MAOA BREAK-OUT SESSION #6
BIOMECHANICS AND BASIC SCIENCE
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64. Electrode Placement During Stimulus Evoked Electromyographic Monitoring of Iliosacral Screw Insertion: A Finite Element Model

Michael A. Kopec, B.S.
St. Louis, MO
Berton R. Moed, M.D.
St. Louis, MO
*David W. Barnett, Ph.D.
St. Louis, MO

PURPOSE: The purpose of this study was to evaluate the effect of anode location and drill-bit position on the nerve monitoring technique using three dimensional finite element modeling of the pelvis.

METHODS: A three dimensional finite element model of the pelvis was constructed from computed tomography data to evaluate the effectiveness of five electrode locations and four drill bit positions in varying proximity to the S1 nerve root. The effects of changing anode location and the drill bit position along its insertion path on current density in the S1 nerve root were assessed relative to the magnitude of the maximum current density ($|J_{max}|$) in the nerve root. Five anode locations (drill bit insertion site, ipsilateral anterior superior iliac spine [IASIS], contralateral anterior superior iliac spine [CASIS], dorsal midline [DM], and ventral midline [VM]). The drill bit insertion path was divided, from lateral to medial, into four stations: (1) the iliac side of the sacroiliac joint, (2) anteromedial to the nerve root, (3) the normal final resting position at the midpoint of the sacral body, and (4) across the midline approaching the contralateral nerve root. $|J_{max}|$ was determined for an applied current of 7.28 mA to the drill bit with the closest point of the drill bit to the nerve set at 5 mm.

RESULTS: The DM, VM, and CASIS anode locations provided $|J_{max}|$ data on the proximity to the neural structure in directions that were significantly attenuated at the other two anode locations. As the drill bit moved from lateral to medial from station one to station 2, $|J_{max}|$ was noted to increase. Conversely, moving from II to III and III to IV decreased the peak $|J_{max}|$ by 16.8% and 3.1% respectively.

CONCLUSIONS: The CASIS, VM, and DM anode locations provide adequate monitoring of the spinal nerve roots during iliosacral screw insertion. Furthermore, data variations obtained with anode locations that place the nerve root outside of the primary electric field (i.e., between the anode and cathode) should be anticipated. In addition, in every screw placement procedure there should be an incremental rise in current threshold as the drill bit passes anteromedial to the nerve root.

65. The Effect of Patellar Eversion on the Quadriceps Mechanism of the Rabbit

*Frank L. Walter, M.D.
Detroit, MI
David C. Markel, M.D.
Southfield, MI

Minimally invasive total knee arthroplasty (MITKA) is gaining in popularity and acceptance. One of the primary tenants of MITKA is lack of patellar eversion combined with a quadriceps sparing approach. This approach claims to limit damage to the extensor mechanism and promises an earlier return to function after MITKA. We hypothesized that patellar eversion of the rabbit patella would lead to an increase in muscle and tendon damage as well as increased inflammatory cell infiltrate when compared to a patella that was retracted during a simulated total knee arthroplasty exposure. Two groups of ten rabbits each had a midline approach to the knee performed on each knee. In group I, the patella was everted in the right knee and retracted in the left knee. In group II, the patella was retracted in the right knee and everted in the left knee. Group I had the intervention performed for two hours and the animals were sacrificed and had their extensor mechanisms harvested immediately. Group II rabbits had the intervention performed for three hours and their wounds were closed. These rabbits were then placed into their cages for 48 hours before returning to the operating suite for harvest of their extensor mechanisms. Hematoxylin and eosin stains and Van Gieson staining were used to prepare specimens for analysis. In Group I, there was no evidence of inflammation or disruption of the muscular or tendinous units. In Group II, there was an increase in inflammation and damage to the muscular and tendinous units in the specimens which were everted as compared to the non-everted side. Based on these results, we continue to recommend not everting the patella in TKA as a way of limiting postoperative inflammation and subsequent pain which will likely lead to a quicker rehabilitation and an earlier discharge from the hospital.

