30 of the 38 patient files (78.9%). This makes it difficult to identify patients who may or may not have been previously trained to use ladders. Additionally, in 25 cases, the mental and social health of individuals was absent from patient charts. Also, factors such as type of ladder used (single arm or double-arm), whether or not the individual was assisted by someone else, and specific knowledge of ladder-usage experience would be important in creating specific public safety directives for ladder usage. Steps to improve the effectiveness of this study would be to create a prospective review of all patients with ladder-related injuries with detailed data collection of these factors which were lacking in this review.

Currently, the U.S. Consumer Product Safety Commission (CPSC) and the National AG safety Database website, sponsored by the National Institute of Occupational Safety and Health publish tips for safe ladder use, and the September 2006 issue of Consumer Reports magazine rated ladders based on strength, ease of use, tipping/swaying, and walking with the ladder.[1]

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Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Arthroscopic Grafting of Hill Sachs Lesions Using Osteochondral Allograft Transplantation in 24 Patients: A Retrospective Study

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Abstract

Hill-Sachs lesions significantly increase the recurrence rate of anterior shoulder instability after arthroscopic repair. Numerous procedures have been proposed to treat these lesions. We present the results of twenty-four consecutive patients who underwent arthroscopic grafting of the Hill-Sachs lesion using osteochondral allograft transplantation. The American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) and Western Ontario Shoulder Instability Index (WOSI) were used as outcome measures. Nineteen of 24 patients followed-up and successfully completed the WOSI and ASES questionnaires. The average post-operative ASES score was 75.8 (range 16–100) and the average post-operative WOSI score was 724.5 (range 95–2031). The average ASES score was 85 for small lesions, compared to 59 for large lesions ($p < 0.01$). The average WOSI score for small lesions was 540 compared to 1041 for large lesions ($p = 0.065$). Osteochondral allograft transplantation may represent a viable treatment option for patients with small Hill-Sachs lesions.

Introduction

The arthroscopic treatment of anterior shoulder instability has gained popularity with increasingly higher rates of clinical success. Recent reports demonstrate rates of recurrent instability comparable to open surgery.[1, 2] However, the presence of bony defects of the glenoid and humeral head (Hill-Sachs lesions) adversely affect the success of arthroscopic treatment.[3, 4] Burkhart and De Beer reported a 4% recurrence rate for arthroscopic treatment of anterior instability in the absence of significant bony lesions. This was in contrast to the 67% recurrence rate seen in patients with either significant anterior glenoid bone loss (inverted pear) or Hill-Sachs lesions which engaged the glenoid rim in abduction external rotation ("engaging" Hill-Sachs Lesion).[4]

Several investigators have recommended various surgical treatments of the large Hill-Sachs lesion, including open Bankart repair with significant restriction of external rotation to prevent "engagement" of the lesion with the glenoid,[4] the Latarjet procedure (open segmental allografting of the defect),[5] transhumeral head plasty,[6] rotational humeral head osteotomy,[7] and arthroscopic filling or "remplissage."[8] Open procedures obviously engender more pain and morbidity than arthroscopic surgical approaches to the shoulder. Recently, subscapularis insufficiency has been reported in a number of patients subsequent to open Bankart repair.[9]

Chapovsky and Kelly[10] proposed a method of filling the Hill-Sachs lesion arthroscopically using allograft tissue to stabilize the humeral head defect associated with recurrent shoulder instability. We report the results of a series of 24 patients who underwent synthetic grafting of the posterolateral humeral head defect by arthroscopic approach.

Materials and Methods

Since April 2005, the senior author has performed the arthroscopic grafting of large humeral head defects in 24 patients. Patients with less than six-months follow-up were excluded from this retrospective study. Patients were chosen for humeral head grafting if there was an inverted pear glenoid or an engaging Hill-Sachs lesion on arthroscopic examination (Figure 1). Determination was made to fill the defect based on associated glenoid defect and/or glenoid engagement of the defect in abduction and external rotation of the shoulder.

Technique

All surgeries were performed in the lateral decubitus position using ten pounds of longitudinal traction with the arm in approximately 45 degrees abduction and 25 degrees of forward flexion. A high anterosuperior portal was made employing an outside-in approach, approximating the anterolateral corner of the acromion. The anterolateral portal was used as

Figure 1

a viewing portal to determine the presence of the inverted pear glenoid and the potential for engagement of the humeral head defect with the glenoid. While viewing from the frontal portal, an accessory inferoposterior portal was made using a spinal needle so that the perpendicular access to the humeral head defect could be attained (Figure 2). The portal was widened with a hemostat and, without a cannula, the OATS system harvester (Arthrex, Naples, FL) was used to prepare the lesions for donor plugs within the bone defect (Figure 3). On the back table, OBI plugs (polyDL lactide-co-glycolide/ $CaSO_4$: Osteobiologics Inc., San Antonio, TX) were prepared for delivery by malletting the OATS donor trephines into the OBI plug casings such that approximately a 17 mm in length donor sample was attained. Donor plugs were either 6 mm or 8 mm width OATS trephines. Once the recipient site and donor plugs were prepared, the OBI plugs were delivered into the recipient site using the OATS system under arthroscopic visualization. Care was taken to ensure that the donor plugs were flush to the adjacent articular surface by use of the oversized OATS tamp (Figures 4 and 5). In some cases with larger Hill-Sachs lesions, no attempt was made to fill the entire defect. Rather, the regions that were seen to engage under arthroscopic visualization, were grafted. One to three plugs were used in this series. Patients were placed in abduction slings post-operatively and given instructions to follow a standard post-instability repair protocol. Patients were instructed to wear the sling four weeks before engaging in physical therapy. Follow-up consisted of cataloging any complications; including nerve injury, loose body formation, infection, and recurrence of shoulder instability. Patients were asked to complete a WOSI instability questionnaire and the ASES subjective shoulder evaluation scale.

Scoring Systems

The WOSI and ASES Subjective Shoulder Evaluation Scales were used to determine success of the arthroscopic repair. Patients were asked to complete these questionnaires post-operatively.

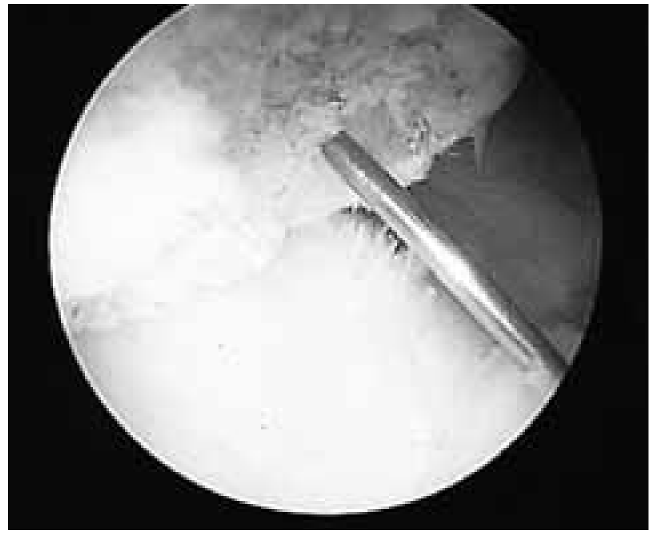

Figure 2

Figure 3

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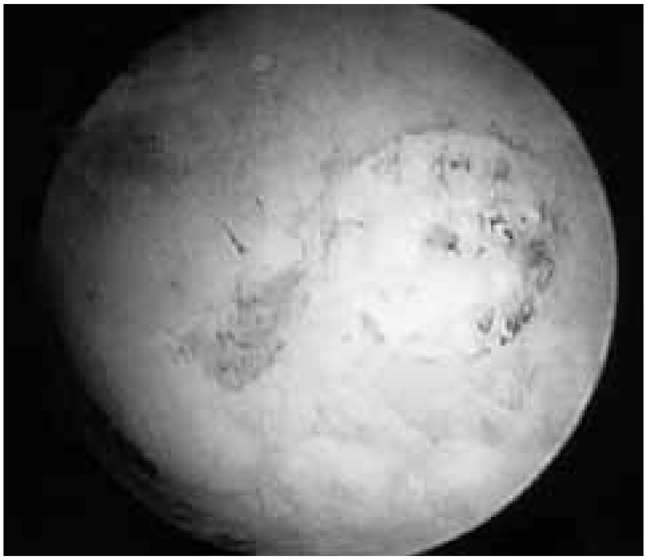

Figure 5

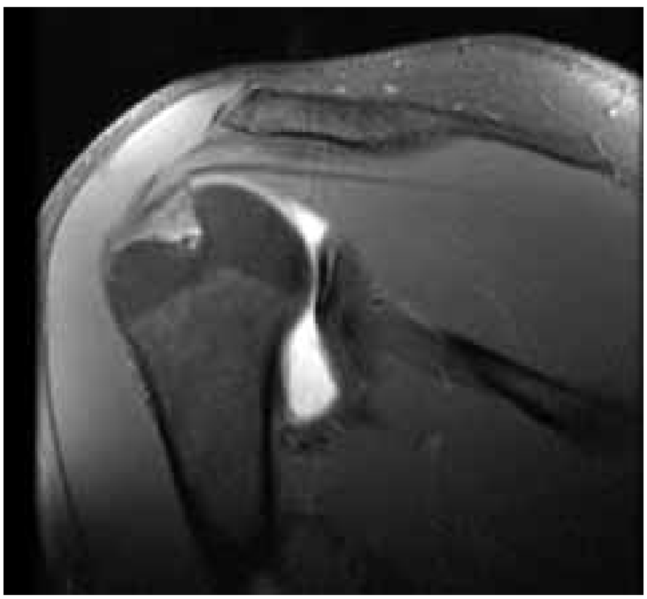

Figure 6

Results

Nineteen of twenty-four patients were available for follow-up and successfully completed the WOSI and ASES questionnaires. The average post-operative ASES score was 75.8 (range 16–100) and the average post-operative WOSI score was 724.5 (range 95–2031). Patients were further analyzed based on the size of the lesion as determined intra-operatively. A small lesion is defined as less than 9 mm in diameter and a large lesion is defined as greater than 9 mm in diameter. The average ASES score was 85 for small lesions, compared to 59 for large lesions ($p < 0.01$). The average WOSI score for small lesions was 540 compared to 1041 for large lesions ($p = 0.065$). The most common complications related to the procedure were recurrence of instability and re-dislocation.

