28th Annual Scientific Meeting

Limb Lengthening and Reconstruction Society:
ASAMI–North America

July 19 & 20, 2019

Fairmont Copley Plaza

Boston, MA

LLRS: ASAMI–North America

Future Meetings

AAOS Specialty Day

March 28, 2020

Orlando, FL

29th Annual Scientific Meeting

July 17 & 18, 2020

New York, NY

Upcoming AAOS Meeting

2020 Annual Meeting

March 24–28, 2020

Orlando, FL

For more information:

Karen R. Syzdek, Executive Director

info@llrs.org

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

LLRS: ASAMI–North America
Meetings & Presidents

Year	Location	President
1990	Baltimore, MD	Dror Paley, MD
1991	Kiawah, SC	Stuart A. Green, MD
1993	San Francisco, CA	Alfred D. Grant, MD
1994	New Orleans, LA	Deborah Bell, MD
1995	Orlando, FL	Jason Calhoun, MD
1996	Atlanta, GA	Mark T. Dahl, MD
1997	San Francisco, CA	John Herzenberg, MD
1998	New Orleans, LA	James Aronson, MD
1999	Dana Point, CA	J. Charles Taylor, MD
2000	Lake Buena Vista, FL	Charles T. Price, MD
2001	Berkeley, CA	Richard S. Davidson, MD
2002	Las Colinas, TX	John J. Gugenheim, MD
2003	Boston, MA	James C. Binski, MD
2004	Toronto, Ontario, CANADA	John G. Birch, MD
2005	New York, NY	William G. Mackenzie, MD
2006	San Diego, CA	James. J. Hutson, Jr., MD
2007	Chicago, IL	David W. Lowenberg, MD
2008	Albuquerque, NM	George Cierny, III, MD
2009	Louisville, KY	Paul T. Freudigman Jr., MD
2010	New York, NY	John K. Sontich, MD
2011	Chicago, IL	Doreen DiPasquale, MD
2012	Cincinnati, OH	James J. McCarthy, MD
2013	New York, NY	S. Robert Rozbruch, MD
2014	Montreal, Quebec CANADA	Sanjeev Sabharwal, MD
2015	Miami, FL (ILLRS Congress)	Reggie C. Hamdy, MD
2016	Charleston, SC	Joseph R. Hsu, MD
2017	Park City, UT	Karl Rathjen, MD
2018	San Francisco, CA	Kevin W. Louie, MD
2019	Boston, MA	J. Spence Reid, MD

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

First Vice President and Program Chair

Austin T. Fragomen, MD
Fellowship Director, LLCRS
Associate Professor, Weill Cornell
Associate Attending, Orthopaedic Surgery
Hospital for Special Surgery
535 East 70th Street
New York, NY 10021
fragomena@hss.edu
212–606–1550
Twitter: @SmyL_NY
FB: @limblengtheningny

Program Committee

Austin T. Fragomen, MD

J. Spence Reid, MD

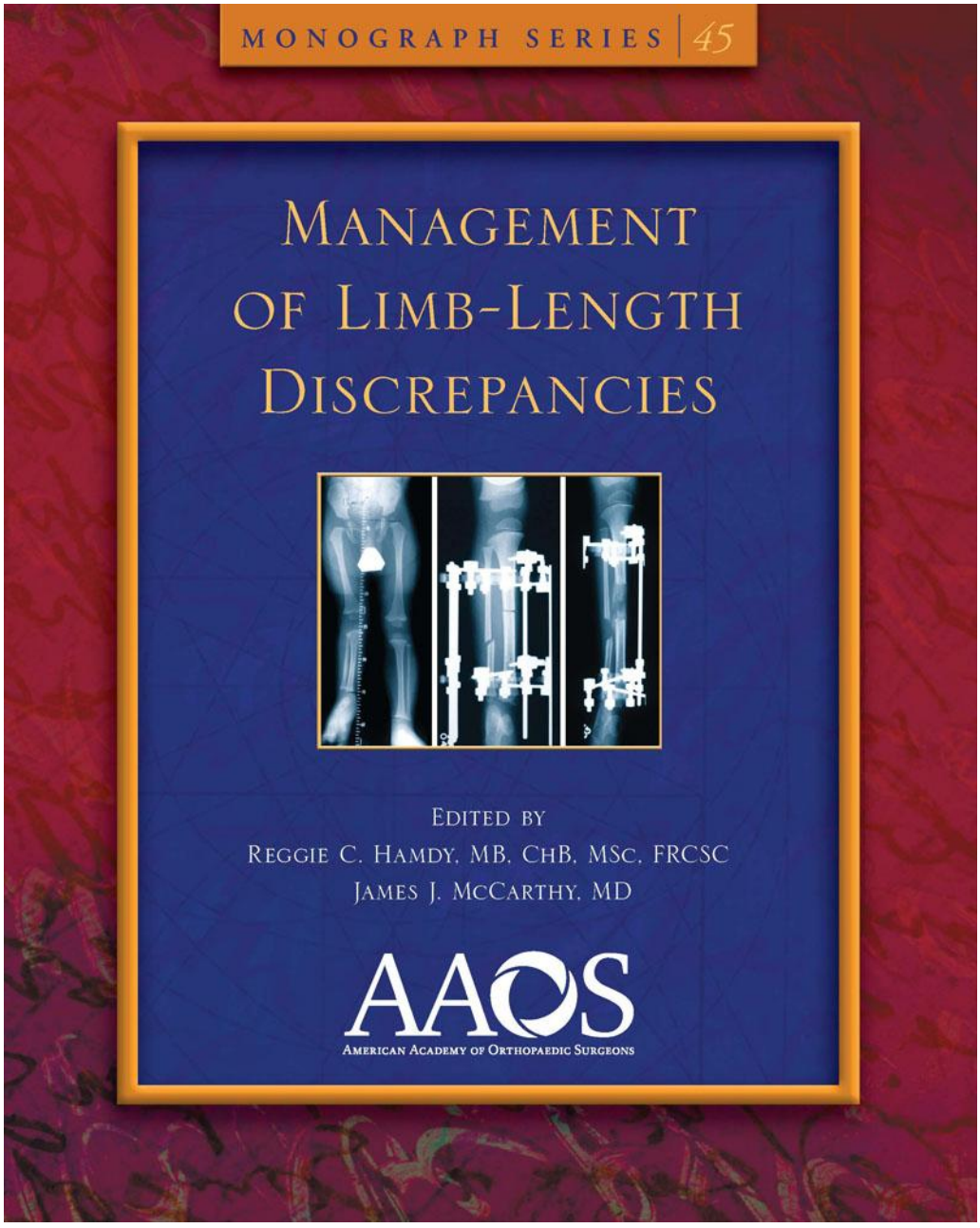
Raymond W. Liu, MD

Karen R. Syzdek, Executive Director

Please place your mobile devices on vibrate or silent.

Management of Limb–Length Discrepancies

Reggie Hamdy and Jim McCarthy (Eds.)



To review and order online visit

http://www3.aaos.org/product/details_page.cfm?code=05202&dlink=05202TOC.cfm

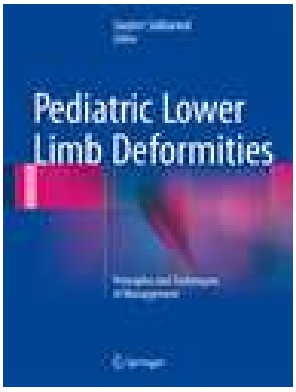
Pediatric Lower Limb Deformities

and

Limb Lengthening and Reconstruction Surgery Case Atlas Series

Pediatric Lower Limb Deformities

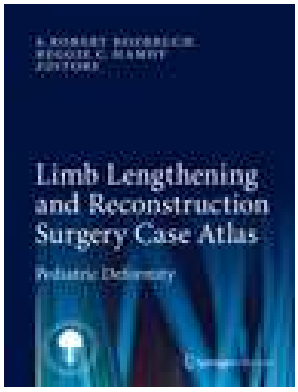
Sanjeev Sabharwal (Ed.)



Pediatric Deformity

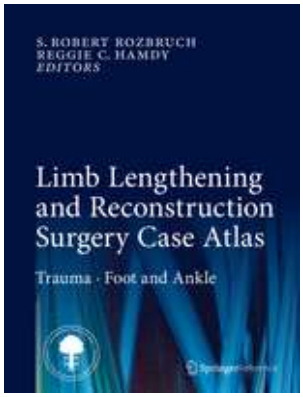
S. Robert Rozbruch and

Reggie C. Hamdy (Eds.)



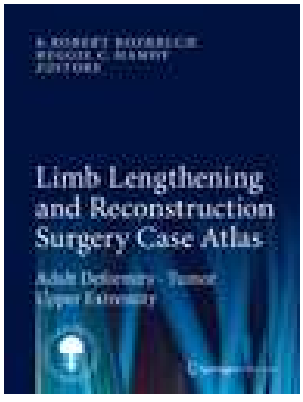
Trauma • Foot and Ankle

S. Robert Rozbruch and
Reggie C. Hamdy (Eds.)



Adult Deformity • Tumor
Upper Extremity

S. Robert Rozbruch and
Reggie C. Hamdy (Eds.)



To order, go to www.springer.com • Search “limb lengthening”

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Welcome Guest Speakers

Presidential Lecture Guest Speaker

William G. Mackenzie, MD, FRCSC, FACS

The Shands and MacEwen Endowed Chair of Orthopaedics
Chairman Department of Orthopaedic Surgery,
Nemours/Alfred I. duPont Hospital for Children
Professor of Orthopaedic Surgery,
Sidney Kimmel Medical College at Thomas Jefferson University

Allesandro Codivilla Guest Speakers

Patrick Downes, PsyD
Jessica Kensky, RN

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Limb Lengthening and Reconstruction Society

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Helpful Web Sites

LLRS: ASAMI–North America

http://www.llrs.org

American Academy of Orthopaedic Surgeons (AAOS)

http://www.aaos.org

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

2018–2019 Officers and Executive Board

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Kevin W. Louie, MD

Membership Chair
S. Robert Rozbruch, MD

Research Chairman
Mitchell Bernstein, MD

Immediate Past President
Kevin W. Louie, MD

Limb Lengthening and Reconstruction Society

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28th Annual Scientific Meeting

Objectives

Upon completion of LLRS's 28th Annual Scientific Meeting, physicians will be able to:

- apply the latest developments in the orthopedic subspecialties of limb lengthening and reconstruction;
- discuss the principles of tissue generation by distraction (distraction histogenesis); and
- understand surgical techniques of distraction histogenesis.

Selection of Content

Selection of material for presentation at the 28th Annual Scientific Meeting, July 19 & 20, 2019, was based on scientific and educational merit. The selection process does not imply the treatment modality or research methodology is necessarily the best or most appropriate available.

LLRS disclaims formal endorsement of methods or research methodology used, and further disclaims any and all liability for claims which may arise out of the use of techniques discussed or demonstrated whether those claims shall be asserted by a physician or another person.