66. Characterization of Scaffold Carriers for BMP-9 Transinduced Cell-Based Gene Therapy in Bone Regeneration for Spinal Fusion

Andrew Todd, M.D.
Chicago, IL
*Patrick M. Bolt, M.D.
Chicago, IL
Hue Luu, M.D.
Chicago, IL
Quan Kang, M.D.
Chicago, IL
Purnendu Gupta, M.D.
Chicago, IL
Anthony Montag, M.D.
Chicago, IL
Rex Haydon, M.D.
Chicago, IL
Tong-Chuan He, M.D., Ph.D.
Chicago, IL

BACKGROUND CONTEXT: We have recently demonstrated that BMP-9 is one of the most osteogenic BMPs both in vitro and in vivo. Although comparisons of carriers combined with recombinant BMP-2 have been performed previously, no comparison of carriers for cell-based gene therapy has been performed. In order for further development of gene therapy to occur, it is essential to define the ideal carrier for this application.

PURPOSE: To compare the ability of three carriers to promote osteogenesis in a mouse model of cell-based gene therapy using BMP-9.

STUDY DESIGN/SETTING: A study on the efficacy of collagen sponge, hydroxyl-appetite tri-calcium phosphate (HA-TCP), and demineralized bone matrix (DBM) as carriers for cell-based gene therapy using BMP-9 in a mouse model.

PATIENT SAMPLE: Not applicable.

OUTCOME MEASURES: Radiographic evaluation of bone formation using plain radiography and histologic evaluation by a musculoskeletal pathologist.

METHODS: Forty athymic nude mice were randomized into four groups for subcutaneous implantation of carrier and mouse mesenchymal stem cells infected with adenovirus expressing BMP-9. Each mouse also had a control placed which consisted of carrier with cells infected with adenovirus expressing Green Fluorescence Protein (GFP). One of the four groups had only infected cells injected subcutaneously with no carrier. The following groups were defined: (1) collagen type I sponge, (2) HA-TCP, (3) DBM, and (4) the subcutaneous injection group. The mice were sacrificed at four weeks and plain radiographs obtained. Histologic evaluation of the implantation sites was performed.

RESULTS: In the collagen sponge group, 9 of 10 (90%) had radiographic evidence of new bone formation, 8 of 9 (89%) in the HA-TCP group, 3 of 6 (50%) in the DBM group, and 4 of 9 (44%) in the cell only group. Histologic findings from select samples included the following: better quality and larger amounts of bone were found in the collagen sponge and HA-TCP samples; a more uniform distribution of cells and bone was noted throughout the collagen sponge samples when compared to the other carriers; a decreased number of cells was noted in DBM samples when compared to the other carriers.

CONCLUSIONS: Collagen type I sponge and HA-TCP carriers consistently produce more bone than DBM carrier in cell-based gene therapy using BMP-9. Addtionally, collagen

sponge and HA-TCP provide a better environment for cell based gene therapy as evidenced in the histologic data.

DISCLOSURES: No disclosures.

CONFLICT OF INTEREST: No conflicts.

67. Support and Satellite Cells Within the Rabbit Dorsal Root Ganglion: Ultrastructure of a Perineuronal Support Cell

*Krzysztof B. Siemionow, M.D.
Cleveland, OH
James N. Weinstein, D.O.
Lebanon, NH
Robert F. McLain, M.D.
Cleveland, OH

BACKGROUND: The role of dorsal root ganglion neurons in the generation of acute and chronic pain processes has been better delineated over the past few years, but the role of the satellite support cells that are so closely associated with the neuronal cell bodies remains poorly understood. This study assessed the range of morphometries presented by satellite cells of the rabbit DRG, in order to determine whether more than one population of satellite cells could be identified.