Figure 7. OATS in place.

Table 1

			Lesion Size	
Subject #	**ASES Score**	**WOSI Score**	**Small**	**Large**
1	100	95	Y	N
2	100	132	Y	N
3	60	1483	N	Y
4	83	1004	Y	N
5	85	128	Y	N
7	95	901	Y	N
8	45	1516	Y	N
9	78	592	N	Y
10	68	193	N	Y
12	81	840	Y	N
13	55	206	Y	N
15	87	569	Y	N
16	100	99	Y	N
19	87	662	N	Y
20	67	1075	N	Y
21	16	2031	N	Y
22	97	663	Y	N
23	42	1250	N	Y
24	95	328	Y	N

Table 2

	Small Lesion	**Large Lesion**	**p**
ASES	59.7	85.3	<0.01
WOSI	540.1	1040.8	0.065

Discussion

To our knowledge, this is the first study to present outcome data for the arthroscopic grafting of Hill-Sachs lesions using Osteochondral Allograft Transplantation (OATS). This procedure can yield excellent results in a select group of patients, specifically those with small lesions (<9 mm). Patients with large lesions (>9 mm) had significantly worse outcomes, based on the ASES questionnaire, when using this technique. The WOSI showed a trend toward better outcomes with small lesions, but the difference was not found to be statistically significant.

For successful outcomes in the surgical approach to shoulder instability, attention must be placed to the presence of Hill-Sachs lesions. Our study reports the retrospective outcomes of a novel approach to bone grafting the lesions arthroscopically. Other methods of addressing the Hill-Sachs lesions, including transhumeral head plasty,[6] rotational humeral head osteotomy[7] require the associated morbidity of extensive open surgical dissection. The "remplissage,"[8] a more recent technique involving grafting the defect with rotator cuff tissue, may prove to show promising results, based on preliminary data. Our results suggest that for the treatment of small Hill-Sachs lesions, arthroscopic OATS may be used successfully to decrease recurrence rates after surgery for shoulder instability.

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Medical Student Research Project

Supported by The John Lachman Orthopedic Research Fund and Supervised by the Orthopedic Department's Office of Clinical Trials

Healing of Tibia Gunshot Fractures: A Radiographic Analysis of Gunshot Fractures and Non-penetrating Fractures

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Abstract

Introduction: Fractures caused by gunshot injuries are increasing as gun violence increases in civilian settings. The mechanism of injury is uniquely different in a fracture caused by a gunshot versus non-penetrating injuries; therefore, there may be differences in healing patterns. We conducted a retrospective control-matched radiographic analysis of tibia shaft fractures caused by gunshot injuries versus matched tibia shaft fractures from non-penetrating injuries that were both treated with reamed intramedullary rod fixation to determine differences in time to union.

Methods: A retrospective chart review was performed on all patients seen at our urban academic medical center presenting with a gunshot tibia shaft fracture from January 1, 2004 to December 31, 2007. Only patients between the ages of 18-89 with small-arms gunshot tibia shaft fractures, treated with a reamed intramedullary rod, and who followed up at regular intervals of 4–6 weeks with a total minimum of six months of follow-up were included, yielding 10 patients (Group A). An additional 10 patients with non-penetrating tibia fractures meeting the same inclusion criteria were selected as a control-matched population (Group B). The same surgical technique and post-operative course had been used in both groups. Serial radiographs were examined and fracture union was defined as the presence of bridging callus on orthogonal anteroposterior and lateral radiographs.

Results: Group A patients were 100% male with an average age of 29. Group B patients were 60% male, 40% female, with an average age of 33. Group A fractures had nine AO type C and one AO type B patterns while Group B had four AO type B and six AO type A fracture patterns. All Group B fractures were closed injuries. The mean time to fracture union in Group A was 19.5 weeks versus 11.8 weeks for Group B ($p < 0.05$). There was one case of osteomyelitis in Group A and two nonunions, one of which ultimately required dynamization to induce union. There were no complications in Group B.

Conclusion: Patients sustaining gunshot fractures may experience a longer time to union as well as higher rates of complications than their non-penetrating counterparts when treated in a similar manner. The greater time to union and higher complication rate should be taken into account during the post-operative management of gunshot tibia fractures. Multiple variables may play a factor in the longer time to union in the gunshot fracture group including thermal injury, contamination, greater fracture severity (as evidenced by the greater number of AO type C fractures in Group B) and subsequent comminution and/or bone loss.

Introduction

Fractures caused by gunshot injuries are increasing as both gun ownership and gun violence increases in urban settings.[1–4] In the United States deaths from gunshot injuries are 90 times more common than in any other industrialized country.[5] Similarly, deaths from gunshot injuries outnumber deaths from motor vehicles in eight states.[6]

The mechanism of injury from a gunshot is uniquely different than a fracture caused by a fall or other non-penetrating injuries. Fractures caused by projectiles are associated with extensive soft tissue damage, wound contamination, thermal injury, variable fracture displacement, comminution, and instability.[7–9] Similarly, protocols for the management of gunshot fractures vary but typically involve a combination of wound management and skeletal stabilization.

In many cases gunshot injuries can be treated successfully with non-operative measures such as local wound debridement, tetanus, antibiotic prophylaxis, and splinting.[10] But cases of long bone fractures of the lower extremity warrant expeditious surgical stabilization. The tibia is a common site of gunshot injuries. Brown et al. reported that tibia fractures due to gunshots represented 14% of all gunshot fractures in their series.[1] There are several methods used to repair routine gunshot and non-gunshot induced tibia fractures including external fixation, open reduction internal fixation with plate and screws, and intramedullary nailing.[11] The result of these multiple variables may lead to differences in fracture healing and complications.

In order to better understand healing patterns for gunshot fractures, we conducted a retrospective control-matched radiographic analysis of tibia shaft fractures caused by gunshot injuries versus matched tibia shaft fractures caused by non-penetrating injuries. Both fracture groups were treated with reamed intramedullary nail fixation and were examined for differences in time to union and complication rates.

Materials and Methods

Data Collection

Approval from the Institutional Review Board for a retrospective chart review was first obtained. Charts were reviewed for all patients between the ages of 18–89 years of age who presented to the emergency room of our academic medical center with a small-arms gunshot tibia fracture who subsequently underwent intramedullary rod fixation between January 1, 2004 and December 31, 2007. Only patients who followed-up regularly at 4–6 week intervals for a minimum of 6 months post-operatively were included for data collection. Ten patients met the above criteria and were defined as Group A (see Figure 1A). Ten additional patients with non-penetrating tibia shaft fractures also treated with intramedullary rod fixation during the same period were selected to represent a matched cohort population and were designated Group B (see Figure 1B).

All patients had their charts, operative reports, and radiographic images reviewed. Demographic data collected included patient age, sex, date of fracture, type of fracture, extremity involved, associated injuries, date of surgery, related complications, and presence of neurovascular disorder. Furthermore, patient follow-up was recorded and time to union was determined by analysis of radiographic imaging. A healed fracture was defined as the presence of bridging callus on orthogonal anteroposterior and lateral radiographs.

Surgical Technique

The surgical treatment was the same in both populations and included: closed reduction of the fracture, proximal tibia entry, guidewire placement, reaming of the reduced fracture, and rod insertion followed by proximal and distal interlocking screw fixation. For Group A, the gunshot wound was debrided and allowed to close by secondary intention. No cases required a primary or secondary wound coverage procedure.

Radiographic Analysis

Serial radiographs were followed at 4–6 week intervals and a healed fracture was defined as the presence of bridging callus on orthogonal anteroposterior and lateral radiographs (see Figure 2). Time to union was calculated in weeks from the date of surgery to the time of radiographic fracture healing.

Figure 1A. A gunshot fracture of the Tibia representative of Group A fractures.

Figure 1B. A non-gunshot fracture of the Tibia representative of Group B fractures.

Figure 2. A healed gunshot fracture of the Tibia.

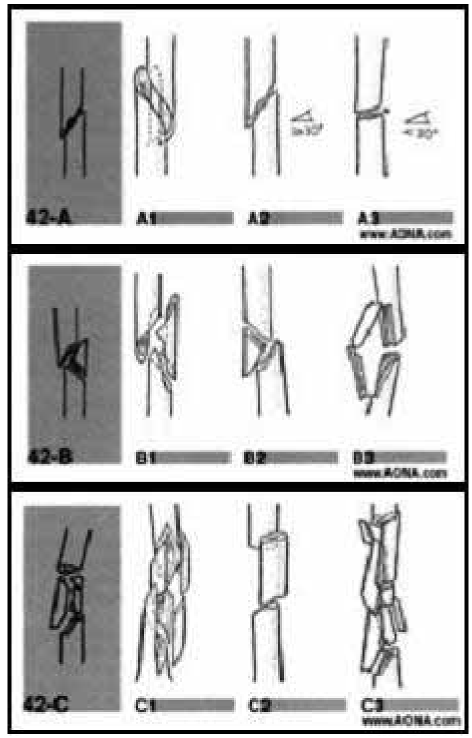

Figure 3. AO Classification of Tibia diaphyseal fractures.

Results

Group A patients were 100% male with an average age of 29. Group B patients were 60% male, 40% female, with an average age of 33. All Group A fractures were caused by standard velocity small-arms bullets. All Group B fractures were caused by closed means including falls from height, motor vehicle accidents, and motor vehicle versus pedestrian accidents.

The AO Comprehensive Classification of Long Bones was used to classify the fractures[12] (see Figure 3). Group A fractures had nine AO type C and one AO type B patterns while Group B had four AO type B and six AO type A fracture patterns (see Table 1). In addition, 30% of patients in Group A had an associated fibula fracture compared to 10% in Group B (see Table 2).