Food and Drug Administration

LLRS notes that approval of the FDA or national equivalent of its lists from other countries, is required for procedures and drugs that may be considered experimental. Instrumentation and procedures presented at the 28th Annual Scientific Meeting may not have received the approval of the appropriate federal authority, LLRS supports the use of techniques with the requisite government approval only.

Faculty Disclosure

Faculty members are required to disclose whether they have a financial arrangement or affiliation with a commercial entity related to their presentation(s). This disclosure in indicated on the Faculty List.

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

The LLRS appreciates its Corporate Partners and Exhibitors

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Thank you for the generous grant

NuVasive Specialized Orthopedics, Inc.

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Exhibitors

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Stryker Trauma & Extremities

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Thank you for the In–kind Donation

Baltimore Limb Deformity Course

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Exhibitors

(listed in alphabetical order)

The LLRS thanks the following entities for their generous support.

LIFEBRIDGE HEALTH
Rubin Institute for Advanced Orthopedics

Baltimore Limb Deformity Course – Register for an intensive course covering deformity correction planning and limb lengthening. An internationally renowned faculty will provide didactic and hands–on lab instruction. Learn about fellowship opportunities. 410–601–9798; www.deformitycourse.com

Biocomposites® At Biocomposites, we are distinct in that our team of specialists is singularly focused on the development of innovative calcium compounds for surgical use. Our innovative products are at the forefront of calcium technology and range from bone grafts to matrices that can be used in the presence of infection. We are proud to be driving improved outcomes across a wide range of clinical applications, in musculoskeletal infection, trauma, spine and sports injuries, for surgeons and patients alike.

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Cura Surgical and its international distributors offer Silverlon® wound dressings, island dressings, negative pressure dressings and IV/Catheter Dressings which enhances the overall surgical experience for patients and surgeons.

DePuy Synthes
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DePuy Synthes Companies, part of the Medical Devices & Diagnostics (MD&D) ohnson, offers an uparalleled breadth of products, services, programs and research and development capabilities, that are designed to advance patient care and deliver clinical and economic value to health care systems throughout the world.

devise ortho

Devise Ortho makes the Drive Rail System, a joint spanning external fixation system for lengthening, with features that enhance ease of use for the patient and caregiver.

NUVASIVE
SPECIALIZED ORTHOPEDICS, INC.

The PRECICE system from NuVasive Specialized Orthopedics is an adjustable intramedullary device that once implanted, utilizes an external remote controller to non–invasively lengthen the femur and tibia to treat limb length discrepancy.

Orthofix is a diversified, global medical device company focused on developing and delivering innovative repair and regenerative solutions to the spine and orthopedic markets. 469–742–2500; www.orthofix.com

OrthoPediatrics is a global orthopedic company focused exclusively on providing surgical solutions which improve the lives of children with orthopedic conditions. Products include those for trauma and deformity correction, scoliosis, and sports medicine applications. www.orthopediatrics.com

For the surgeon's treating complex deformities and acute fractures, Smith & Nephew delivers the industry's most comprehensive portfolio of external fixation solutions. The TAYLOR SPATIAL FRAME is the most advanced and versatile circular fixation system on the market, allowing for uncompromised stability with infinite adjustability to achieve precise anatomic alignment. www.smith–nephew.com; www.spatialframe.com

Stryker is one of the world's leading medical technology companies and together with our customers, we are driven to make healthcare better. The Company offers a diverse array of innovative products and services in Orthopaedics, Medical and Surgical, and Neurotechnology and Spine, which help improve patient and hospital outcomes.

WITTENSTEIN intens GmbH: Development, production and marketing of innovative implants for use in orthopaedics and traumatology. The core product is the FITBONE®, an intramedullary lengthening system for limb lengthening of the femur and tibia. +49 7931 493–0 Email: info–intens@wittenstein.de

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Meeting Evaluation

The meeting evaluation is online. Please go to the following link and complete the evaluation by **Friday, August 2, 2019**. *Your responses are needed for CME credit to be valid.*

https://www.surveymonkey.com/r/LLRS2019

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Continuing Medical Education

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the American Academy of Orthopaedic Surgeons and the Limb Lengthening and Reconstruction Society. The American Academy of Orthopaedic Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of 9.5 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Please join us next year!

29th Annual Scientific Meeting

Convene One Liberty Plaza

July 17 & 18, 2020

New York, NY

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Please complete the evaluation online at

https://www.surveymonkey.com/r/LLRS2019

on or before **August 2, 2019**.

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Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Agenda

Friday – July 19, 2019

7:15 a.m.	Registration Opens
7:15–8:00 a.m.	Continental Breakfast – Rostrum/Ballroom Foyer *Visit Corporate Partners*
8:00–8:05 a.m.	Welcome/Introduction/Disclosure *J. Spence Reid, MD* and *Austin T. Fragomen, MD*
	Session I: Foot and Ankle/Upper Extremity Moderator: Douglas Beaman, MD
8:05–8:11 a.m.	Subtalar Distraction Arthroplasty, A New Joint Preservation Technique *Ali Ghasemi*
8:12–8:18 a.m.	Integrated Reconstruction for Chronic Foot Dislocations *Douglas Beaman, MD*
8:19–8:25 a.m.	Limb Salvage Reconstruction by Ankle Arthrodesis and Lengthening Using Intramedullary Nailing of the Tibia – *Sherif Dabash, MD*
8:26–8:32 a.m.	Lengthening of the Humerus using a Motorized Lengthening Nail: A Retrospective Comparative Series – *Stewart G. Morrison, MBBS*
8:33–8:41 a.m.	Discussion
	Session II: Basic Science/Infection I Moderator: Raymond W. Liu, MD
8:42–8:48 a.m.	Retrograde Femoral Nailing Through an Open Physis does not Impair Growth in Pigs – *Ahmed Abdul–Hussein Abood, MD*
8:49–8:55 a.m.	Reverse Dynamization Accelerated Bone Healing in a Large Animal Osteotomy Model – *Christopher A. Iobst, MD*
8:56–9:02 a.m.	Effect of Wire Tip Design and Material on the Wire Temperature during Drilling – *Kelsey Millonig, DPM, MPH*
9:03–9:09 a.m.	An MRI Based Study on Whether the Patella is Truly Centered between the Femoral Condyles in the Coronal Plane – *Nihar Shah*
9:10–9:18 a.m.	Discussion

Session II: Basic Science/Infection II
Moderator: Austin T. Fragomen, MD

9:19–9:25 a.m.	Biological Activity of Human Induced Membranes: Temporal Differences Between Femoral and Tibial Sites – *Kevin Tetsworth, MD*
9:26–9:32 a.m.	Intramedullary Antibiotic Depot does not Preclude Successful Intramedullary Lengthening or Compression *Jessica C. Rivera, MD, PhD*
9:33–9:39 a.m.	Predictors of Successful Limb Salvage for Patients with Chronic Osteomyelitis of the Tibia and Ankle – *Aaron Lam, MD*
9:40–9:46 a.m.	Biomechanical Comparison of Compression Plating versus an Electromagnetic Intramedullary Nail in Compression Utilizing a Femoral Sawbones Model – *Alex Mierke, MD*
9:47–9:55 a.m.	Discussion
9:56–10:15 a.m.	Refreshment Break – Rostrum/Ballroom Foyer *Visit Corporate Partners*

Session III: Tumor/Miscellaneous I
Moderator: Lee M. Zuckerman, MD

10:16–10:22 a.m.	Bioexpandable Prostheses Bone Lengthening after Resection of Malignant Bone Tumors in Children – *Prof. Rainer Baumgart*
10:23–10:29 a.m.	Immediate, All Internal Distraction Osteogenesis after Tumor Resection *Lee M. Zuckerman, MD*
10:30–10:36 a.m.	Biological Reconstruction with Bone Transport after Resection of Malignant Bone Tumors – *Prof. Rainer Baumgart*
10:37–10:43 a.m.	Explanted Magnetic Nails: Can They Be Reactivated? *John E. Herzenberg, MD*
10:44–10:52 a.m.	Discussion

Session III: Tumor/Miscellaneous II
Moderator: Kevin W. Louie, MD

10:53–10:59 a.m.	Proximal Tibial Osteotomy for Genu Varum: Deformity Correction with Plate versus External Fixator – *Ali Ghasemi*

11:00–11:06 a.m.	High Dose NSAIDS after Osteotomy Surgery Reduce Opioid Consumption without Affecting Bone Healing *Austin T. Fragomen, MD*
11:07–11:13 a.m.	Dilute Peripheral Nerve Catheters: A Unique Method to Decrease Postoperative Narcotic Usage in Limb Reconstruction Patients *Christopher A. Iobst, MD*
11:14–11:21 a.m.	Prevalence of Vitamin D Deficiency in Limb Lengthening Patients *Jessica C. Rivera, MD, PhD*
11:22–11:29 a.m.	Discussion
11:30 a.m.–12:15 p.m.	**Presidential Guest Lecture** *Think Beyond the Extremities – Complications in Skeletal Dysplasia* *William G. Mackenzie, MD, FRCSC, FACS* The Shands and MacEwen Endowed Chair of Orthopaedics Chairman Department of Orthopaedic Surgery, Nemours/Alfred I. duPont Hospital for Children Professor of Orthopaedic Surgery, Sidney Kimmel Medical College at Thomas Jefferson University
12:15–1:10 p.m.	Lunch
	Session IV: Internal Lengthening Nails Moderator: S. Robert Rozbruch, MD
1:16–1:22 p.m.	Results of Retrograde, Femoral Lengthening and Using the Reverse Planning Method – *Aaron J. Huser, DO*
1:23–1:29 p.m.	Magnetic Nails: Mechanical Failure Rate and Types of Failures Observed in 245 Limb Segments – *John E. Herzenberg, MD*
1:30–1:36 p.m.	Going to Great Lengths for the Elderly: Nail Lengthening Over 60 *K. Patrick Powell, MD*
1:37–1:43 p.m.	The Accuracy of Blocking Screw Assisted Intramedullary Nailing for Limb Lengthening and Deformity Correction – *Sherif Dabash, MD*
1:44–1:52 p.m.	Discussion
1:53–2:40 p.m.	**Difficult Case Presentation** Moderator: Joseph R. Hsu, MD *Joseph R. Hsu, MD* *J. Spence Reid, MD*

2:41–3:00 p.m.	Refreshment Break – Rostrum/Ballroom Foyer *Visit Corporate Partners*
3:00–3:15 p.m.	**Clinician Scholar Career Development Program Presentation** *Wendy Ramalingam, MD*
	Session V: Trauma I Moderator: Stephen M. Quinnan, MD
3:16–3:22 p.m.	The Utility of Routine Cultures in Low Risk Nonunion Surgeries *Joseph R. Hsu, MD*
3:23–3:29 p.m.	ON Path: Outpatient Nonunion Pathway: Surgical Tactic and Pathway *Joseph R. Hsu, MD*
3:30–3:36 p.m.	Prospective Observational Study of an Integrated Therapeutic InitiatiVe for Extremities (POSITIVE): Implementation of an Integrated Orthotic and Rehabilitation Program in the Civilian Setting – *Andrew D. Wohler*
3:37–3:43 p.m.	Intentional Temporary Deformity in Type IIIA and IIIB Tibia Fractures with Hexapod Frame to Assist in Soft Tissue Coverage *J. Spence Reid, MD*
3:44–3:52 p.m.	Discussion
3:53–4:45 p.m.	Business Meeting – *LLRS Members only*
5:45 p.m.	Buses depart for President's Reception – exit hotel onto Trinity Place
6:30–8:30 p.m.	**President's Reception** Isabella Stewart Gardner Museum 25 Evans Way Boston, MA 02115
8:45 p.m.	Buses depart for Fairmont Copley Plaza from front of Museum