METHODS: Ten adult New Zealand white rabbits were anesthetized and perfused with a mixture of saline and Karnovsky's fixative. After the animals were sacrificed, the cord and roots were excised, and the spinal nerves were sectioned 1.0 cm distal to the DRG at each level. Ganglia were excised and post-fixed in quarter-strength Karnovsky's fixative for two hours. Sections were post-stained with uranyl acetate and Reynolds' lead citrate. Sections from L2–L5 ganglia were prepared, cut, and analyzed under a transmission electron microscope. Neurons and their associated satellite cells for study were identified by component-biased selection.

RESULTS: One hundred ninety neurons were selected for analysis. Three subgroups of satellite cells were identified. The predominant group was typical of previously described satellite cells, forming a thin, continuous sheet over the surface of each neuron. A second subgroup appeared more consistent with undefined stromal cells adjacent to the neuron, but not actually in contact with it. A third subgroup consisted of highly complex and unusual cells. We identified 19 satellite cells (4%) that did not conform to any previous description of either satellite cells or other glial cell lines. These cells were characterized by larger nuclei, with numerous inclusions, and by the unique and extensively convoluted reflections of the cellular membrane. These cells were often "perched" or "piggy-backed" on top of a convoluted and multilayered cytoplasmic sheet.

CONCLUSION: A new type of support cell in the rabbit dorsal root ganglion, representing a different cell line or a highly adapted cell with specific functional capacities (protein synthesis, transport, communication, etc.) different from those of a typical satellite cell.

68. Fatigue Performance of THR Constructs Using Composite Femurs

*Gregory P. Ballard, M.D.
Wichita, KS
Peter J. Czuwala, MSBE
Wichita, KS
Alexander M. C. Chong, MSAE, MSME
Lawrence, KS
Elizabeth A. Friis, Ph.D.
Lawrence, KS
Francis W. Cooke, M.D.
Wichita, KS

BACKGROUND: Synthetic analogue femurs have been used in numerous quasi-static laboratory total joint replacement and fracture fixation studies to simulate the structural properties of bone. However, the fatigue resistance of such analogue models is currently unknown. The objective of the study was to determine and compare the fatigue resistance of third and fourth generation analogue bone models in a clinically relevant simulated total hip replacement (THR) fatigue test.

METHODS: Six third generation and six fourth generation synthetic analogue femur bone models (model #3306, Pacific Research Labs, Vashon, WA) were used for this study. The bone models were broached and Exeter™ prostheses (Stryker/Howmedica/Osteonics, Mahwah, NJ) were implanted using Simplex P® (Stryker) bone cement vacuum-mixed in a standard operating room environment. The femurs were sectioned below the distal plug and the proximal femurs prepared for one-legged stance loading. Constructs were mounted into MTS test systems and subjected to cyclic compressive loading under load control from 2.67 kN with R = 0.1 at 5 Hz while in an environmental chamber filled with saline solution at 37 0C. The number of cycles, actuator displacement, and load magnitudes were recorded using LabVIEW. One million loading cycles represented approximately one year of simulated loading in vivo. Bone-implant constructs were tested for up to ten million cycles or until complete structural failure of the construct.

RESULTS: Structural failure of the third generation femurs occurred at a mean of 3.16 million cycles although crazing occurred much earlier in all specimens. All fourth generation femurs withstood 10 million cycles with no total structural failure; minor crazing occurred in two specimens.

CONCLUSIONS: The results provide evidence that the fourth generation analogue bones exhibit superior performance in in-vitro fatigue testing simulating THR applications as compared to the third generation bones in this proximal femur model.

69. Biomechanical Testing of Displacements After Selective Cutting of Acromioclavicular Joint Ligaments

*Steven J. Lalliss, M.D.
San Antonio, TX
John F. Kragh, Jr,. M.D.
San Antonio, TX

PURPOSE: Type III acromioclavicular joint injuries are common injuries, and there is disagreement whether to treat these injuries operatively or non-operatively. Classification schemes have historically viewed coracoclavicular ligament rupture as involving both the conoid and trapezoid ligaments simultaneously. We believe that some injuries that appear to be type III injuries on static plain films may actually be type IV injuries, with significant posterior displacement, seen on cross-arm adduction stress radiographs. We believe that type III injuries actually consist of a continuum of intermediate injury patterns, with injury to either the conoid or trapezoid ligaments or both.