The mean time to fracture union in Group A was by 19.5 weeks versus 11.8 weeks for Group B ($p < 0.05$) (see Figure 4). In Group A, 3 of 10 patients had intact fibulas. The times to union were 16, 12, and 14 weeks respectively. All but one patient in Group B (non-GSW), demonstrated an intact fibula, and time to union here was 10 weeks.

There were two cases of nonunion, as defined as a lack of radiographic healing by 24 weeks, in Group A. There was one case of osteomyelitis in Group A. There were no complications in Group B. All patients in this study ultimately achieved radiographic union (see Table 3).

Table 1. Fracture AO Classification by Group

Group A (GSW) (N = 10)		Group B (non-GSW) (N = 10)	
C3.3	60%	A1.2	50%
C3.2	20%	B2.3	40%
C1.3	10%	A2.2	10%
A2.2	10%		

Table 2. Fracture Details

Subjects	Location	Fibula Fx	Time to Union (Weeks)	Complications
Group A (Gunshot Fracture)				
1	Middle	Y	15	
2	Distal	Y	32	Nonunion
3	Proximal	N	18	Osteomyelitis
4	Distal	Y	34	Non-union
5	Middle	Y	10	
6	Middle	Y	16	
7	Middle	N	12	
8	Proximal	Y	22	
9	Distal	Y	22	
10	Middle	N	14	
Group B (Non-Gunshot Fracture)				
1	Distal	Y	6	
2	Distal	Y	4	
3	Distal	Y	12	
4	Distal	Y	7	
5	Distal	Y	10	
6	Distal	Y	8	
7	Middle	Y	11	
8	Proximal	Y	12	
9	Middle	Y	12	
10	Middle	N	10	

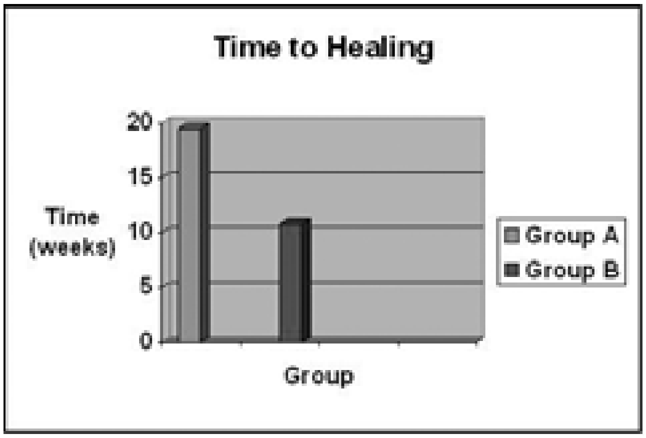

Figure 4. Time to radiographic healing.

Table 3. Complications and Secondary Procedures

Groups	Time to Union (Weeks)	Nonunion	Osteomyelitis	Dynamization
A	19.5	2	1	1
B	11.8	0	0	0

The first nonunion case ultimately healed by 34 weeks while the other underwent dynamization at 24 weeks resulting in healing by 32 weeks. In nonunion case #1, the gunshot fracture was a C3.3 pattern. Radiographic union was ultimately obtained by 34 weeks without any secondary procedures. In nonunion case #2, the gunshot fracture was also a C3.3 pattern. The fracture displayed bridging callus on only lateral views and underwent dynamization at 24 weeks. The patient subsequently displayed radiographic healing with bridging callus on orthogonal views by 32 weeks.

In the osteomyelitis case, the gunshot fracture was again a C3.3 pattern. The patient presented at 16 weeks post-operatively with copious drainage from his gunshot wound sites. The patient underwent multiple wound debridements with maintenance of the nail. The patient ultimately displayed radiographic healing by 19 weeks despite the infection with the help of long-term antibiotic suppression. At 13 months post-operatively the intramedullary nail was removed due to persistent drainage.

Discussion

The fracture morphology and soft tissue damage caused by gunshots to the tibia vary with the muzzle velocity of the weapon and tumble of the bullet.[13] Gunshot injuries can be divided into two types based on the muzzle velocity: high-velocity (greater than 2,000 feet/sec) and low-velocity (less than 2,000 feet/sec). Civilian firearms typically cause low-velocity injuries manifested with punctuate lesions and variable underlying fracture comminution, similar to the fractures incurred in Group A.[9] The morphology of fractures resulting from gunshots in Group A displayed significantly greater comminution than Group B patients as evidenced by the greater number of AO Type C fractures in Group A than in Group B.

It can be speculated that the combination of comminution, thermal necrosis from the blast-effect, as well as the degree of contamination might all contribute to the greater time to union and increased complication rate experienced in Group A. Moreover, the degree of bone loss exhibited by the greater number of AO C type fractures can be assumed to adversely affect the time to union seen within the gunshot group.

Leffers and Chandler studied 41 tibia fractures caused by civilian gunshot injuries. They separated their study population into low-velocity (78%) with gunshots less than 680Nm, intermediate (15%) between 680–1627Nm, and high-energy (7%) with gunshot velocity greater than 1627Nm. They identified longer initial hospitalization, higher fibular fracture incidence, more neurologic deficits, and a higher incidence of infection. Similarly, the time to fracture union was also higher, although their two cases of nonunions were in the low-energy group which was attributed to advanced age in one case and an intact fibula in another.[14]

The presence or absence of an intact fibula can affect fracture union. The fibula can provide additional stability and maintain the tibia's length in cases with extensive comminution or bone loss. However, the fibula can also induce delayed union or nonunion if it results in distraction at the fracture site. In our series, the non-gunshot fracture group had a higher incidence of associated fibula fractures by virtue of mechanism alone. The torque and twisting moments associated with falling explains the higher incidence of fibula fractures seen in the non-gunshot cohort. However, the three cases with intact fibulas in our non-gunshot Group A did not have an increased time to union.

Wiss et al. applied interlocking nailing of low-velocity gunshot fractures of the femur. At an average follow-up of 16 months the results were excellent with all fractures healed by an average of 23 weeks (range 14–40 weeks), with no cases of infection, but there were two cases of delayed union and seven malunions.[15]

Aside from intramedullary fixation, reports in the literature have identified similar success with both external fixation and plating of tibia gunshot fractures. Crainz et al. presented the use of an external fixator with uneventful healing confirmed by the first year following removal of the fixator at six months.[16] Atesalp et al. utilized compression-distraction plating and a circular external fixator frame on four tibia fractures with fibular fractures caused by close-range low-velocity gunshots. They observed fracture union in all cases within an average of 3.5 months with no major complications.[17]

Our study had multiple limitations. We were dependent on a retrospective sample as well as uncontrolled compliance with weight-bearing and wound care. Additional patient co-morbidities such as poly-traumatic injuries and immuno-suppression were not controlled for. In addition, patients with gunshot fractures often present from lower socioeconomic backgrounds that can further bias outcome measures. Lastly, despite the clear difference in time to union between the two groups the study sample remains small (n = 20) and both fractures did not have the same fracture classifications, with Group A representing higher energy injuries as evidenced by the greater prevalence of AO Type C patterns.

Conclusion

Patients sustaining fractures secondary to gunshot injuries may experience longer times to radiographic union as well as a higher complication rate. We hypothesize that these differences in healing and complications may be a product of several variables including the extent of soft tissue injury, fracture comminution, thermal necrosis, and local contamination. These variables should be taken into consideration when evaluating and treating gunshot tibia fractures.

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Case Report

Late Hematogenous Seeding of a Total Knee Arthroplasty After a Dental Procedure: A Case Report

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Abstract

It is recommended by both the American Academy of Orthopaedic Surgery (AAOS) and the American Dental Association (ADA) to use antibiotic prophylaxis for routine dental procedures for 1–2 years after a total joint arthroplasty.[1, 2] What is more controversial is whether to continue this practice after this initial time period. The consensus in the guidelines is that prophylaxis is not needed beyond the first two years unless the patient falls in a high risk category. High risk is defined as those patients who are immunosuppressed by inflammatory arthritis, drugs, or radiation or those patients with serious comorbidities like prior joint infections, malnutrition, hemophilia, HIV, insulin dependent diabetes, or malignancy. The risk is also deemed higher with more involved dental procedures with a high risk of bleeding; these include tooth extractions, periodontal surgery, dental implants, and root canal surgery. All of these procedures can increase the incidence of bacteremia which can seed an artificial joint. Regular fillings or restorative dentistry are considered low risk procedures for causing bacteremia and antibiotic prophylaxis is not recommended for these procedures. The recommended antibiotic regimens have been outlined by both Academies in several bulletins.[1, 2] The use of antibiotic prophylaxis after the 1–2 year postoperative period is quite controversial. We are reporting a case of late hematogenous infection after a minor dental procedure.

Case Report

We present the case of a 58-year-old male who underwent an uneventful cemented total knee arthroplasty for osteoarthritis of his left knee. He had underlying medical comorbidities of cardiac arrhythmia in the past and non-insulin dependent diabetes mellitus. He had no postoperative problems during his hospitalization and was discharged home on the fourth postoperative day. Perioperative antibiotic prophylaxis with cefazolin was used for 24 hours as per our protocol. He had no post hospital discharge issues and was followed in the office at routine intervals. He returned to regular work and did use antibiotic prophylaxis for all of his routine dental appointments for three years.

Three years postoperatively, he forgot to take his antibiotics when he went to his dentist and underwent routine amalgam tooth restoration under local anesthesia. This was not invasive and his dentist noted almost no bleeding. He did note that he had poor dental hygiene with moderate gingivitis and prescribed chlorhexidine mouthwash to decrease the gingivitis. Approximately seven days later, he noticed pain, swelling, and warmth in his knee. He noted a low grade fever of 100.3°. He presented to the hospital and was admitted to our service. Examination at that time showed a low-grade temperature, a 1+ effusion of his knee, diffuse tenderness around the knee, no cellulitis or redness, and significant restriction of motion secondary to pain. X-rays showed no loosening or destruction and no periosteal reaction. The knee was aspirated of cloudy fluid with 96,000 WBCs with 81% polys, which eventually grew out β-hemolytic streptococcus.