Saturday – July 20, 2019

7:15 a.m.	Registration Opens
7:15–8:00 a.m.	Continental Breakfast – Rostrum/Ballroom Foyer *Visit Corporate Partners*
8:00–8:05 a.m.	Announcements
	Session VI: Trauma II Moderator: Mitchell Bernstein, MD
8:06–8:12 a.m.	Plate Assisted Bone Segment Transport Utilizing a Magnetic Intramedullary Limb Lengthening System: Five Patients *Kory D. Blank, MD*
8:13–8:19 a.m.	Plate Assisted Bone Segment Transport in the Femur Using a Magnetic Internal Lengthening Nail – *John D. Wyrick, MD*
8:20–8:26 a.m.	Single versus Double Level Corticotomy for the Treatment of Segmental Tibia Bone DefectUsing the Balanced Cable Transport and Then Nailing Method – *Stephen M. Quinnan, MD*
8:27–8:33 a.m.	Balanced Cable Transport with Circular External Fixation and Then Nailing for Segmental Tibia Bone Defects – *Stephen M. Quinnan, MD*
8:34–8:42 a.m.	Discussion
8:43–9:45 a.m.	**Alessandro Codivilla Presentation** *What Limb Trauma Patients Can Teach Surgeons – Lessons from the Boston Marathon Bombing* *Patrick Downes, PsyD* *Jessica Kensky, RN*
9:45–10:00 a.m.	Refreshment Break – Rostrum/Ballroom Foyer *Visit Corporate Partners*
10:01–10:30 a.m.	Poster Session – *please visit the posters in the back of the meeting room*
	Session VI: Pediatrics I Moderator: David Podeszwa, MD
10:31–10:38 a.m.	The Use of Growth Modulation in Conjunction with Motorized, Internal, Femoral Lengthening in Patients with Congenital Femoral Deficiency – *Aaron J. Huser, DO*

10:39–10:46 a.m.	Correction of the Lower Extremity Mechanical Axis Deviation in Children with Angular Deformities of the Knee treated with Guided Growth Hemiepiphysiodesis – *Oussama Abousamra, MD*
10:47–10:54 a.m.	Foot Height Difference Does Contribute to Ultimate Leg Length Discrepancy in Fibular Hemimelia Patients – *Ashley Startzman, DO*
10:55–11:02 a.m.	Comparison of the White–Menelaus and Anderson–Green Predictions of Growth Remaining in the Distal Femur and Proximal Tibia *Marina Makarov, MD*
11:03–11:13 a.m.	Discussion
	Session VI: Pediatrics II Moderator: Jill C. Flanagan, MD
11:14–11:21 a.m.	Proximal Tibia Vara is a Hidden Deformity in a Subset of Patients with Congenital Posteromedial Bowing of the Tibia *Jeanne M. Franzone, MD*
11:22–11:29 a.m.	Current Use of Patient–Reported Outcomes in Pediatric Limb Deformity Research – *Kouami Amakoutou, MD*
11:30–11:37 a.m.	Syme Amputation: Is there an Ideal Limb Length Discrepancy? *Stewart G. Morrison, MBBS*
11:38–11:48 a.m.	Discussion
11:49 a.m.–12:10 p.m.	President's Remarks and Introduction of 2019–2020 President *J. Spence Reid, MD* and *Austin T. Fragomen, MD*

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New York, NY

Limb Lengthening and Reconstruction Society

Association for the Study and Application of the Methods of Ilizarov–North America

Disclosures

Program Committee

Austin Thomas Fragomen, MD: (New York, NY)
Submitted on: 05/01/2019
Limb Lengthening Research Society: Board or committee member
Nuvasive: Paid consultant; Paid presenter or speaker
Smith & Nephew: Paid consultant; Paid presenter or speaker
Synthes: Paid consultant; Paid presenter or speaker

Raymond W Liu, MD: (Cleveland, OH)
Submitted on: 04/09/2019
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics Corporation: Royalties paid to my institution, part of which are placed into a research fund that i control: Other financial or material support
Pediatric Orthopaedic Society of North America: Board or committee member

J Spence Reid, MD: (Hershey, PA)
Submitted on: 05/01/2019
Clinical Orthopaedics and Related Research: Editorial or governing board
Journal of Orthopaedics and Traumatology: Editorial or governing board
Limb Lengthening Research Society: Board or committee member
Smith & Nephew: Paid presenter or speaker
Synthes: Paid consultant; Research support
Zimmer: Research support

Karen R Syzdek STAFF: (Austin, TX)
(This individual reported nothing to disclose); Submitted on: 04/25/2019

Faculty

Ahmed Abdul–Hussein Abood, MD: (Denmark)
(This individual reported nothing to disclose); Submitted on: 04/11/2019

Oussama Abousamra, MD: (Los Angeles, CA)
(This individual reported nothing to disclose); Submitted on: 06/03/2019

Hamza M Alrabai, MD: (Towson, MD)
(This individual reported nothing to disclose); Submitted on: 04/08/2019

Kouami Amakoutou Sr, MD: (Togo)
(This individual reported nothing to disclose); Submitted on: 04/11/2019

Austin Michael Beason, MD:
(This individual reported nothing to disclose); Submitted on: 03/29/2019

Gisele Bailey: (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 04/05/2019

Rainer Paul Baumgart, MD: (Germany)
Submitted on: 02/19/2019
Gesellschaft für Extemitaetenverlaengerung und –rekonstruktion: Board or committee member
implantcast: IP royalties; Paid consultant; Paid presenter or speaker
Wittenstein intens: IP royalties; Paid consultant; Paid presenter or speaker

Tillmann Baumgart: (Germany)
Submitted on: 04/17/2019
Implantcast: IP royalties; Paid consultant
Wittenstein intens: IP royalties; Paid consultant

Douglas N Beaman, MD: (Portland, OR)
Submitted on: 04/16/2019
Acumed, LLC: Paid consultant
Smith & Nephew: Paid presenter or speaker
Stryker: Paid consultant

John G Birch, MD: (Dallas, TX)
Submitted on: 04/04/2019
Journal of Children's Orthopedics: Editorial or governing board
Orthofix, Inc.: IP royalties

Kory Dane Blank, MD: (Springfield, IL)
(This individual reported nothing to disclose); Submitted on: 06/20/2019

Michael J Bosse, MD:
Submitted on: 05/23/2019
Orthopaedic Implant Company: Stock or stock Options

Kolby Buckner, PA:
(This individual reported nothing to disclose); Submitted on: 04/08/2019

Iciar M Davila Castrodad, MD
(This individual reported nothing to disclose); Submitted on: 06/18/2019

Alexander Cherkashin, MD: (Dallas, TX)
Submitted on: 04/17/2019
Orthofix, Inc.: IP royalties; Paid consultant

Christine Churchill, BA: (Charlotte, NC)
(This individual reported nothing to disclose); Submitted on: 06/11/2019

Janet Donohue Conway, MD: (Baltimore, MD)
Submitted on: 05/21/2019
Arthrex: Other financial or material support
Avitus Orthopaedics: Other financial or material support
Biocomposites: Other financial or material support
Biomet: Paid consultant
Cerament: Paid consultant
CyMedica Orthopedics: Other financial or material support
DePuy Synthes: Other financial or material support
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Session I: Foot and Ankle/Upper Extremity

Moderator: Douglas Beaman, MD

Subtalar Distraction Arthroplasty, A New Joint Preservation Technique

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What was the question?
Isolated subtalar osteoarthritis (OA) is a devastating disorder, usually occurring after trauma and particularly in the setting of an intraarticular calcaneal fracture. Currently, subtalar fusion surgery is the treatment of choice in managing subtalar OA after failure of conservative treatment. Unfortunately, subtalar fusion increases the load over the adjacent midfoot and ankle joints, which affects the outcome of the surgery over time. Popular in the ankle, distraction arthroplasty offers another joint–preserving option, particularly important for active patients. In contrast to fusion as a salvage procedure, subtalar distraction arthroplasty allows the possibility of maintaining the function of the arthritic subtalar joint while reducing pain and improving the overall function of the foot and ankle joint.

How did you answer the question?
We performed subtalar distraction arthroplasty on six patients with symptomatic and refractory subtalar OA. This study reviewed charts and X–rays pre–operatively and post–operatively.

What are the results?
The average age of the patients was 59 years old (51–69). The mean duration of post–operative follow–up was 31.7 months (15.2–51.8). The inversion of the ankle joint changed from 15.8 degrees (10–25) pre–operatively to 15 degrees (10–20) post–operatively, and the eversion from 5.8 degrees (0–10) to 10 degrees (0–20), respectively. We found an increase in subtalar joint space from 1.5 mm (0–3) to 2.7 mm (2–4) before and after surgery, respectively. Compared to pre–operative conditions, we saw a decrease in subchondral sclerosis in all cases post–operatively. Initial clinical results are promising, and we intend to follow–up on these. Complications include one patient with sensory neuralgia.

What are your conclusions?
Preliminarily, results of subtalar distraction arthroplasty as a new joint preservation technique are encouraging. Limitations include our sample size, though we anticipate studying more patients prospectively. Our research suggests the possibility of subtalar distraction arthroplasty as an effective treatment for symptomatic subtalar OA. This operation can be helpful in the management of subtalar OA in active patients who need preservation of foot and ankle motion.

Integrated Reconstruction for Chronic Foot Dislocations

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What was the question?
Can the chronically dislocated hindfoot or midfoot be successfully salvaged without major bone resection using a method of gradual re–alignment with hexapod external fixation followed by arthrodesis using internal fixation?

How did you answer the question?
Nine patients treated with gradual hexapod (Taylor Spatial frame) reduction and staged arthrodesis of chronic foot dislocations were retrospectively reviewed. Chart review and radiographic analysis were performed. There were four male and five female patients with an mean age of 56 years. Mean follow–up was 27 months. All had neuropathy; six were diabetic charcot, one had Charcot Marie Tooth, one idiopathic, and one had rheumatoid arthritis.
Dislocations were present for at least two months and upto three years. Five patients had preoperative ulcerations. Six had peri–talar dislocations and three had midfoot dislocations.