MATERIALS AND METHODS: We measured superior, anterior, posterior, and axial compression and distraction of the clavicle relative to the acromion after sequential sectioning of the acromioclavicular (AC) capsular ligaments and then either the conoid or trapezoid ligaments.

RESULTS: Sectioning of the AC ligaments resulted in a significant increase in the anterior and posterior displacement of the clavicle on the acromion as well as distraction of the AC joint. Sectioning of the AC and conoid ligaments increased anterior displacement, but posterior translation was affected insignificantly. Sectioning of the trapezoid had the opposite effect, significantly increasing posterior displacement, but having little effect on anterior displacement.

CONCLUSIONS: Our data suggest that intermediate acromioclavicular injury patterns may exist, yet previous classifications do not describe trapezoid ligament injury in combination with acromioclavicular capsular ligament disruption. We believe that posterior displacement of the clavicle and compression of the acromioclavicular joint is symptomatic and warrants consideration for surgical treatment.

70. Biomechanics of Elite Windmill Softball Pitching

*Michael E. Brunet, M.D.
Alexandria, LA
Sherry L. Werner, Ph.D.
New Orleans, LA
Gregory W. Stewart, M.D.
New Orleans, LA
Mr. John A. Guido
New Orleans, LA

A significant number of time-loss injuries to the upper extremity in elite windmill softball pitchers has been documented. The number of outings and pitches thrown in one week for a softball pitcher is typically far in excess of those seen in baseball. Shoulder stress in professional baseball pitching has been reported to be high and has been linked to pitching injuries. Shoulder distraction has not been studied in an elite softball pitching population. The purpose of this study was to investigate the relationships between kinematic parameters and shoulder distraction, and to compare the magnitudes of joint loads to those reported for collegiate softball and professional baseball pitchers. Three-dimensional, high-speed (120 Hz) video data were collected on rise balls from 24 elite softball pitchers during the 1996 Olympic Games. Kinematic parameters related to pitching mechanics and resultant kinetics on the throwing shoulder were calculated. Multiple linear regression analysis was used to relate shoulder stress and pitching mechanics. Shoulder distraction stress averaged 80% body weight for the Olympic pitchers. Sixty-nine percent of the variability in shoulder distraction can be explained by a combination of seven parameters related to pitching mechanics. Normative ranges for kinematic and kinetic parameters have been established for an elite population of windmill pitchers. Joint loads at the shoulder are similar to those reported in professional baseball pitching, which suggests that these athletes are at risk for overuse injuries. Specific parameters of pitching mechanics correlate with clinically significant injury patterns. Interventions in throwing mechanics to decrease shoulder forces may translate into lower rates of time-loss injury in this group of athletes.

71. The Relationship Between Ceramic Femoral Head Diameter and Burst Strength

Brad Crow, M.D.
Columbia, MO
Nick Burlingame, Ph.D.
Alfred, NY
Louis Serafin, M.D.
Port Huron, MI
*B. Sonny Bal, M.D.
Columbia, MO

INTRODUCTION: Large diameter femoral heads confer increased range of motion and stability in total hip arthroplasty. In ceramic femoral heads, large diameters could also confer increased resistance to catastrophic rupture. The purpose of this study was to determine the possible correlation between the diameter and the burst strength of ceramic femoral heads.

MATERIALS AND METHODS: Femoral heads made of implant-grade magnesia-stabilized zirconia were loaded to failure. All specimens were derived from the same manufacturing batch. Three study groups were compared, each consisting of 10 femoral heads with the following diameter/neck length configurations respectively: 22.2 mm/0, 26 mm/-3.5, and 28 mm/-3.5. Heads were fitted to a 12/14 mm style trunnion (5.72^{o} angle). Each trunnion was made of heat treated implant grade Titanium alloy (Ti6V4Al ELI). A compressive load was applied through a copper washer on mild steel cone until mechanical failure of the head. The mean loads to failure were compared to detect statistical differences between study groups.