The patient then underwent arthrotomy, synovectomy, and polyethylene exchange in an attempt to retain the prosthesis. He was sent home on IV cefazolin as this was a sensitive organism. He returned nine weeks later with recurrent knee pain and swelling. His sedimentation rate was 17 (normal < 10 mm/hr) and a C-reactive protein of 6.39 (normal < 0.8 mg/dl). A repeat knee aspirate showed no growth. He was restarted on IV cefazolin then switched to PO cephalexin. His symptoms did not subside and he underwent explant of the prosthesis and insertion of a hinged antibiotic spacer. He was switched to oral clindamycin by the Infectious Disease consultants. Eight weeks following the explant, he had spacer removal and reimplantation of the knee prosthesis with antibiotic impregnated cement.

Discussion

This case illustrates the dilemma that faces all joint replacement surgeons. Total joint arthroplasties are never totally free from the risk of late infections. The rate of late infections around prosthetic joints runs from 0.3–1% in various studies; although this may be underestimated as most community orthopedists do not report their cases in the literature.[3, 4] We do not see this high rate of infection with plates or rods that we use for fracture patients and most orthopedists do not use any antibiotic prophylaxis for procedures in these patients. However, it is clear that late hematogenous seeding of joint prostheses does occur, especially when bacteremia is induced.[5] Some authors believe that an immune-incompetent fibro-inflammatory zone surrounds the total joint implant and actually impairs the body's ability to fight bacteria.[6] In most instances, the body disposes itself of these organisms as native joints do not get infected after dental work, colonoscopy, or foot surgeries, unless the patient is quite ill to begin with. This is not the case in total joint patients. Even healthy patients must use antibiotics for 1–2 years if they are having any invasive procedures done according to the AAOS and ADA recommendations.

This case report demonstrates a late infection three years after the index procedure with a low risk dental procedure in a relatively low risk patient. Therefore, surgeons should be advised to use prophylactic antibiotics in every patient after a total joint replacement in every invasive procedure, despite the patient's underlying medical condition. Some purists may worry about antibiotic sensitivity, cost effectiveness, or allergic reaction. However, these patients have already received perioperative antibiotics before their index operation. The risk of superinfection with one pre-procedure dose is outweighed by the benefit of preventing the disastrous complication of a joint infection.[7]

In conclusion, all total joint arthroplasty patients deserve lifelong antibiotic prophylaxis if they undergo invasive procedures or if they have an infection elsewhere in their body. The risk-benefit ratio favors this approach and is contrary to the accepted guidelines of the AAOS and ADA.

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Review

Treatment of Forearm Fractures

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Overview

The radius and ulna comprise the two bony structures of the forearm. These two bones function symbiotically as a unit. As such, their anatomy and movement should be viewed as a single dynamic process as opposed to two isolated anatomic structures. Both bones are connected by the distal radioulnar joint (DRUJ), proximal radioulnar joint (PRUJ), and the interosseous membrane (IOM). The IOM is a fibrous sheath that separates the anterior and posterior compartments and is a secondary restraint to proximal migration of the radius relative to the ulna. According to Skahen et al. this sheath, which originates on the radius and inserts onto the ulna, consists of central band, accessory band, a proximal band, and a membranous portion.[1] The average length of both the radius origin and ulna insertion is approximately 10.6 cm.[1] The IOM serves primarily as a ligament and is critical in the maintenance of longitudinal forearm stability. According to Hotchkiss et al., the IOM contributes approximately 71% of the longitudinal forearm stiffness when the radial head is excised.[2] The radial head serves as the primary restraint to proximal migration of the radius with the central band of the IOM and the triangular fibrocartilage complex (TFCC) acting as secondary restraints. These structures together facilitate transition of stress and permits fluid motion of the forearm from pronation to supination.

The radius, ulna, IOM, TFCC, DRUJ, and PRUJ form the forearm ring.[3] This ring works in concert to allow for forearm pronation and supination. A disruption of this ring at any site can result in loss of normal forearm motion. Therefore, the goal of forearm fracture management is anatomic maintenance of the ring in order to preserve motion and function.

Diagnosis

A patient with a forearm fracture typically presents with a painful right arm. Tenderness is noted and is worsened with hand motion and forearm rotation. Vigilant evaluation of the radial, median, and ulnar nerves is warranted. The radial and ulnar artery must also be evaluated. If palpable pulses are not felt, Doppler examination is warranted. Neurovascular injury in closed radius and ulna fractures is an uncommon but serious complication. Compartment syndrome of the forearm is second only to the leg and must be considered in all cases of forearm fractures with significant swelling, pain out of proportion, and altered neurovascular examinations.

The risk for neurovascular embarrassment is increased with open fractures. All wounds should be diligently evaluated with the understanding that the site of a wound and fracture may not be at the same level at presentation but may have communicated at the time of injury. Most nerve injuries are neuropraxic, however hard signs of a nerve injury should be treated accordingly.

Thorough radiographic evaluation of the forearm should include anteroposterior and lateral views of the forearm, as well as dedicated views of the wrist and elbow. The radius and ulna must be examined thoroughly across their entire lengths including the DRUJ and PRUJ. Traction views can aid in characterization of a fracture. Radiographs can readily make the diagnosis of forearm fractures and advanced imaging modalities including computed tomography or magnetic resonance imaging are rarely necessary except in cases of pathologic lesions.

Fractures

Forearm fractures can be divided into four distinct fracture patterns: Isolated radius or ulna fracture, Combined radius and ulna fracture, Galleazi Fracture, and Monteggia Fractures. Each fracture will be discussed including treatment principles and techniques.

Isolated Radius Fractures

Isolated radius shaft fractures are controversial and are typically assumed to be a Galeazzi Fracture until proven otherwise. Standard treatment involves an anterior approach to the radius with plate fixation. Recently we have come to realize that not all isolated radial shaft fractures necessarily involve the DRUJ. Rettig et al. reviewed 40 patients with a Galeazzi fracture at an average period of 38 months who underwent fracture stabilization via the anterior approach and standard plate fixation. They found that fractures of the shaft within 7.5 cm of the “mid-articular” surface of the radius were at high risk for DRUJ involvement whereas those beyond 7.5 cm were not so and acted as an isolated radial shaft fracture.[5]

Similarly, Ring et al. reviewed their series of 36 patients with radial shaft fractures.[6] They used a DRUJ disruption with greater than 5 mm of positive ulnar variance as an indicator of a Galeazzi fracture. Nine such patients were treated with plate fixation and DRUJ repair with either temporary pinning and/or large ulnar styloid repair, whereas the remaining 27 patients only underwent plate fixation without DRUJ stabilization and early mobilization with good results. They identified that isolated radial shaft fractures are more common than Galeazzi fractures.

Galleazi Fracture

A Galeazzi fracture consists of a fracture of the shaft of the radius with an associated DRUJ disruption. The extent of DRUJ injury can be classified as either stable, partially unstable (subluxable), or unstable (dislocated).[7] Macule et al. further classified Galeazzi fractures based on the location of the radius fracture relative to the radial styloid; type 1: 0–10 cm, type 2: 10–15 cm, and type 3: >15 cm from styloid.[8] Again, Rettig et al. identified that the risk for DRUJ injury is greatest when the radial shaft fracture is within 7.5 cm from the articular surface.[5]

Closed treatment of this fracture has been uniformly poor with Hughston et al. citing a 92% unsatisfactory outcome in a group of 38 patients treated without operative intervention.[9] Operative fixation is the treatment of choice hence its eponym: "fracture of necessity." The preferred technique is an anterior approach followed by plate fixation of the radius and reduction of the DRUJ. Plate fixation is best achieved with a dynamic compression plate and screw purchase of 6–8 cortices on each side of the fracture. Concentric reduction and stability of the DRUJ is best achieved by anatomic reduction of the radius. Residual DRUJ instability after radius fixation can be treated with temporary pinning of the DRUJ in supination and/or repair of an ulnar styloid fracture, size permitting.

Mohan et al. reviewed 50 Galeazzi fractures treated only with anatomic plate fixation and without DRUJ repair that resulted in 40 good, eight fair, and two poor results.[10] Similarly, Strehle and Gerber identified that anatomic plate fixation of the radius and indirect reduction of the DRUJ was sufficient.[11] Bhan and Rath reviewed their experience with Galeazzi fractures and recommended that fractures with delayed treatment should be immobilized in supination in a long arm cast after open plate fixation of the radius and DRUJ reduction.[12]

Isolated Ulna fractures

The isolated ulna fracture, also known as a "night stick" fracture, is a common injury usually resulting from a direct blow to the ulna. The treatment of such injuries is highly variable and is based on the fracture's stability. Fractures are deemed unstable if there is more than 10 degree angulation, more than 50% displacement of ulnar shaft, proximal one-third ulnar shaft involvement, and DRUJ or PRUJ instability.[13] Multiple non-operative measures have been shown to be effective in the management of isolated ulnar fractures including: ace wraps, forearm braces, short arm casts, or long arm casts.[14–17]

Atkin et al.[31] studied patients with isolated stable forearm fractures and compared ace wrap vs short arm cast vs long arm cast. They found that all fractures united by 7.2 weeks, although six of nine patients initially treated with an ace wrap were converted to short arm casts secondary to pain. They concluded that short arm casting for eight weeks is sufficient for closed treatment of ulnar shaft fractures.[15] Pollack et al. treated 71 patients with isolated ulna fractures. They showed that a long arm cast for 10.5 weeks resulted in an 8% non-union rate and cast less than two weeks along with motion as tolerated after cast removal resulted in a 100% union rate. A five percent loss of forearm rotation was noted.[14] Zych et al. reported a 100% union rate with two weeks of long arm casting followed by forearm bracing. The necessity of an interosseous mold within the brace was stressed in order to limit radial angulation.[16] Sarmiento et al. studied 287 patients treated with functional bracing and reported a 12 degree loss of pronation and one degree loss of supination in proximal fractures, a 10 degree loss of pronation and two degree loss of supination in middle third fractures, and five degree loss of pronation and seven degree loss of supination in distal third fractures.[17]

Operative intervention should be reserved for unstable fractures. The goal of operative intervention is avoidance of malunions or nonunions and preservation of forearm rotation with anatomic reduction and plate fixation. Open reduction and internal fixation with dynamic compression plates has resulted in consistently good outcomes. Leung and Chow performed open reduction and internal fixation on twenty nine isolated ulnar shaft fractures and noted a 100% union rate.[18]

Combined Radius and Ulna Fracture

Combined radius and ulna fractures of the forearm, also known as a "both bones fracture" are defined as an isolated diaphyseal fracture of both the radius and ulna with no injury to the DRUJ or PRUJ (see Figures 1A and 1B). Closed treatment of both bones fractures has routinely led to poor outcomes with significant losses in forearm rotation. In 1951, Evans et al. reviewed his series of 50 patients treated with closed reduction under general anesthesia and reported on the high incidence of residual loss of forearm rotation with residual malalignment.[19] Thus closed treatment should be reserved for critically injured patients or for those with substantial medical comorbidities.