What are the results?
All patients achieved a stable plantigrade and functional foot position. All fusions healed except for one talonavicular joint in a peritalar dislocated foot. Alignment and healing were confirmed with radiographic assessment including hindfoot alignment view and foot views. All preoperative ulcerations healed. Five patients with peritalar dislocations had frame modification at the time of arthrodesis, and the frame was retained until healing (mean frame time was 6.8 months). Four patients had frame removal at time of arthrodesis (mean frame time was 2.6 months). Spatial frame butt type foot frame constructs were utilized for all midfoot dislocations. Spatial frame miter type frame constructs were utilized for four of the peritalar dislocations. Two peritalar dislocations were treated with other frame configurations, and both developed complications (one talonavicular nonunion and one deep infection). Other complications included further surgery in two midfoot dislocations, two forefoot wire complications, and one ankle deformity during peritalar correction.

What are your conclusions?
Chronic dislocations of the adult neuropathic foot can be successfully salvaged using integrated fixation methods. The use of staged internal fixation following gradual reduction with external fixation was safe and effective in this cohort except for one patient with RA and soft tissue compromise. The miter frame construct is particularly useful for the realignment of the peritalar dislocation.

Limb Salvage Reconstruction by Ankle Arthrodesis and Lengthening Using Intramedullary Nailing of the Tibia

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What was the question?
Despite improving methods for the early treatment of complex fractures involving the ankle joint, many patients develop debilitating ankle arthritis often associated with deformity and bone loss. Osteonecrosis of the talus, collapse of the plafond, and resection of non–viable bone cause bone loss with significant leg length discrepancy. The technique of ankle arthrodesis combined with simultaneous proximal tibial lengthening using circular external fixation has been the gold standard treatment for providing patients recovered length with an infection–free and functional limb. A new method to gain the length using the intramedullary nail (IMN) gives the same result with no infections and good patient satisfaction.

How did you answer the question?
Fourteen patients underwent staged ankle arthrodesis and proximal tibial lengthening for limb salvage reconstruction using the IMN. One of these patients had simultaneous fusion and lengthening in the same surgery. Preoperative diagnosis included: posttraumatic arthritis (7), pilon fracture (2), Charcot ankle (2), avascular necrosis of the talus (1), failed total ankle replacement (1), failure of lengthening with external fixation (1). We evaluated demographics, amount of shortening, amount of lengthening, average time with nail, infection rate, time to healing, and ASAMI score.

What are the results?:
The average age of the patients was 44 years old (30–62). The average amount of limb shortening for patients after ankle fusion was 35.9 mm (18–50) while lengthening was 36.7 mm (18–50). Patients had the nail for an average of 479 days (248–730). There were no surgical infections. All osteotomy sites healed after an average 202 days (106–365); Charcot patients healed after 321 days. Bone healing index (BHI) was 56.0 days/cm (21.2–123.4) among the whole cohort. BHI was 87.5 days/cm for the Charcot patients and 49.7 days/cm for all others (P=0.04). ASAMI bone scores were excellent or good among all patients.

What are your conclusions?:
Ankle arthrodesis with proximal tibial lengthening using the IMN was well–tolerated. Patients had good clinical outcomes with no post–operative complications. We recommend using the IMN in staged ankle arthrodesis and proximal tibial lengthening for limb salvage reconstruction.

Lengthening of the Humerus using a Motorized Lengthening Nail: A Retrospective Comparative Series

Stewart G. Morrison, MBBS, Andrew G. Georgiadis, MD, Mark T. Dahl, MD
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What was the question?
Humeral lengthening can be accomplished via the historic standard of external fixation, or more recently via the use of intramedullary motorized lengthening nails. Our group wished to consider the technical factors involved in performing humeral lengthening with an intramedullary device, as well as compare the results to those achieved using external fixation.

How did you answer the question?
We conducted a retrospective, review of pediatric humeral lengthenings performed at our centre. The time period surveyed included use of external fixation (EF) as well as the use of a motorized nails (MN) for lengthening. We compared lengthening magnitude achieved, duration of lengthening, and frequency and type of complications encountered.

What are the results?
13 humeral lengthenings were performed in 9 patients. 6 lengthenings were performed using MN technique, and 7 using EF technique. All EF lengthenings were done through a proximal corticotomy, six of which required angular deformity correction. Five of six MN lengthening were performed retrograde. The average lengthening achieved was 8.5 ± 1.3 cm in the EF group, and 6.6 ± 2.3 cm in the MN group. The duration of lengthening averaged 114 days in the MN group, and 103 days in the EF group. Two patients underwent an initial EF lengthening of a humerus, and then underwent a second lengthening using MN technique. 2 of 6 (33%) MN lengthenings and 3 of 7 (43%) EF lengthenings experienced complications during treatment. Two patients in the MN group underwent planned reversal and redeployment of their motorized nail to attain the planned lengthening magnitude.

What are your conclusions?
Humeral Lengthening using motorized intramedullary nails is a safe technique that avoids some of the complications of external fixation including pin site infection. It is well tolerated by patients. For lengthenings of a large magnitude, reversal and reuse of motorized nail should be considered and carefully planned.

Session II: Basic Science/Infection I

Moderator: Raymond W. Liu, MD

Retrograde Femoral Nailing Through an Open Physis Does Not Impair Growth in Pigs

Ahmed Abdul–Hussein Abood, *MD*, Ole Rahbek, MD, Bjarne Møller–Madsen, MD,
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What was the question?
The aim of this study was to asses physeal healing and bone growth after insertion of a retrograde femoral nail thorough the centre of the physis in a skeletally immature experimental porcine model.

How did you answer the question?
Eleven immature pigs were included in the study. One leg was randomised for operation with a retrograde femoral nail (diameter 10.7 mm), whilst the non–operated contralateral remained as control. All nails were inserted centrally in coronal and sagittal plane under fluoroscopic guidance, and the nails spanned the physis. The nails were removed at 8 weeks. Both femora in all animals underwent MRI at baseline (pre–operatively), 8 weeks (after nail removal) and 16 weeks (before euthanasia). Femoral bone length was measured at 5 sites (anterior, posterior, central, lateral and medial) using 3d T1–weighted MRI. Growth was calculated after 8 weeks (growth with nail) and 16 weeks (growth without nail). Physeal cross–sectional area and percentage violated by the nail was determined on MRI. Operated side was compared to non–operated. Corresponding 95% confidence intervals were calculated.

What are the results?
No differences in axial growth were observed between operated and non–operated sides. Mean growth difference was 0,61 mm [–0,78;2,01] whilst the nail was inserted into the bone and 0,72 mm [–1,04;1,65] after nail removal.
No signs of angular bone deformities were found when comparing operated side to non–operated side. No premature bony healing at the physis occurred. Histology confirmed fibrous healing.
Mean physeal violation was 5.72% [5.51; 5.93] by the femoral nail.

What are your conclusions?
The insertion of a retrograde femoral nail through the centre of an open physis might be a safe procedure with no subsequent growth arrest.

Reverse Dynamization Accelerated Bone Healing in a Large Animal Osteotomy Model

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What was the question?
Studies have shown that manipulation of the local mechanical environment around a fracture site influences fracture healing. Understanding the nature of these mechanical cues, and the biological responses is very important as this ultimately determines the quality, the type of tissue formed, and the rate and success of the healing process. The mechanical environment is determined by the stiffness of fracture fixation and weight bearing; if fixation is either too flexible or too rigid, then the healing might fail. Based on this knowledge, some authors have suggested that the delayed introduction of controlled motion, dynamization, changing from a rigid to a more flexible fixation as healing progresses, may lead to faster maturation of bone. However, the benefits of this process have been very modest, and has not greatly influenced clinical practice. In contrast, superior healing has been previously reported using a counter intuitive process called Reverse Dynamization in a small animal model, where the fracture is initially fixed with a more flexible, followed by a rigid fixation. The hypothesis is that a fracture that's initially stabilized less rigidly would allow micromotion and encourage cartilaginous callus formation, and once substantial callus has formed, the stabilization is converted to a rigid configuration to allow vascularization and accelerated remodeling. Therefore, the aim of this study was to investigate if bone healing can be accelerated using Reverse Dynamization in a 2 mm goat osteotomy model.

How did you answer the question?
Fifteen immature, neutered male Spanish cross goats underwent an identical surgical procedure after IACUC approval. Each goat had a circular external fixator applied to the right hind limb using the same construct: reference wire and two half pins on the proximal ring and two wires and a half pin on the distal ring block. A transverse 2 mm osteotomy was created halfway between the proximal and middle rings using a sagittal saw. The goats were then divided into three groups: Static group (S, n=6; four threaded rods connecting the proximal and middle rings to stabilize the fracture), Dynamized group (D, n=6; four threaded rods containing the 2 mm axial dynamizers to stabilize the fracture), Reverse Dynamization group (RD, n=3; started with the 2 mm axial dynamizers and were converted to threaded rods at three weeks after surgery). The goats were allowed to begin weight bearing immediately after surgery. Each animal had weekly pin care and radiographs of the fracture site. At the end of week 8 the goats were euthanized, and both limbs of each goat were evaluated using MicroCT and mechanical testing. Statistical analysis was performed between the experimental groups after each sample was normalized to the corresponding contralateral bone values. For comparisons between the groups, an unpaired T–test was performed, with differences considered statistically significant at $p < 0.05$.

What are the results?
Weekly radiographs showed earlier and bigger callus formation in the Dynamized groups (D and RD). In agreement with weekly radiographs, MicroCT results showed that the callus size was bigger and achieved near significance between Static vs. Dynamized groups (D p=0.08 vs RD p=0.06), but it was not different between both dynamization groups. There was more bone formed in both dynamization groups (D and RD) compared to the Static group, but significance was only reached

between the Static and Dynamized groups (p=0.04). Bone volume fraction was also significantly different between Static and Dynamized (p=0.05), but was not different between Static and Reverse Dynamized groups. Bone mineral density was higher in the Reverse Dynamized group compared to Static and Dynamized group which reached nearly significant difference (p=0.06). Moreover, the tibial defects that healed under conditions of Reverse Dynamization were considerably stronger in torsion than the defects stabilized with Static and Dynamized fixation regimens (p=0.02 and p=0.01 respectively). Furthermore, tibias in the Dynamized groups (D and RD) were also significantly different from the intact bone (for both p =0.001).

What are your conclusions?

This preliminary data confirm the influence of modulating the mechanical environment on the healing of osteotomies in the goat model. The best results were achieved using Reverse Dynamization as was demonstrated by torsional testing and microCT. The bones that healed under the Reverse Dynamization regimen were significantly stronger and had higher bone mineral density, suggesting accelerated remodeling process. This data agreed with previous small animal studies demonstrating that the axial stiffness of the fixator can be modulated to maximise the regenerative capacity of bone healing. Although promising, the sample numbers per group were relatively small, therefore, those findings will have to be confirmed in a larger study.