RESULTS: 22 mm/0 heads failed at a mean compressive load of 17,626 lbs.; 26 mm/-3.5 heads at 32,637 lbs.; and 28 mm/-3.5 heads at 43,539 lbs. These differences between study groups were statistically significant ($p<0.05$).

CONCLUSION: Modern manufacturing methods and material improvements have reduced, but not eliminated the risk of ceramic femoral head breakage. The present data demonstrate that the load to failure increases with increasing diameter of the femoral head. These results suggest that in addition to hip stability, the increased resistance to failure caused by static loading may be another advantage of large-diameter ceramic femoral heads.

72. Analysis of Axial Torques in Total Hip Arthroplasty

*James D. Mitchell, M.D.
Wichita, KS
John R. Schurman, II, M.D.
Wichita, KS
Peter J. Czuwala, MSBE
Wichita, KS
Jeff R. S. Leiter, MSBE
Winnipeg, Canada
Francis W. Cooke, Ph.D.
Wichita, KS

INTRODUCTION: Head offset is often manipulated to create stability in total hip arthroplasty (THA). This may promote torsional instability leading to premature failure of the femoral component. The effects of varied femoral offset and neck shaft angle on the torsional loads seen in physiological loading of THA constructs were investigated.

METHODS: Femoral components with two neck angles (125˚ and 140˚) and five head offsets (35, 40, 45, 50, and 60 mm) were implanted into four synthetic analog femurs. The distal end of the femur was potted and secured to the load cell of an 858 MTS servohydraulic biaxial mechanical test system. Reported maximum 3-D physiological loading forces for normal walking, rising from a chair, and stair climbing were applied to the femoral head of the construct through a pseudo-acetabulum via an adjustable pulley system. Torque about the longitudinal axis of the femur was analyzed with respect to neck shaft angle and head offset for the given loading vectors. Experimental and analytical torques were compared and an algorithm developed to predict torques about the longitudinal axis of the femoral component for various mechanical constructs.

RESULTS: Preliminary results indicate increased head offset produces greater axial torsion regardless of neck shaft angle. Hip flexion angle affects torsional loads independent from offset and can significantly increase torque environment.

CONCLUSIONS: An experimentally validated algorithm can predict the torsional loads to be resisted to ensure the stability of an arthroplasty construct.

73. Pull Out Strength Variance Among Self-Tapping Screws in Osteoporotic Bone: Theoretical Answers to Biomechanical Issues

*Andrew J. Schoenfeld, M.D.
Akron, OH
Gregory A. Vrabec, M.D.
Akron, OH
Glen Njus, Ph.D.
Akron, OH
Mr. Suneel Battula
Akron, OH
Vivek Sahai, M.D.
Akron, OH

Osteoporosis, a condition characterized by a decrease in bone mass with decreased bone density, is a serious cause of fractures in the United States. The necessity of providing adequate osteofixation in osteoporotic fractures is a difficult dilemma that has only been marginally addressed in the literature.

Recent studies have demonstrated that the pullout strength of STS increase with insertion depth up to 1 mm beyond the far cortex, but statistically significant increases in pullout strength, have not been appreciated with insertion beyond 1 mm.

This study attempted to apply these findings to a synthetic “osteoporotic” bone model and determine whether the above recommendations hold true. One hundred and twenty self-tapping screws were randomly divided into five groups, each representing a different depth of insertion. Peak force was determined using an Instron 8511 materials testing system with all trials ending in screw pullout. A statistically significant difference was found for screws inserted 1 mm short of the far cortex, flush with the cortex, as well as 1 mm and 2 mm beyond the far cortex. The conclusions based on these results corroborate anecdotal recommendations that were refuted by two recent studies on pullout strength of STS in healthy bone. The results of this study indicate that self-tapping screws must be inserted 2 mm beyond the far cortex in osteoporotic bone in order to achieve adequate fixation.