The goal of operative intervention for both bones fractures is stable anatomic reduction and plate fixation of both the radius and ulna with restoration of radial bow and forearm rotation. Restoration of the radial bow is particularly imperative and is defined as the maximal height of the radius arch and is on average around 15 mm. The usual location is 60% of radial length distal to the radial ulnar joint. Mathews et al. showed that a 10 degree malreduction of the radius will not limit anatomic forearm rotation however a 20 degree loss of forearm rotation was shown to limit range of motion.[20]

Multiple surgical treatment options exist for the treatment of both bones fractures, and include open reduction and plate fixation, external fixation, and intramedullary rodding.

Figure 1. (**A** and **B**) Anteroposterior and Lateral views of a Both Bones fracture of the forearm.

External fixation is typically reserved for management of open fractures or associated soft tissue injuries. Intramedullary fixation will be discussed at greater length in the last section.

Open reduction and fixation with dynamic compression plates has become the workhorse for management of both bones fractures (see Figures 2A and 2B). Principles of fixation include restoring length, radial bow, and preservation of forearm rotation. Complications include loss of forearm rotation, shortening, and wrist pain. To ensure stable fixation and minimize the risk for nonunions six to eight cortices should be obtained on each site of the fracture. In addition, separate incisions should be placed to approach both the radius and ulna individually to avoid post-operative sysnostosis formation. Anderson et al. reviewed 330 fractures of the radius, ulna, or both bones. All were treated with compression plating. They reported a 97.9% union rate for radius fractures and 96.3% union rate for ulna fractures. Only 11% of this patient group was observed to have a poor functional outcome.[21]

Monteggia Fracture

A Monteggia fracture consists of a fracture of the proximal ulna with an associated dislocation of the radial head.[22] It has been estimated that the Monteggia fracture pattern represents approximately 1–2% of all forearm fractures.[22] The associated radial head fracture implies an inherent violation of the annular ligament, which binds the radius to the ulna.[3] The Bado classification has divided Monteggia fractures into four distinct categories with respect to the location of the radial head:[23] Type I is an anterior dislocation of radial head, and occurs with excessive forearm pronation. Type II is a posterior dislocation of radial head, and occurs with excessive axial loading of the forearm along with elbow flexion. Type III is a lateral dislocation of the radial head, and occurs with forced abduction of the elbow. Finally, Type IV represents both a proximal ulna and radius fracture. This dislocation occurs with excessive forearm pronation and subsequent fracture through the radial neck. Jupiter et al. further sub-divided the Bado type II fracture has been subdivided into four groups.[24] In type IIa, the fracture of the ulna involves the distal part of the olecranon and the coronoid process, in type IIb the fracture is at the metaphyseal-diaphyseal juncture, distal to the coronoid process, in type IIc the fracture is diaphyseal and in type IId the fracture extends to the proximal half of the ulna.

Ring et al. reviewed their experience with 48 Monteggia fractures with an average follow-up of 6.5 years that were treated with plate fixation or tension-band wiring of the ulna and closed reduction of the radial head.[25] According to the Broberg and Morrey system they yielded 38% excellent, 46% good, 4% fair, and 12% poor. Three quarters of the fair and poor outcomes were Bado type II injuries with concomitant fractures of the radial head.

Konrad et al. reviewed their experience with 47 Monteggia fractures with an average follow-up of 8.4 years that were treated with plate fixation or tension-band wiring of the ulna and closed reduction of the radial head.[26] According to the Broberg and Morrey system they yielded 47% excellent, 26% good, 19% fair, and 8% poor. The poor outcomes were correlated with Bado Type II, Jupiter Type IIa, radial head, and coronoid fractures. All radial head and coronoid fractures were treated with screw fixation. Their results support the hypothesis that posterior radial head dislocations and the more proximal ulna fracture (Jupiter IIa) might be a poor prognostic indicator. In contrast Bado type I fractures are less common in adults but consistently yielded superior results to Bado type II. Both of these results are consistent with Ring et al.'s findings.

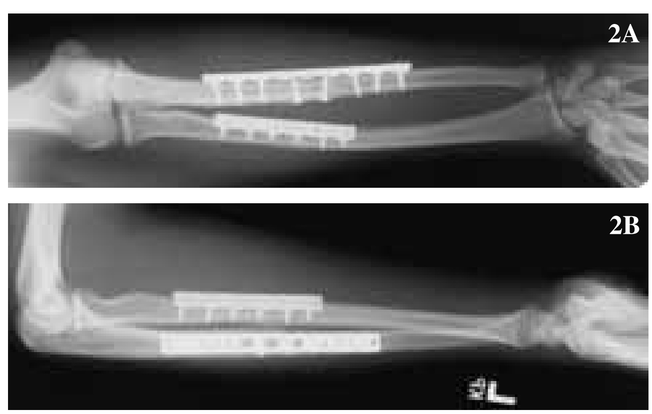

Figure 2. (**A** and **B**) Anteroposterior and Lateral views of a Both Bones fracture after fixation with dynamic compression plate fixation.

Anatomic reduction of the radiocapitellar joints and PRUJs are vital to successful treament of this fracture pattern. Bado type II patterns needed to be approached cautiously particularly if associated with a radial head or coronoid fracture. Closed reduction should be limited to patients with significant comorbidities that precludes operative intervention.

New Directions

Intramedullary Fixation

Intramedullary fixation of forearm fractures is an old concept that has recently regained popularity. Although open reduction and plate fixation has well-established success in forearm fracture management, complications secondary to extensive open dissection, disruption of periosteal blood supply, and the risk for re-fracture at the end of the plates exists.

Intramedullary fixation was used routinely prior to open plating techniques for both bones fracture but fell out of favor due to inadequate fracture reduction and failure to restore forearm motion. The first intramedullary nail results were reported by Sage et al. Post operatively the intramedullary nail was protected with a long arm cast for three months.[27] A 6.2% non-union rate was reported as well as difficulty in restoring normal forearm motion.

More recently, improved designs for intramedullary nails for forearm fracture has been introduced with pre-contoured fluted designs and interlocking screws. These newer designs afford better restoration of normal anatomy, particularly radial bow, and fracture rotational control with interlocking screws. Weckbach et al. treated 33 forearms with fractures of the radius, ulna, or both bones with a new intramedullary nail and they reported a 97.5% union rate at 4.4 months with an average DASH score of 13.7, and full range of motion restored in 86% of cases.[28] Radial bow was maintained by pre-bending of the nail prior to insertion. Lee at al applied pre-contoured fluted intramedullary nails in 38 patients with either isolated or combined fractures of the radius and ulna.[29] All fractures healed within 14 weeks except for one nonunion in the case of an open fracture. They achieved 92% good to excellent results with an average DASH score of 15.

Locked Plate Technology

Locked plating technology has become ubiquitous in orthopaedic fracture management. The first broad application of this technology was with the Less Invasive Stabilization System (LISS; Synthes, Paoli, PA). The LISS system involved a titanium alloy plate and utilized unicortical self-drilling, self-locking screws placed through an external jig. Improved rates of union were noted for distal femur fractures when compared to traditional plates.[30] Today there are two types of locked plate systems, either fixed trajectory (see Figure 3) or variable trajectory locking systems.

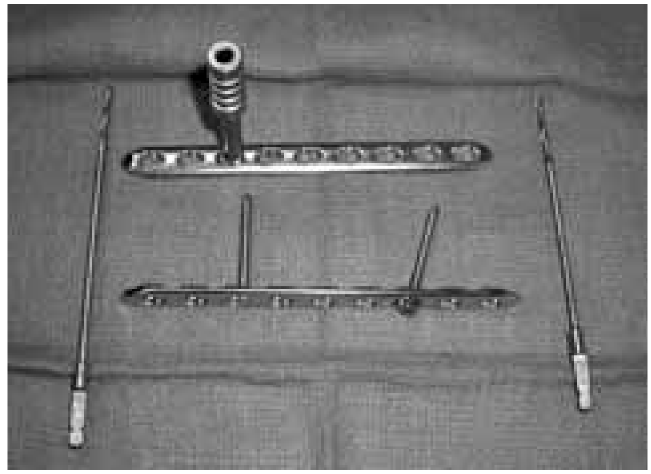

Figure 3. A fixed trajectory locked plate illustrating a locked screw and guide and non-locking screws.

The earlier designs with fixed trajectory screws promoted unicortical locked screw constructs but yielded proximal plate pull-out with torsion.[31] Limitations in screw placement with fixed trajectory screws harkened the development of variable trajectory screws. This design is particularly useful in peri-prosthetic and peri-articular fractures where the ability to re-direct screws is critical for adequate fixation. The variable trajectory plates allow angulation of screw placement followed by end-point tightening. These designs rely on hoop stresses and additional interface between the screw head and plate.[32] Unfortunately no studies to date compare the strength of either the fixed or variable trajectory construct to the other.