Effect of Wire Tip Design and Material on the Wire Temperature during Drilling

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What was the question?
Percutaneous wire placement is an essential component of external fixation procedures. Thermal–related damage during wire insertion can cause soft tissue and bone necrosis and lead to serious complications. Wire temperature during drilling can be affected by a number of variables. The aim of this study is to determine the effects of two such variables: wire tip design and the wire material. There are three common wire tip designs: trochar, bayonette, and drill tips. The bayonette tip can be further subdivided into short centric bayonette, long centric bayonette and long eccentric bayonette tips. The long eccentric bayonette tip is also known as the Ilizarov wire, since it was first introduced by the Ilizarov center in Kurgan Russia. Wires used in external fixation are made either from stainless steel or titanium. Determining the lowest heat producing tip shape and wire material will establish recommendations to decrease the chance of thermal damage in an effort to reduce pin site infections and instability with external fixation.

How did you answer the question?
Rigid Polyurethane Foams (RPF) blocks were utilized to simulate cortical bone drilling. The blocks were 10 mm thick and have a density of 50 pounds per cubic foot (PCF). This thickness and density were chosen for clinical relevance. A custom–made computerized drill used to employ controlled drilling parameters of 600 RPM at an advancement rate of 2.5mm/sec. Wires were drilled 20mm beyond the block thickness to obtain a 20mm plunge. A FLIR infrared thermography camera (Wilsonville, Oregon, USA) and FLIR Report Studio software were used to record the thermal data. The following data points were recorded: the temperature of the wire tip at the exit point of the RPF block, the maximum temperature recorded between wire exit and final resting position, and the time the wire temperature was above 47°C as this is described in the literature as temperature of thermal osteonecrosis. The following five stainless steel wire tips were tested: 1) trochar tip (TT), 2) drill–tip (DT), 3) short centric bayonette tip (SBT), 4) long centric bayonette tip (LBT) and 5) long eccentric bayonette (Ilizarov) tip. In addition, titanium wires with the Ilizarov tip were compared with stainless steel wires. Ten data points were collected for each wire tip and wire material type.

What are the results?
One–way ANOVA and Kruskal Walis tests were conducted followed by post–hoc Tukey's test to compare the wire tip design. All data reported is mean ± standard deviation. The Ilizarov tip wires showed the least heat production with the lowest exit temperature at 48.61°C± 7.37°C. This was statistically significant ($p<0.05$) as compared to all wire tips except the LBT wire. Ilizarov tip wires also demonstrated the lowest maximum recorded temperature (73.28 °C ± 5.58°C) followed closely by the LBT wires, however this maximum temperature was only statistically significantly lower when compared to the TT and SBT wires ($p<0.05$). Sequentially from lowest maximum temperature to highest, the wire tips were as follows: Ilizarov, LBT, DT, SBT, and finally TT. The Ilizarov tip wire had the shortest amount of time the wire temperature was recorded above 47°C at 29.5 ± 4.97 seconds this was significantly less time compared to all other wire tip designs ($p<0.05$). Regarding wire material, the Student's t test and Mann–Whitney tests were conducted. The

Effect of Wire Tip Design and Material on the Wire Temperature during Drilling *continued*

Kelsey Millonig, DPM, MPH

comparison of the exit temperature and maximum temperatures were not statistically significant between stainless steel and titanium Ilizarov wires. The time the wire temperature was recorded above 47°C was statistically significant with titanium at 11 ± 2.11 seconds compared to stainless steel at 29.5 ± 4.97 seconds ($p<0.05$).

What are your conclusions?

Heat production is influenced by both wire barrel friction and wire tip design. The geometry of the eccentric compared to centric tip creates a wider canal to allow decreased friction between the bone and the wire. Even though all wire samples in the study produced drilling temperature greater than 47°C, the Ilizarov tip wires demonstrated the lowest temperature and fastest cooling times. Utilizing the titanium as compared to stainless steel allowed for faster cooling of the wire yielding significantly less time at higher temperatures. Based on the results, the titanium wires with the Ilizarov tip are the superior choice to decrease possible thermal damage.

An MRI Based Study on Whether the Patella is Truly Centered between the Femoral Condyles in the Coronal Plane

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What was the question?
An AP knee radiograph is classically evaluated as adequate if the patella is centered between the femoral condyles. Our previous anatomic studies have demonstrated a tendency for lateral patellar deviation on a true AP view. However, past findings were largely based on cadaveric samples that were limited by the lack of soft tissue influence. The examination of MRI studies in clinical patients is a necessary next step in the evaluation of patellar positioning on a true AP knee radiograph.

How did you answer the question?
In order to determine whether there was variation in patellar position across a random population 106 MRIs were selected excluding those with cartilaginous or ligamentous trauma, obvious deformity, or damage to osseous structures. ImageJ software was then used to measure the maximum intercondylar width, the maximum patellar width, and the distance from the lateral patellar edge to the lateral femoral condylar edge. All measurements were made with respect to a line parallel to the distal aspect of the femoral condyles. Patellar centering was calculated as a percentage of total distal femoral intercondylar width, and anatomically qualified how lateral the center of the patella is located on the distal femur, with a value of zero representing a perfectly centered patella and positive values indicating lateral deviation.

What are the results?
Mean age of the population was 29.4 ± 14.0 years. There were 35 males and 71 females included in the study. Mean patellar centering was 0.08 ± 0.04. The intraclass correlation coefficient for patellar centering was 0.83 between two observers measuring 20 samples, demonstrating high interobserver reliability.

What are your conclusions?
This MRI based study demonstrates that the patella is rarely perfectly centered and is usually positioned slightly laterally within the femoral condyles. This study is supportive of our previous reports of a lateral patellar centering with a mean value of 0.13 ± 0.04 in adult cadaveric specimens and suggests that the amount of lateral positioning is partially mitigated by the soft tissue. The use of supine MRI scans makes this data relevant to a patient on the operating room table. Further study is necessary to determine if patellar positioning remains laterally deviated on standing radiographs.

Session II: Basic Science/Infection II

Moderator: Austin T. Fragomen, MD

Biological Activity of Human Induced Membranes: Temporal Differences Between Femoral and Tibial Sites

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What was the question?
Human induced membranes formed in association with femoral defects clinically appear to be more robust than those from tibial defects. The anatomical origin of an induced membrane may be a more important influence than the time interval between stages. This study examined the biological activity of human induced membranes with respect to both their anatomical site and the length of the interval between stages. Specific attention was directed towards identifying temporal changes in the gene expression pattern, tissue morphology, and osteogenic and angiogenic protein localization, considering the differences between tibial and femoral specimens.

How did you answer the question?
Membranes were harvested from 16 clinical cases of bone defects which were managed using the Masquelet technique, returning for the second stage between 4 and 20 weeks. Biopsies of induced membranes (n=16) and control samples (normal fascia; n=16) were collected from femoral and tibial defects. Samples (10x10mm) were morselized, and then stored at –80oC prior to gene expression analysis of relevant growth factors for bone repair using qRT–PCR. Different samples (20x10 mm) were used for histology and stained with haematoxylin and eosin (H&E). Immunohistochemistry (IHC) was used to localize proteins with osteogenic and angiogenic potential. Comparisons were made between femur and tibia and corrected for time differences between stages.

What are the results?
Bone–like tissue was observed on the outer layer of the induced membranes with H&E. CD68, a marker of macrophage lineage, was homogenously expressed within the membranes, while in the fascia it was mostly absent. VEGF, a potent angiogenic factor, was consistently expressed in blood vessels of both fascia and membrane. Quantitative analysis revealed the number of active cell nuclei and the average cell density in induced membranes (2.77 x 105 cells/mm3) was more than double when compared to fascia (1.14 x 105 cells/mm3; $p < 0.05$). Gene expression analyses revealed that the growth factors relevant to bone repair were significantly up–regulated in membranes as compared to fascia. Membranes revealed significantly up–regulated cell proliferation, cell–cell and cell–matrix adhesion, chemokines, interleukins, and platelet activation genes in femurs, as compared to tibias, which had more down–regulated genes. Growth factors specific to bone mineral metabolism and skeletal development were similarly expressed in both groups. Femoral membranes were more cellular and vascular at earlier time points, compared to tibial specimens. The optimal gene expression appeared to be between 8–12 weeks for femoral specimens, with maximal expression at 10 weeks. Tibial specimens appeared very similar in many respects, with a 4–week delay that may be related to less soft tissue cover locally. The optimal gene expression appeared to be between 12–16 weeks for femoral specimens, with maximal expression at 14 weeks. Most importantly, membranes from both sites demonstrated significant expression of growth factors relevant to bone healing for a prolonged period, and human induced membranes appear to be highly biologically active for many weeks.

Biological Activity of Human Induced Membranes: Temporal Differences Between Femoral and Tibial Sites *continued*

Kevin Tetsworth, MD

What are your conclusions?

The Masquelet technique has been heralded by some as a revolution in the management of skeletal defects, although others continue to report mixed clinical outcomes. The preferred timing to return for the second stage has been an ongoing topic of considerable debate. Preliminary results from this study suggest the anatomical location of origin of a human induced membrane might be a more important factor in regards to influencing the biological response than the time interval between stages. However, this difference is most apparent in the differential gene expression, as it evolves with time following implantation of the PMMA spacer. Specimens from both femoral and tibial defects exhibited significant biological activity for a prolonged period post–operatively, exceeding previous expectations established from basic science research in small animal models.

Intramedullary Antibiotic Depot does not Preclude Successful Intramedullary Lengthening or Compression

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What was the question?
Many patients with post traumatic limb length discrepancies and nonunions have a history of infection either from external fixation pins or previous treatment. Intramedullary nailing of canal that has had a previous history of infection or external fixation can promote reactivation of an indolent infection. We propose a technique of intramedullary antibiotic impregnated calcium sulfate prior to insertion of a magnetic internal lengthening nail as a means to lengthen or compress bones with an active infection, history of infection, or risk of infection.

How did you answer the question?
A retrospective, multicenter study was performed. Case logs of four limb reconstruction surgeons were surveyed for co–treatment of long bones with calcium sulfate as an intramedullary antibiotic depot and insertion of a magnetic internal lengthening nail. Technical and peri–operative complications and ability of the intramedullary device to achieve surgical lengthening or compression goal without impediment was noted.

What are the results?
Eleven patients were treated with combined internal lengthening/compression nail and resorbable calcium sulfate antibiotic depot (STIMULAN®). Three patients had known active infection in the intramedullary canal, four had a history of osteomyelitis, and four had a risk of or concern intramedullary infection due to prior external fixation or recalcitrant nonunion. Seven patients were treated for lengthening while four underwent compression of a recalcitrant nonunion. In nine cases, the intramedullary nail passed without the antibiotic depot impeding nail placement. In two cases, the ceramic set prematurely and required repeated reaming which was then following by successful depot delivery and nail passage. In all eleven cases, the intramedullary telescoping nail functioned as desired with targeted length and compression achieved.

What are your conclusions?
Concomitant use of resorbable intramedullary calcium sulfate antibiotic depot does not impede intramedullary lengthening/compression. It appears to not affect time to union or quality of the regenerate. This technique provides the limb reconstruction surgeon with the ability to treat or prevent infection while utilizing the advantages of modern internal lengthening devices.