Indications for locked fixation include osteopenic bone, segmental bone loss, or excessive comminution.[33, 34] Specific fracture applications with support for its use in the literature includes peri-articular fractures (specifically the distal femur, proximal tibia, proximal humerus, and distal radius), peri-prosthetic fractures, and nonunions.[35] Several complications also exist with locking plate technology which include but are not limited to nonunion, malunion, fracture distraction, loss of diaphyseal fixation, and difficulty with hardware removal.[35] The cost, estimated to be as much as three times for conventional systems, is also a major concern.[35]

Unlike peri-articular fractures of the forearm where the management of fracture fixation has been improved with locking technology, its role in the treatment of shaft fractures of the radius and ulna remains unclear. Fulkerson et al., using a synthetic ulna, compared strength of either conventional or locked plates when place under repetitive axial loads.[33] They concluded that the bicortical locked screw configuration was superior to conventional non-locked screws in comminuted osteopenic bone. The use of only unicortical locked screws was not recommended. In contrast, Weiss et al. studied the role of locking plate technology in an ulna osteotomy model with a 1 cm residual fracture gap and they did not identify a mechanical advantage with the locked plates.[36]

We recommend routine consideration of the use of locking plate technology in the management of peri-articular fractures of the forearm such as with distal radius of olecranon fractures. In the case of radius and ulna shaft fractures, we recommend considering its use in cases with advanced osteopenia, bone loss, and extensive comminution. In applying a locked plate the same approaches are utilized as with traditional plates. Locked plates do not require intimate contact between the plate surface and bone. To avoid malreduction of the bone and to maximize plate to bone contact, locking plates can be pre-contoured and should initially be fixed with non-locking screws. To avoid deformation of the locked screw sites, contouring is done with all locking guides in place. The placement of non-locking screws first allows for the plate to be pulled down to bone. This is followed by placement of locking screws. Once locking screws are placed further reduction of the plate down to bone cannot be achieved. Lastly, six cortices should still preferably be obtained on both sides of the fracture.

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Lectureship

The John Lachman Lecture at the Pennsylvania Orthopaedic Society

Presented by:

Linda L. Emanuel, MD, PhD

"Financial Conflicts of Interest in Orthopaedics"

Dr. Emanuel is currently the Buehler Professor of Medicine at Northwestern's Feinberg School of Medicine and is also a professor at the Kellogg School of Management at Northwestern University. Prior to joining Northwestern University, Dr. Emanuel was Vice President of Ethics Standards and Head of the Institute for Ethics at the American Medical Association. Dr. Emanuel moved to Chicago to create the Institute of Ethics at the AMA and to expand ethics standards. Dr. Emanuel has fostered and supported the deliberations of the Council on Ethical and Judicial Affairs and the continuing evolution of this Council's 150-year-old Code of Ethics.

Dr. Emanuel pointed out that the Bayh-Dole Act of 1980 encouraged investigators to commercialize research conducted with government funds. She further pointed out that the primary interest of researchers was to discover generalizable knowledge. They also have secondary interests, i.e., publishing, income generation, political activism, etc. Thus, a conflict between the primary and secondary interests, in which the secondary interest may distort judgments relating to the individual's primary interests can occur. A conflict of interests affecting one's judgment is common. The problems arise, however, when these conflicts are not recognized nor adequately dealt with. Financial support by the pharmaceutical industry can influence research on interpretation of data. Stated is the fact that disclosure is not a sufficient safeguard against financial conflicts. Dr. Emanuel further cited management principles and prohibitions as found in the American Academy of Orthopedic Surgeons Standards of Professionalism as required safeguards.

Although clearly controversial, Dr. Emanuel's lecture was well received and clearly in keeping with the Lachman principles of integrity, education and excellence in patient care.

Joe Torg, MD

Lectureship

The Howard H. Steel Lecture at the Philadelphia Orthopaedic Society

Presented by:

Brian Jared Cole, MD

"Articular Injuries with Emphasis on the Younger Patient"

The Philadelphia Orthopaedic Society gathered on September 8th, 2008 for its annual lectureship in honor of one of its most respected and loved professors, Howard H. Steel. Dr. Steel, who was on hand for the occasion, was introduced by Dr. Albert Weiss of Temple Orthopaedics and Shriner's Hospital for Children. Dr. Weiss fondly reminisced on memories of his residency and long relationship with Dr. Steel.

This year's Steel lecture, "Articular injuries with emphasis on the younger patient" was given by Dr. Brian Jared Cole, Professor of Orthopaedic Surgery and head of the Cartilage Restoration Center at Rush University. Diagnosis and treatment options for articular cartilage disease and meniscal deficiency were discussed. Techniques such as microfracture, osteochondral grafting, and autologous chondrocyte implantation were reviewed. Dr. Cole also addressed meniscal allograft transplantation techniques and commented on future options for the treatment of articular cartilage problems.

Of note, the Philadelphia Orthopaedic Society honored Dr. Andrew Collier, past president 2007–08, for his leadership, procurement of endowed lectureships, and contributions to our profession.

Abtin Foroohar, MD

Ray Moyer Inducted into the Temple University Athletic Hall of Fame

Dr. Ray Moyer, Temple University team physician, was inducted into the Temple University Athletic Hall of Fame alongside former basketball coach John Chaney on Saturday, January 24, 2009. Since 1978, Dr. Moyer, the Howard Steel Professor of Orthopaedic Surgery in the Temple University School of Medicine, has served as the team physician for Temple's student-athletes as well as the Medical Director of Temple's pioneering sports medicine centers. During his career, he has cared for thousands of athletes from the high school level to the pros, providing the same high standard of care to all.

The ceremony, which took place in the Great Court of Temple's Mitten Hall, was a celebration of Dr. Moyer's career and service to the University. Friends, family colleagues, coaches, and many of the athletes he served, were among those in attendance. Those who could not be in attendance such as Bruce Arians, Offensive Coordinator for the Super Bowl Champion Pittsburgh Steelers; former NFL player Lance Johnstone; past Temple University President Peter Liacouras; and Dr. Joe Torg, sent their reflections, memories, and well-wishes via video. In addition, Pennsylvania Governor, Edward G. Rendell, proclaimed the day, "Dr. Ray Moyer and Coach John Chaney Day" across the Commonwealth.

In an interview with Mike Kern of the *Philadelphia Daily News,* John Chaney talked about Dr. Moyer and their induction together into the Hall of Fame. Chaney said, "I made it very clear I was not interested . . . unless they [also] recognized Dr. Moyer. A lot of people don't realize, here's a guy who's been there not only for Temple, but for the city, the 76ers, for high school kids. I remember when I coached at Gratz, he and Dr. Torg were doing things [for] free . . . for people who didn't have any money. This guy is something very special." Chaney also went on to say, "I know Dr. Moyer is somewhat like me. He's always in the background, but his devotion to the hospital and the university has always been there. He was there before me, working with the community, with poor people. Most people have come and gone."

Dr. Moyer was introduced by Temple Sports Medicine athletic trainer and friend Jim Rogers, who echoed Chaney's remarks about Dr. Moyer's selfless and tireless dedication to the University and the athletic department. Following the official induction into the Hall by Temple Athletic Director Bill Bradshaw, Dr. Moyer came to the podium. In his remarks, he thanked his brothers and sisters, all of whom were in attendance, many travelling from as far away as California. Dr. Moyer expressed how fortunate he was to be given many opportunities due to the sacrifices made by his siblings that came before him. He also thanked his children, Jed, a Temple medical student, and Emily, a registered nurse and Master's nursing student at the University of Pennsylvania, and also his wife Page, who herself has been a fixture on the sidelines and at Dr. Moyer's side assisting him for many years.

An outstanding athlete in his own right, Dr. Moyer's career in athletics began as a student at Pennridge High School, where he earned All-Buxmont recognition in football and baseball, as well as all-state honors in baseball. He attended Lafayette College, where he continued his baseball career and earned a place on the National Association of Intercollegiate Athletics All-American team. After graduation from Lafayette in 1963 with a degree in biology, he was drafted by the Chicago Cubs. Dr. Moyer graduated from the University of Pennsylvania Medical School in 1968 followed by an internship at the University of Vermont. He joined the Navy and served as a flight surgeon in Vietnam attached to a Marines unit from 1970–1971. In 1972, Dr. Moyer came to Temple for his orthopaedic residency, where he has continued in practice through today. In addition to his service to Temple's athletes, he was also team physician for the Philadelphia 76ers from 1988 to 1990.

Esteemed and admired by all who know him for his quiet and effective approach to his responsibilities, Dr. Moyer's induction into the Hall of Fame is without question deserving and overdue.

Jennifer Hagopian, MEd, ATC

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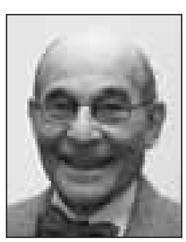

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Temple University Hospital
Department of Orthopaedic Surgery and Sports Medicine
House Staff 2008–2009

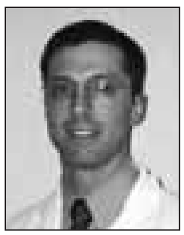
Simon Chao, MD
PGY-5

Neil MacIntyre, MD
PGY-5

Carlos Moreyra, MD
PGY-5

Alyssa Schaffer, MD
PGY-5

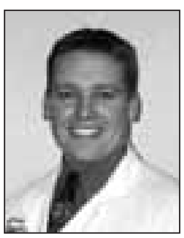
Abtin Foroohar, MD
PGY-4



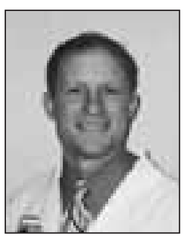
John Parron, MD
PGY-4

Allen Tham, MD
PGY-4

Irfan Ahmed, MD
PGY-4

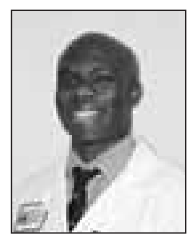


Ian Duncan, MD
PGY-3

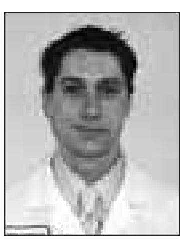


Brian George, MD
PGY-3

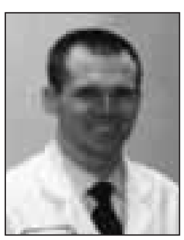
Christopher Kestner, MD
PGY-3



Gbolabo Sokunbi, MD
PGY-3



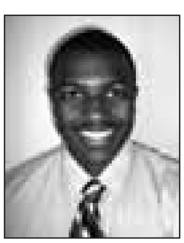
Nate Bodin, MD
PGY-2



John Fowler, MD
PGY-2

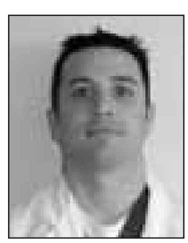
Jung Park, MD
PGY-2

John Richmond, MD
PGY-2



Emmaneul Atiemo, MD
PGY-1

Katherine Criner, MD
PGY-1



Joseph Dwyer, MD
PGY-1

Matthew Kleiner, MD
PGY-1

Snapshots from 2008–2009


The Trauma team getting their Ilizarov on


PGY-2 class


Represent!


Temple Ortho at the AAOS Vegas '09


PGY-5s and the Wetzels


Getting their Letournel on


At the Top of the Bell Tower — POS


About to save some lives in clinic


Taking care of business


Punishment for the interns


Quick, snap a picture while they're all dressed up

Working the OR schedule

Does he have a license to carry that?

“You’d better not put this picture in the journal!”

Department of Orthopaedic Surgery and Sports Medicine Graduating Residents 2009

Simon Chao, MD

Simon grew up in southern New Jersey. He graduated from the University of Pennsylvania, majoring in the History and Sociology of Science and Biological Basis of Behavior. He then completed his medical school at Temple, graduating AOA. Simon is pursuing a Spine Surgery Fellowship at Massachusetts General Hospital and Brigham and Women's Hospital in Boston, Massachusetts.

Neil MacIntyre, MD

Neil grew up in Durham, North Carolina. He attended Cornell University where he earned a Bachelor's Degree in Economics. Neil completed his medical school training at Temple University School of Medicine. He has been accepted for a fellowship in Orthopaedic Trauma at the Hospital for Special Surgery at Weill Cornell Medical College in New York, New York.

Carlos Moreyra, MD

Carlos grew up in Miami, Florida. He graduated from Florida International University with a Bachelor of Arts in Chemistry. He completed his medical training from Temple University. Carlos is pursuing a fellowship in Sports Medicine at the Center for Athletic Medicine in Chicago, Illinois.

Alyssa A. Schaffer, MD

Alyssa grew up in Scranton, PA. She is a graduate of the University of Pennsylvania where she graduated with a Bachelor's Degree in Biology. She earned her medical degree at Temple University School of Medicine. Alyssa is pursuing a fellowship in Hand Surgery at Baylor University in Houston, Texas.

Temple AO Trauma Fellow 2008–2009

Siddharth B. Joglekar, MD

Siddharth, fondly known as "Sid," is originally from Bombay, India. He came to us after completing a fellowship in total joint arthroplasty at the University of Minnesota. Sid completed his medical school as well as orthopaedic residency training in India prior to coming to the United States for additional fellowship subspecialty training. As would be expected, he has a particular interest in complex orthopaedic trauma and has been an asset to the Temple orthopaedic program during his stay with us. His genuine good nature and sense of humor will be missed after he leaves to start his fellowship in spine surgery back in Minnesota. (He's actually a big fan of the cold weather, believe it or not!) We wish him the best of luck in his future endeavors.

Update on the Residency Program

I will begin my update of the Temple Ortho Residency Program by saying that the program remains strong and continues to thrive. Last year's graduating class of Drs. Wade Andrews, Kris Matullo, Joe Morreale, and Bill Pfaff all passed Part 1 of their ABOS Board Exams extending our streak of a 100% pass rate on Part 1 to six years. In addition, this year we underwent our scheduled ACGME program site review and received high marks including continued full accreditation and were rewarded the maximum five-year period prior to another required site visit.

Since taking over the reigns of the residency program, a number of changes have been implemented. The Fox Chase Cancer Center experience combined with the Jeanes Hospital rotation has been a great success providing the residents with a new and unique Orthopaedic Oncology experience. Similarly, the shift of our Pediatrics experience to St. Christopher's Hospital for Children also continues to be a success as our residents are benefiting from working at one of only two Level 1 Pediatric tertiary care trauma centers in Philadelphia. Similarly, the Shriner's Hospital for Children continues to be an integral and vibrant part of the Pediatric experience. The rotations at Abington Memorial Hospital, now under the direction of Dr. Andrew Star, also continues to provide a superb high-volume community experience.

Research efforts continue to grow amongst the residents. Over this past year, our residents have presented research at almost every major national meeting. Much of their success is categorized for you in this journal. Monthly research meetings are held to review the progress and steps involved in their many studies. Joanne Donnelly has been critical in providing the necessary day-to-day resources. Similarly, we are thankful to the John Lachman Society's generous support of these research endeavors. Beginning this year, on the annual Research Day, a new tradition will be initiated with the presentation of a "Senior Thesis" by each of the graduating chief residents.

Lastly, I'd like to share a few parting words on our graduating residents. After careful analysis of the highest RVU-per-case ratio, Dr. Simon Chao has chosen to pursue a fellowship in Spine Surgery. I am particularly proud to see another Temple alum go on to train at the Massachusetts General Hospital. Moreover, Simon deserves additional praise for his tireless and often thankless work as the Editor of this Journal for the past two years. Dr. Neil MacIntyre has remained true to his word and plans on pursuing a fellowship in Traumatology. Despite being wooed by multiple institutions including his great whale, Duke, he is moving on to New York City to train at the Hospital for Special Surgery. Neil has developed a confident but humble approach that will serve him well. Dr. Carlos Moreyra is taking his trance-music and unflappable conservative beliefs to Chicago for a Sports Medicine fellowship. Thereafter, we are proudly looking forward to his service in the United States Navy. Last but not least, Dr. Alyssa Schaffer (pronounced ah-liss-a) has chosen to perform a Hand Surgery fellowship. Alyssa has always impressed with her poise and presence and I know that she will continue to impress as a budding hand surgeon.

I am particularly proud of these four residents as they were my juniors when I was a chief resident. It's been a privilege watching them develop into excellent Orthopaedic Surgeons. I commend each of them for their hard work and diligence as residents in our program and look forward to having them carry the title of Temple Orthopaedic alumni as they move forward in their professional careers.

Asif M. Ilyas, MD

News from the Department of Orthopedic Surgery and Sports Medicine Office of Clinical Trials and Research Support

The Office of Clinical Trials and Research Support was established in 2004 under the direction of Pekka A. Mooar, MD, and supported by the School of Medicine's Office of Clinical Trials. Ms. Joanne Donnelly is the full-time research and program coordinator.

We are happy to report the program is thriving and is continuing its commitment to encourage and facilitate faculty and resident research projects. This office is entrusted with providing the resources to help approve, finance, publish, and disseminate the Department's many and invaluable academic projects. Our support begins with preparing potential studies for evaluation by the Institutional Review Board, and ensuring their approval. We continue through our work with Arleen Wallen (office of clinical trials), to assist in the development of all budgets and legal contracts, and Craig Pfister who acts as the industry liaison to bring any clinical or device trials to the attention of the faculty members. In short, the residents and faculty are never alone in their drive to contribute to the orthopaedic academic community. In addition, this office sponsors several creative projects to encourage such vital participation.

Over the past year, The Orthopaedic Department has continued the tradition of meeting with the members of the Temple Medical Student Orthopaedic Interest Group known as the OIG. This group of mainly freshmen medical students has grown exponentially in the past four years ensuring our commitment to offering knowledge and guidance to any Temple medical student interested in our specialty.

Dr. Mooar and Ms. Donnelly currently direct the Summer Medical Research Program, funded by the John Lachman Orthopedic Research Fund. Students embark on the formidable task passing the human subjects ethics training certificate program before tackling their respective projects. The eight-week-long research session provides the students the knowledge to prepare their research documents, work with John Gaughan, PhD, who assists with statistical analysis, and Barbara Kuchan from Temple Information Services and Education Programs who guides students on the best ways approach researching articles.

Under the guidance of Joseph S. Torg, MD, and Ms. Donnelly, all of the students meet each Tuesday to appraise the progress of their work. Previous OIG students have stated that the weekly meeting was extremely helpful in developing their manuscripts. The summer of 2008 was a banner year for student research. We hosted 17 (up five from the previous year) students. Ten papers will be published in the *Temple University Journal of Orthopaedic Surgery & Sports Medicine* as a result of that strong effort.

In 2009, we will host 20 students and look forward to another meaningful and engaging group of Temple OIG medical students.

2008 Summer Medical Student Research Projects:

See Journal under "Medical Student Research Projects"

2009 Proposed Summer Medical Student Research Projects:

Dr. Torg (7 projects)

- Corticosteroid Use in Sports Medicine Practices and Reported Complications with Particular Regard to Indications and Contraindications: A Meta Analysis
- Narcotic Addiction Syndrome in Orthopedic Patients
- Beach and Water Recreational Catastrophic Events
- Indications and Contraindications for the Use of Schedule II Controlled Substances in an Orthopedic Practice
- Meta-analysis of Patients Greater than 40 Years of Age Who Have Undergone Meniscal Repair
- Opiate Psychosis and Its Relationship to Urban Crime
- Outcome of Arthroscopic Repair of Rotator Cuff Repairs

Dr. Mooar (6 projects)
- Over-Treatment and Under-Treatment of Pain in an Orthopaedic Patient
- Missed Potential Drug Reactions/Toxicity in an Orthopaedic Outpatient Setting
- Transient Renal Failure in TKA and THA: Risk Factors, Rate Prevention Strategies
- DVT in Knee Arthroscopy
- Vitamin D and HIV Patients
- Vitamin D and Low Energy Orthopaedic Injuries

Dr. Rehman (3 projects)
- Complications Associated with Selective Embolization of Pelvic Hemorrhage in Trauma Patients
- ATV (All Terrain Vehicle) Injuries in an Urban Level 1 Trauma Center
- Healthcare Provider Attitudes Towards Orthopaedic Gunshot Victims

Dr. Ilyas (2 projects)
- Meta-Analysis of the Treatment of Wrist Osteonecrosis
- Amputations of the Hand

Dr. Sewards (2 projects)
- Case Reports and Review of Literature of Acute Brachial Neuritis
- Review of Pertinent Anatomy of Arthroscopic Portals of the Shoulder

Current Industry-Sponsored Clinical Trials Drug or Device:

Omeros Corporation
ACL Reconstruction
Pekka A. Mooar, MD, Principal Investigator

Smith and Nephew
(TRUST) Trial to Evaluate Ultrasound in the Treatment of Tibia Fractures
Saqib Rehman, MD, Principal Investigator

Synthes Spine
Moderate Lumbar Spinal Stenosis
F. Todd Wetzel, MD, Principal Investigator

Current Investigator Initiated Studies Coordinated by the Office:

What Is the Optimal DVT Prophylaxis for Orthopaedic Trauma, Knee Arthroscopy and Total Joint Arthroplasty Patients? PI: Bruce Vanett, MD, John Fowler, MD, Michael O'Malley, MSIV. *IRB #11957*.