Predictors of Successful Limb Salvage for Patients with Chronic Osteomyelitis of the Tibia and Ankle

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What was the question?
(1) how successful was the limb salvage treatment protocol at controlling infection; (2) how successful was the treatment at healing infected non–unions; and (3) what were the predictors of failure of the treatment protocol in eradicating infection and healing non–unions?

How did you answer the question?
We retrospectively analyzed records of patients from the combined database of the infectious disease (ID) and limb lengthening & complex reconstruction (LLCR) services at a major academic center. Patients medical charts and radiographs were reviewed. Demographic information including comorbidities and prior treatments were recorded. Key parameters collected include primary treatment method, number of limb salvage surgeries performed by our LLCR service, use of antibiotic loaded cement–coated nails or beads, need for soft tissue coverage, and presence of non–union. Information on the individual infection and treatment protocol including cultured organism, total number of samples collected, number of positive samples, type and duration of acute IV antibiotics used, and type and duration of chronic daily PO antibiotics used after IV treatment for suppression were recorded. Radiographs of each patient were independently reviewed and graded according to the Cierny–Mader classification system. For fracture related infection (FRI) cases, the osteomyelitis was classified as confirmed or suspected. Confirmed FRI was defined by the presence of a draining sinus or 2 or more positive cultures obtained at the salvage surgery. Patients with a suspected FRI included those with a history of previous FRI but with no sinus and only one isolated positive or no positive intraoperative cultures at index salvage surgery. At latest follow–up, available patients completed a routine follow–up survey. The primary outcome was infection control without the need for amputation or chronic antibiotic suppression and successful healing of infected non–unions.

What are the results?
Mean follow–up was 3.9 years. Out of the sixty–seven patients (mean age: 51.4 years) treated for chronic osteomyelitis, fifty–four had an associated non–union. Sixty–one patients (91.0%) had their infection controlled by limb salvage. Five ultimately required amputation and one remained on daily chronic antibiotics. Diabetics complicated with neuropathy and increasing numbers of limb salvage surgeries were associated with a significantly higher failure rate. Forty–eight out of fifty–four patients (88.9%) also had successful healing of their infected non–union. Diabetes and need for more limb salvage surgeries were also found to have a significantly higher failure rate.

What are your conclusions?
Limb salvage is a reliable and successful treatment for patients with chronic osteomyelitis and infected non–unions of the lower extremities. Diabetic neuropathy is a risk factor that significantly impedes the success of limb salvage.

Biomechanical Comparison of Compression Plating Versus an Electromagnetic Intramedullary Nail in Compression Utilizing a Femoral Sawbones Model

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What was the question?
To compare the amount and distribution of compression generated by an electromagnetic intramedullary nail and a 4.5 mm limited contact dynamic compression plate (LCDCP).

How did you answer the question?
Transverse osteotomy sites (AO/OTA 32–A3) were created in the femoral shaft of ten fourth generation composite femurs utilizing a sagittal saw at the same location. An antegrade 10 degree trochanteric nail and an 8–hole, broad, 4.5mm LCDCP were used for fixation. Five separate nails and plates were used for each group. A pressure mapping sensor was placed at the osteotomy site. The nail was compressed using the external remote controller until stalling of the motor was audible. The LCDCP was compressed by placing a neutral screw proximally followed by three eccentrically drilled compression screws on alternating sides of the osteotomy site. Overall compression and distribution of the compression was compared between the two groups, and p–values < 0.05 were considered statistically significant. Statistical analysis was conducted using SPSS 21.0

What are the results?
The nail generated an average of 345.5 lbs/in2 across the osteotomy sites. The LCDCP generated an average of 101.4 lbs/in2 ($p < 0.001$) with the initial compression screw, 134.8 lbs/in2 ($p < 0.001$) after the second screw, and 151.52 lbs/in2 ($p < 0.001$) after the third screw. The area of distribution of the compression was noted to be significantly more uniform in the nail group ($p = 0.046$). There were no mechanical failures and no fracturing of the sawbones identified by inspection or fluoroscopy. All the motors functioned normally after testing was completed.

What are your conclusions?
Plating is the standard for obtaining compression across a transverse fracture site. This study demonstrates that an electromagnetic intramedullary device is capable of generating significantly more compression when compared to a broad 4.5 mm LCDCP in a sawbones model. The results of this study indicate that electromagnetic intramedullary nail systems may be an ideal alternative to compression plates for treatment of fractures, nonunions, and delayed unions that would normally benefit from compression plating.

Session III: Tumor/Miscellaneous I

Moderator: Lee M. Zuckerman, MD

Bioexpandable Prostheses – Bone Lengthening after Resection of Malignant Bone Tumors in Children

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What was the question?
Expandable endoprostheses could be an option after resection of malignant bone tumors of the lower extremities in children and adolescents not only to bridge the defect but also to overcome limb length discrepancy. To achieve equal limb length at maturity different concepts of expandable endoprostheses are available. One option is to lengthen the prosthesis with an internal power unit but especially in cases of a huge demand of lengthening the relationship from prosthesis to the remaining bone becomes worse. As consequence a new "biological" idea was to lengthen not the prosthesis but the remaining bone as it is performed frequently in cases of congenital or posttraumatic limb length discrepancies. What is the state of the art to use fully implantable lengthening nails in cases when a tumor prosthesis is in place? When lengthening should be done and which results can be expected?

How did you answer the question?
The prosthesis is equipped with an encapsulated electromotor which enables the device to perform distraction in an osteotomy gap with about 1mm/day. The new bone is improving the relationship from bone to prosthesis and therewith the potential stability of the final stem. The device is fully implantable and can be used in a minimal invasive way for femur lengthening when limb length discrepancy is getting more than 3 cm or at maturity. 11 patients (7m, 4f) were treated with the bioexpandable prosthesis. In 6 cases the femur and in 2 cases the tibia and in 3 cases the femur and the tibia were lengthened after resection of an osteosarcoma (7) or a Ewings–sarcoma (4). The mean age of the patients was 14 years and the mean amount of lengthening was 74mm. In 2 cases lengthening was performed in 2 steps and in 1 case it was performed in 3 steps. Meanwhile the first 5 patient were getting the final coated stem after removal of the active components.

What are the results?
All lengthening procedures could be finished without complications. There was no infection and no technical problem. The bone regenerate in one tibia case was poor so that bone grafting had to be performed from the iliac crest. In one case a temporarily contracture of the knee joint was observed which recovered completely after finishing lengthening. In one early case a breakage of the nail happened 2 years after lengthening just before the replacement to the final prosthesis was planned.

What are your conclusions?
The "bioexpandable" prosthesis is a new concept for limb lengthening after tumor resection in children. The latest version of the prosthesis allows minimal invasive lengthening of the remaining bone via small scin incisions not only for the femur but for the tibia as well.

Immediate, All Internal Distraction Osteogenesis after Tumor Resection

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What was the question?
Reconstruction of large bony defects after tumor resection is challenging. The use of distraction osteogenesis after tumor resection allows for intercalary reconstruction utilizing the patient's own bone. All internal transport utilizing intramedullary nails is a newer technique for bone reconstruction. The present study aimed to evaluate the initial results of this technique along with complications.

How did you answer the question?
Five cases of all internal distraction osteogenesis and bone transport utilizing an electromagnetic intramedullary nail were reviewed retrospectively. Three patients were treated for isolated metastatic renal cell carcinoma, one for metastatic myxoid liposarcoma, and one for isolated neuroendocrine carcinoma. Three cases of plate assisted bone segment transport were performed, one case of acute shortening followed by immediate lengthening, and one case utilizing a bone transport nail.

What are the results?
A joint–preserving intercalary resection with negative margins was performed in all cases. Follow–up ranged from 4–12 months. The average defect was 9.8 cm (4–17). The 4 cm defect was treated with acute shortening followed by lengthening starting two weeks after surgery. The defects requiring bone transport averaged 11.3 cm (8–17). All patients underwent successful initial transport of the bone with good regenerate noted. No complication including hardware failure or local recurrence was identified on latest follow–up.

What are your conclusions?
Immediate distraction osteogenesis utilizing an electromagnetic nail after tumor resection formed adequate regenerate despite patients being on chemotherapy and no early complications were noted. The initial experience with this technique is promising for providing a viable method for reconstructing intercalary defects.

Biological Reconstruction with Bone Transport after Resection of Malignant Bone Tumors

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What was the question?
If malignant bone tumors do not affect the growth plate biological reconstruction using the method of callusdistraction may be an alternative to bridge the defect after resection. How effective biological reconstruction with callusdistraction using fully implantable systems or external fixation systems with a motorized traction device for three–dimensional biological reconstruction can be?

How did you answer the question?
7 patients got a biological reconstruction after en–bloc–resection of malignant bone tumors (5 osteosarcomas, 2 Ewing–sarcomas) of the lower leg. The resection boundaries and the oncological concept were maintained according to the established standard in all cases. In 3 cases the defect was located in the diaphysis and a fully implantable system was used to perform bone transport after chemotherapy was finished. In 4 cases the defect was located in the metaphysis, the growth plate was not affected but resected with the tumor. Stabilization was done with an external fixator and bone transport was performed with a single wire transport system and an external motor drive during chemotherapy. In 3 cases a three–dimensional reconstruction of the metaphysis was performed. The mean age was 12 years, the mean defect size was 14cm (11–20). No radiation was applied in any case. In 5 cases limb lengthening was performed later with the system at maturity

What are the results?
In all cases the bone transport was finished without complications and a bony continuity of high quality was achieved. Bone formation was delayed in cases when transport was performed during chemotherapy. Mean time of lengthening was 175 days. There was no deep infection even not in the cases with external fixation for long time under chemotherapy. In 5 cases minor technical problems like screw migration or breakage of the wire occurred which made a re–operation necessary.

What are your conclusions?
If the defect is located in the diaphysis the system offers safe and comfortable options for a biological reconstruction. In the metaphysis technical high demanding external systems are necessary especially if three–dimensional reconstruction should be done. The procedure is time consuming and reconstruction takes time in the early phase of tumor treatment when the survival is still doubtful. Finally, however, the biological reconstruction shows perfect clinical and radiological results and nearly a normal function of the leg.

Explanted Magnetic Nails: Can They Be Reactivated?

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What was the question?
Lengthening nails were introduced in 2011. It may be desirable to perform part of the lengthening, allow bone healing, and return one or more years later to relengthen with the same nail. This strategy may be gentler for the joints and soft tissues. We call this the "sleeper nail" strategy. One obvious benefit is the cost savings compared with nail exchange. Would the mechanism still be functional one or more years later?

How did you answer the question?
We tested 102 routinely explanted nails. The nails come with the male part exposed by 30 mm, with the ability to lengthen an additional 50, 65, or 80 mm depending on the nail model. During testing, nails were prevented from reaching their full capacity of lengthening/retraction to avoid jamming the gears. Using a "fast magnet," the male part was lengthened to 5 mm short of maximum stroke capacity and retracted back to 35 mm. Fully deployed nails were tested for retraction back to 35 mm. The nails passed the test if the male part succeeded in lengthening to 5 mm short of the maximum stroke capacity and back to 35 mm. Failure was defined as the inability or partial ability to complete the process.