Endoscopic Leg Fasciotomy for the Treatment of Exertional Compartment Syndrome: A Case Series. PI: Joseph Torg, MD, Carlos Moreyra, MD. *IRB #12166*.

The Incidence of Deep Infection After Treatment of Open Elbow Fractures. PI: Asif M. Ilyas, MD, Siddharth Joglekar, MD, Martin Alvarez, MSIV. *IRB #12161*.

Burden of Treatment of Orthopaedic Gunshot Wound Injuries: The Philly Experience. PI: Asif Ilyas, MD, Hashim Qureshi, BA (MS candidate May 2009). *IRB #12092*.

Outcome Analysis of Gunshot Tibia Fractures: A Comparison with Open and Closed Tibia Fractures. PI: Saqib Rehman, MD, Simon Chao, MD, John Richmond, MD, Siddharth Joglekar, MD. *IRB #11952*.

Management of Gunshot Pelvic Fractures: A Retrospective Review. PI: Saqib Rehman, MD, Christopher Kestner, MD, Colin Slemenda, BS. *IRB #11857*.

Management of Hand Infections: A Review of Hand Infections Presenting to the Emergency Department of a Major Urban Medical Center. PI: Asif M. Ilyas MD, John Fowler MD, Michael O'Malley, MSIV. *IRB #11424*.

Pathologic Examination of Bullet Injured Bone Fragments. PI: Asif M. Ilyas MD, Neil R. MacIntyre MD (not submitted to IRB for review yet).

Management of Humerus Fractures from Gunshot Injury. PI: Asif M. Ilyas, MD, Joseph Dwyer, MD. *IRB #11422*.

Joanne Donnelly

Instructions to Authors

Editorial Philosophy

The purpose of the *Temple University Journal of Orthopaedic Surgery & Sports Medicine (TUJOSM)* is to publish clinical and basic science research performed by all departments of Temple University that relate to orthopaedic surgery and sports medicine. As such, TUJOSM will consider for publication any original clinical or basic science research, review article, case report, and technical or clinical tips. All clinical studies, including retrospective reviews, require IRB approval.

Editorial Review Process

All submissions will be sent to select members of our peer review board for formal review.

Manuscript Requirements

Manuscripts are not to exceed 15 double spaced type-written pages and/or 5,000 words (minus figures/tables/pictures). The Manuscript should contain the following elements: Title page, Abstract, Body, References, and Tables/Legends. Pages should be numbered consecutively starting from the title page.

(1) Title Page — The first page should contain the article's title, authors and degrees, institutional affiliations, conflict of interest statement, and contact information of the corresponding author (name, address, fax, email address).

(2) Abstract — The second page should be a one-paragraph abstract less than 200 words concisely stating the objective, methods, results, and conclusion of the article.

(3) Body — Should be divided into, if applicable, Introduction, Materials and Methods, Results, Discussion, and Acknowledgements. Tables and figures (in JPEG format) with their headings/captions should be listed consecutively on separate pages at the end of the body, not continuous within the text.

(4) References — Should be listed following the format utilized by JBJS. For example: Smith, JH, Doe, JD. Fixation of unstable intertrochanteric femur fractures. *J Bone Joint Surg Am.* 2002;84:3553–58.

(5) Each page should have continuous line numbers placed, as well as the first author's name, date submitted and page number in the footer.

Submit

- Three hard copies
- Two CDs labeled with the author's last name and manuscript title

***Disclaimer:* This journal contains manuscripts that are considered interpersonal communications and extended abstracts and not formalized papers unless otherwise noted.**

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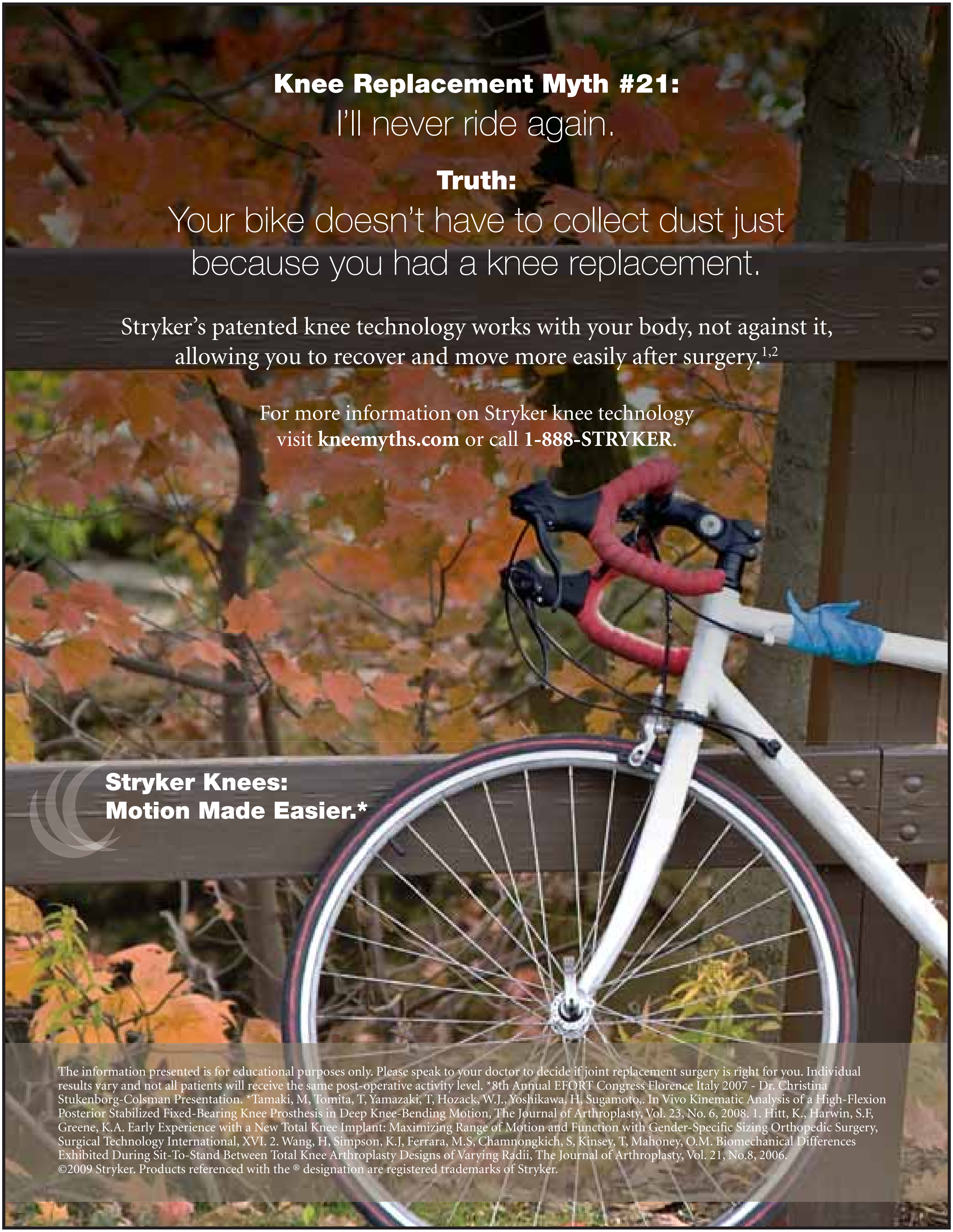
Knee Replacement Myth #21:
I'll never ride again.
Truth:
Your bike doesn't have to collect dust just because you had a knee replacement.
Stryker's patented knee technology works with your body, not against it, allowing you to recover and move more easily after surgery.[1,2]
For more information on Stryker knee technology visit kneemyths.com or call 1-888-STRYKER.
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The information presented is for educational purposes only. Please speak to your doctor to decide if joint replacement surgery is right for you. Individual results vary and not all patients will receive the same post-operative activity level. *8th Annual EFORT Congress Florence Italy 2007 - Dr. Christina Stukenborg-Colsman Presentation. *Tamaki, M, Tomita, T, Yamazaki, T, Hozack, W.J., Yoshikawa, H, Sugamoto,. In Vivo Kinematic Analysis of a High-Flexion Posterior Stabilized Fixed-Bearing Knee Prosthesis in Deep Knee-Bending Motion, The Journal of Arthroplasty, Vol. 23, No. 6, 2008. 1. Hitt, K., Harwin, S.F, Greene, K.A. Early Experience with a New Total Knee Implant: Maximizing Range of Motion and Function with Gender-Specific Sizing Orthopedic Surgery, Surgical Technology International, XVI. 2. Wang, H, Simpson, K.J, Ferrara, M.S, Chamnongkich, S, Kinsey, T, Mahoney, O.M. Biomechanical Differences Exhibited During Sit-To-Stand Between Total Knee Arthroplasty Designs of Varying Radii, The Journal of Arthroplasty, Vol. 21, No.8, 2006.
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