What are the results?
Thirty–seven P1 nails and 65 P2 nails were tested. Mean implantation duration was 16.5 months (range, 4–47 months). In the P1 group, 29 nails (78.4%) passed testing successfully. Eight nails (21.6%) failed testing; all had been fully deployed. In the P2 group, 57 nails (87.7%) passed testing. Eight nails (12.3%) failed testing, one of which was fully deployed.

What are your conclusions?
Dormant nails can be reactivated for further lengthening. Candidate nails for this purpose should not have any obvious signs of damage (bending or breakage) and should not have been fully deployed. However, patients should be told about the potential need for nail exchange if the sleeper nail fails to "wake up."

Session III: Tumor/Miscellaneous II

Moderator: Kevin W. Louie, MD

Proximal Tibial Osteotomy for Genu Varum: Deformity Correction with Plate Versus External Fixator

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What was the question?
Proximal tibial osteotomy (PTO) is a well–known procedure for correction of knee varus. The purpose of this study is to compare the results of deformity correction using 2 different techniques: acute opening wedge correction using plate and screw fixation and gradual correction with a monolateral external fixator.

How did you answer the question?
There were 43 patients with plates and 36 patients with external fixators. All patients had moderate uniplanar varus deformity. We measured radiographic parameters including mechanical axis deviation (MAD), medial proximal tibial angle (MPTA), Caton–Deschamps index (CDI), posterior proximal tibial angle (PPTA), and joint line obliquity angle (JLOA). Accuracy of MAD correction was calculated based on a correction goal of neutral or overcorrection for medial compartment arthritis.

What are the results?
Demographics including age, BMI, sex, and preoperative deformity were similar between the groups. MAD significantly improved from 23.6 mm medial to the midline (SD=8.2 mm) to 6.9 mm lateral to the midline (SD=5.4 mm) ($P<0.001$). Accuracy of MAD correction did not differ between the groups and was 96.1% (SD=8.1%) in the plate group and 98.2% (SD=5.2%) in the external fixator group ($P=0.18$). The MPTA significantly improved from 83.9° (SD=2.9°) to 90.9° (SD=3.3°) ($P<0.001$), and the change was similar between the groups. Differences were noted in patella height with a CDI change of –19.2% (SD=13.7%) and 3.1% (SD=8.0%) for the plate and external fixator groups, respectively ($P<0.001$). The change in JLOA was 1.6 degrees (SD=1.1 degrees) and 0.9 degrees (SD=0.9 degrees) for the plate and external fixator groups, respectively ($P=0.04$).

What are your conclusions?
Conclusion: Reliable correction of moderate varus alignment was achieved with both acute opening wedge with plate and gradual monolateral external fixator techniques. Patella height decreased with the open wedge plate technique. Joint line obliquity was decreased to a greater degree with the open wedge plate technique, perhaps as a result of medial collateral ligament release. The choice of technique should be based on surgeon and patient preference, however external fixation may be a better choice when maintenance of patella height is deemed important.

High Dose NSAIDS after Osteotomy Surgery Reduce Opioid Consumption without Affecting Bone Healing

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What was the question?
The drug–induced opioid epidemic has taken center stage among lawmakers and physicians. Our institute was contributing to this problem in that we had become accustomed to prescribing high quantities of narcotics to patients undergoing limb lengthening and deformity correction to control a very real pain secondary to tissue stretching. A fear that NSAIDs would inhibit bone healing made us loathe to use these medications. Recognizing the need to change we analyzed the literature on NSAIDs and fracture healing and decided that the data was inconclusive. In a collaboration with our anesthesiologist a new post operative pain protocol was generated for all osteotomy patients whose foundation was based on embracing NSAIDs. The new protocol included IV Toradol and IV Tylenol for the first 24 hours post surgery followed by oral Celebrex or Meloxicam and oral acetaminophen. Oral narcotics were then used for breakthrough pain as needed. Patients were noted to have far less pain in the post operative period which was in part due to the NSAID and acetaminophen's ability to control pain but was also secondary to the removal of narcotics which create habituation and hyperalgesia, actually increasing baseline pain over time. This study looks back at the old protocol that relied primarily on narcotics for pain control and compares it with the new protocol that incorporates standing NSAIDs and Tylenol into the post operative pain regimen. The following questions were asked: (1) Did the use of NSAIDs negatively impact bone healing? (2) Did the use of NSAIDs reduce the need for opioids?

How did you answer the question?
This was a retrospective review of a consecutive series of patients treated at a single center by either of two orthopedic surgeons, fellowship trained in deformity correction and limb lengthening. The cohort straddled a major change in practice: the adaptation of NSAIDs into the post op pain protocol. Inclusion criteria were any adult patient that underwent osteotomy of the lower extremity for deformity correction and/or limb lengthening. This included internal and external implants. Patients treated with carbon fiber reinforced polymer were excluded due to their high propensity for delayed bone consolidation. Demographics, time to union and incidence of nonunion were recorded based on review of charts and radiographs. Total medication administered during and after surgery for the entire post op period were recorded from chart review. All patients were in the epic system and all prescriptions were e–prescribed through epic except acetaminophen which was mostly purchased over the counter (OTC) and was poorly documented in the system. Time to union was recorded and bone healing index (BHI) was calculated. For all patients, nonunion status was defined as a bone that failed to heal after surgery and required further surgical intervention to unite. Slowly healing bone was allowed to unite and not considered a nonunion. For deformity correction patients, we used standard Kaplan–Meier analysis to compare time to union between protocols. Then, since the covariates met the assumptions of proportional hazards, we used a Cox proportional hazard model to compare union between protocols including age, sex, laterality, and smoking as covariates. Patients that underwent limb lengthening were analyzed separately, and BHI was compared between the two protocols.

High Dose NSAIDS after Osteotomy Surgery Reduce Opioid Consumption without Affecting Bone Healing *continued*

Austin T. Fragomen, MD

What are the results?
In a cohort of 88 deformity correction patients, 36 received the old protocol, and 52 received the new protocol. 3 patients with nonunion were identified. In crude analysis, there was not a significant difference between protocols in the time to union (Kaplan–Meier log–rank p = 0.96) or in the hazard ratio (HR) for union after adjustment for age, sex, laterality and smoking (HR: 1.00, 95% CI: 0.61 – 1.65). Among the 54 lengthening patients, 34 received the old protocol and 20 received the new protocol. There were no lengthening patients with nonunion. Among the lengthening patients, there was no significant difference in age, sex, smoking status, amount of lengthening, or BHI between groups. Both groups had similar numbers of lengthening surgeries performed with external fixators and internal nails. Total milligrams of morphine equivalents prescribed after discharge was significantly less in patients receiving NSAIDs ($p<0.001$).

What are your conclusions?
The use of NSAIDs after osteotomy and osteoplasty surgery did not negatively impact bone healing for either deformity correction or bone lengthening using distraction osteogenesis and resulted in a dramatic decrease in narcotic consumption. Our center has continued to use the new protocol consisting of maximum dose NSAIDs and acetaminophen for sustained periods of time to control surgical pain. We have witnessed a decrease in overall pain with the reduction in opioids but were unable to study this retrospectively.

Dilute Peripheral Nerve Catheters: A Unique Method to Decrease Post–operative Narcotic Usage in Limb Reconstruction Patients

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What was the question?
The misuse and abuse of opioids in the United States has reached epidemic proportions. For orthopedic surgeons, it has become critical to find alternative pain management strategies that decrease the amount of narcotic pain medication used by our patients. Regional anesthesia has been shown to be a valuable adjunct to post–operative pain management but is difficult to use in limb reconstruction patients for the following reasons: 1) Nerve blocks can impede the motor function of the nerve which prevents the patient from being able to participate in physical therapy 2) Nerve blocks wear off before the acute pain from surgery has completely dissipated 3) Complete nerve blocks may not be safe after osteotomy if they mask symptoms of a developing compartment syndrome. This study evaluates a unique method of pain management after osteotomy surgery using a portable peripheral nerve catheter that administers a dilute solution to provide sensory block without affecting motor function.

How did you answer the question?
Following IRB approval and waiver of the need for individual informed consent, we retrospectively analyzed the medical records of patients between 10 to 40 years of age who had undergone elective lower limb lengthening procedures under general anesthesia or general plus regional anesthesia over a 3–year period. The regional anesthetic technique included peripheral nerve catheters (PNC) with a continuous infusion of a local anesthetic agent. The primary outcome was opioid requirements during the first 48 hours after the surgical procedure. Opioid administration was converted to oral morphine equivalents (ME) for comparison between groups. Data analysis was performed in Stata/IC 14.2 (College Station, StataCorp, LP) with a two–tailed t–test with $P<0.05$ considered statistically significant. The regional anesthesia technique for the femoral osteoplasty subgroup included a postoperative suprainguinal fascia iliaca catheter while the tibial osteoplasty subgroup had adductor canal and sciatic nerve catheters placed. All catheters were inserted in the operating room under ultrasound guidance with sterile technique. After confirming proper position, a test dose of epinephrine 1:200,000, 0.5 μg/kg to a maximum of dose of 15 μg per catheter, was administered to rule out intravascular placement. A bolus dose of 0.2% ropivacaine (0.05 mL/kg of ideal body weight) was administered after proper bedside neurological exam was performed by the surgeon. For tibial osteoplasty patients each of the two catheters received an infusion of 0.1% ropivacaine was started at 0.05 mL/kg/hour per catheter. For the single catheter in the femoral osteoplasty patients an infusion of 0.1% ropivacaine was started at 0.1 mL/kg/hour. As part of the postoperative analgesia regimen, all patients received acetaminophen (intravenous or oral, 10 mg/kg every 4 hours) plus ketorolac (0.5 mg/kg every 6 hours).

What are the results?
A total of 70 osteotomy patients were included in the study with an average age of 14.5 years. General anesthesia was used alone in 29 (42%) patients while general plus regional anesthesia was used in 41 (58%) (Fig 1). Patients undergoing femoral osteotomies with subsequent adjustable intramedullary nail insertion accounted for a total of 37 subjects: 11

Dilute Peripheral Nerve Catheters: A Unique Method to Decrease Post–operative Narcotic Usage in Limb Reconstruction Patients *continued*

Christopher A. Iobst, MD

(30%) received general anesthesia while 26 (70%) receive general plus regional anesthesia (Fig 2). In the tibial osteotomy subgroup with subsequent placement of a hexapod circular external fixator there were a total of 33 patients. Eighteen patients (54%) received general anesthesia and 15 (46%) received general plus regional anesthesia. (Fig 3)

There was a significant decrease in opioid consumption in the general plus regional anesthesia group compared to the general anesthesia only patients. In the entire study cohort, postoperative opioid use over the first 48 hours was 0.5 mg/kg of oral morphine equivalents (ME) in the general plus regional anesthesia group, compared to 1.7 mg/kg of ME in the general anesthesia only group ($p<0.001$). The same outcome was observed in the two subgroups; 48 hours opioid consumption in the femoral osteotomy group receiving general plus regional anesthesia was 0.4 mg/kg ME vs 2.1 mg/kg ME in the general anesthesia only subgroup ($p=0.006$). In the tibial–fibular osteotomies subgroup, the general plus regional anesthesia patients reported at 48 hours a total of 0.7 mg/kg ME compared to the general anesthesia only subgroup where the postoperative opioid requirements were 1.4 mg/kg ME ($p=0.002$). All patients maintained motor function in the treated limb and were able to complete inpatient physical therapy. There were no compartment syndromes.

What are your conclusions?

This method of pain management produced an overall 3.4X reduction in the opioid usage by our patients in the peri–operative period with femoral patients getting 5X less and tibial patients 2X less. The patients were able to maintain motor function and complete inpatient physical therapy without restrictions. The peripheral nerve catheters were portable and could remain in use for up to five days post–operatively. This appears to be a safe and effective technique for decreasing narcotic pain medication use in limb reconstruction patients.

Fig 1. Opioid use among all patients undergoing procedure for lower extremity length discrepancy (N=70) (IQR = Interquartile range)

Opioid use in morphine equivalents	Regional anesthesia (N=41)	No regional anesthesia (N=29)	P
	Median (IQR)	Median (IQR)	
Intraoperative (mg/kg)	0.9 (0.6, 1.0)	0.7 (0.5, 1.0)	0.698
Postoperative 48 hours (mg/kg)	0.5 (0.3, 0.9)	1.7 (1.1, 3.1)	<0.001

Dilute Peripheral Nerve Catheters: A Unique Method to Decrease Post–operative Narcotic Usage in Limb Reconstruction Patients *continued*

Christopher A. Iobst, MD

Fig 2. Opioid use among all patients undergoing femoral osteoplasty for lower extremity length discrepancy (N=37)

Opioid use in morphine equivalents	Regional anesthesia (N=26)	No regional anesthesia (N=11)	P
	Median (IQR)	Median (IQR)	
Intraoperative (mg/kg)	0.9 (0.6, 1.0)	0.6 (0.5, 1.2)	0.642
Postoperative 48 hours (mg/kg)	0.4 (0.2, 0.9)	2.1 (0.9, 3.1)	0.006

Fig 3. Opioid use among all patients undergoing tibial–fibular osteoplasty for lower extremity length discrepancy (N=33)

Opioid use in morphine equivalents	Regional anesthesia (N=15)	No regional anesthesia (N=18)	P
	Median (IQR)	Median (IQR)	
Intraoperative (mg/kg)	0.9 (0.5, 1.1)	0.9 (0.5, 1.0)	0.664
Postoperative 48 hours (mg/kg)	0.7 (0.3, 1.1)	1.4 (1.1, 3.3)	0.002

Prevalence of Vitamin D Deficiency in Limb Lengthening Patients

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What was the question?
Insufficient vitamin D is a common nutritional deficit which has been associated with fracture risk and poor bone health. Serum 25–hydroxyvitamin D [25(OH)D] levels less than levels less than 30 mg/mL are considered insufficient. This research aimed to determine the prevalence of vitamin D deficiency in adult and pediatric patients undergoing limb lengthening.

How did you answer the question?
This retrospective study of patients undergoing limb lengthening with a magnetic internal lengthening nail at a single, referral center between 2014 and 2018 collected age, sex, race, diagnosis, long bone treated, and peri–operative 25(OH)D and serum calcium level for descriptive statistics.

What are the results?
Eighty–four pediatric subjects (mean age 13.6 ± 2.2 years) and 43 adult subjects (mean age 28.3 ± 15.4 years) with available serum 25(OH)D peri–operative results were included. Most subjects were female (69/127, 54%) and Caucasian (103/127, 81%). In the pediatric patients, congenital diagnoses were most common (57/84, 68%) followed by dwarfism (11%), post–traumatic growth arrest (7%), post–infectious growth arrest (6%), and other miscellaneous diagnoses (8%). The mean 25(OH)D level was 33.0 ± 19.6 ng/mL [range 13.1–103.5 ng/mL]. Deficient levels < 20 ng/mL were found in 23/84 (27.4%) of subjects and insufficient levels < 30 ng/mL were found in 29/84 (34.5%) of subjects. A minority of pediatric subjects (32/84, 38.1%) had adequate 25(OH)D levels. Calcium levels were generally normal [mean 8.3 ± 0.4, range 7.6–9.5 ng/mL]. Among adult patients, frequent diagnoses treated were congenital disorders (10/43, 23%), post–traumatic diagnoses (9/43, 21%), and idiopathic disorders (8/43, 19%). The mean 25(OH)D level was 31.7 ± 15.5 ng/mL [range 13.1–95.9 ng/mL]. Deficient levels (< 20 ng/mL) were found in 9/43 (21%) of subjects and insufficient levels (< 30 ng/mL) were found in 16/43 (37%) of subjects, resulting in 58% of subjects having low peri–operative 25(OH)D. A minority of adult subjects (18/43, 42%) had adequate 25(OH)D levels. Calcium levels were generally normal [mean 8.3 ± 0.4, range 7.5–9.0 ng/mL].

What are your conclusions?
Limb lengthening requires optimal bone metabolism for healing of the new regenerate bone. This study found a high prevalence of vitamin D insufficiency in pediatric and adult limb lengthening patients. Identifying these patients pre–operatively may allow for vitamin D "pre–habilitation" to optimize bone health prior to limb lengthening procedures.

Presidential Guest Lecture

Think Beyond the Extremities – Complications in Skeletal Dysplasia

William G. Mackenzie, MD

The Shands and MacEwen Endowed Chair of Orthopaedics
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Session IV: Internal Lengthening Nails

Moderator: S. Robert Rozbruch, MD

Results of Retrograde, Femoral Lengthening and using the Reverse Planning Method

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What was the question?
Motorized, internal lengthening of the femur occurs through the anatomic axis of the bone. This type of lengthening, without correction, lateralizes the mechanical axis of the limb. The Reverse Planning method, popularized by Baumgart, is one of several published methods used to anticipate this deviation and correct for it at the index operation. Therefore, is the Reverse Planning method for retrograde, internal femoral lengthening effective at improving the mechanical axis of the lower limb?

How did you answer the question?
We retrospectively reviewed all patients who underwent osteoplasty and motorized, internal limb lengthening. After reviewing medical charts and radiographs we selected the patients that underwent retrograde, femoral lengthening using the Reverse Planning method. We excluded patients undergoing concurrent, ipsilateral tibial lengthening/deformity corrections or other ipsilateral, femoral corrections. We analyzed and compared the preoperative and immediate post–lengthening radiographs. This included measurement of the mechanical axis deviation (MAD), lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA) and coronal femoral–tibial angle. We also documented the duration of lengthening and total length achieved. Radiographic pre– and post–lengthening measurements were compared using paired t–tests.

What are the results?
21 patients with a mean age of 14+2 years (Range 12+6 to 18+2 years) were identified. An average length of 34 mm (±10mm) was achieved over a mean duration of 52 days (±18 days). The mean preoperative coronal femoral–tibial angle was 6 degrees away from a neutral mechanical axis with a range of 11 degrees of varus to 16 degrees of valgus. The mean postoperative coronal femoral–tibial angle was within 3 degrees of neutral mechanical alignment. The mean LDFA preoperatively was 87 degrees and mean postoperative LDFA was 92 degrees. The difference between pre– and post–lengthening values for the MAD (mean 12mm of medialization, $p = .005$) coronal femoral–tibial angle (mean 4 degrees of varus, $p = .004$), and LDFA (mean increase of 4 degrees, $p = .006$) all reached statistical significance. The change in MPTA did not reach statistical significance. 19/21 patients completed the lengthening with a coronal femoral–tibial angle within 4 degrees of neutral mechanical alignment.

What are your conclusions?
The Reverse Planning method is a reproducible technique for retrograde femoral lengthening achieved a near neutral mechanical alignment of the lower limb in over 90% of the patients treated. However, it may induce a secondary deformity at the distal femur to achieve an improved mechanical axis. A surgeon may determine if this secondary deformity can be tolerated or if additional osteotomies and corrections away from the lengthening site are required before, during or after lengthening is performed.

Mechanical Failure Rate and Types of Failures Observed in 245 Limb Segments

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What was the question?
What is the mechanical failure rate and what are the types of failures observed for nails?

How did you answer the question?
Retrospective medical record review was conducted of 180 patients (245 segments with minimum 1–year follow–up) who underwent limb lengthening using nails. Mechanical failure was recognized as (1) instrumentation/nail mechanical breakage or (2) internal mechanism failure that resulted in backwinding or that stopped the nail from lengthening.

What are the results?
Mechanical failure was observed in 23 nails (22 patients, 23 limb segments). Mechanical failure rate was 9.3% (23 of 247 nails). Only 4.9% (12 of 245 segments) required an additional, unplanned surgery as a result of mechanical failure. Mechanical failure rates of the original nail and a redesigned nail were 11.3% (11/97 nails) and 8.0% (12/150 nails), respectively. During insertion, 2 nails failed the intraoperative distraction test and were replaced during the same procedure. Mechanical failures during the lengthening stage were observed in 8 nails (3 nonfunctioning mechanisms, 2 proximal fixation failure, 1 lead screw failure, 1 backwinding, and 1 crown fragmentation). Mechanical failures were observed in 8 nails during the consolidation period (2 nail fractures, 2 nail plastic deformations, 2 combined plastic deformations and crown fragmentations, 1 isolated crown fragmentation, and 1 backwinding). Extraction–related mechanical failures were reported in 6 nails (2 crown fragmentation, 1 backwinding, 1 set–screw fracture, 1 extractor assembly breakage, 1 mechanism disassembly).

What are your conclusions?
In 247 nails, a 9.3% mechanical failure rate was observed. However, only 4.9% (12 of 245 segments) required an unplanned surgery due to mechanical failure. Mechanical failure rate was decreased for the newer model. Nail function should be closely monitored throughout the lengthening phase. We recommend that efforts continue to be made to improve nail strength and reliability.

Going to Great Lengths for the Elderly: Nail Lengthening Over 60

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What was the question?
What are the outcomes, complications, and viability of lower limb lengthening in geriatric patients (60 years and older) using the magnetic lengthening nail?

How did you answer the question?
Multicenter retrospective medical record review was conducted of 11 patients (7 men, 4 women, mean age, 65 years [range, 60–72]) who underwent lengthening (8 femora, 4 tibiae) using nails. Etiologies included traumatic injury (8 patients), knee fusion (1 patient), congenital condition (1 patient), and cosmetic concern (1 patient). Mean lengthening goal was 3.8 cm (range, 1.5–6.0 cm). Radiographic review utilized digital films in conjunction with clinical notes to determine preoperative limb length discrepancy, the amount of lengthening achieved, and the dates of full distraction and complete consolidation.

What are the results?
Mean distraction index was 0.66 mm/day (range, 0.29–0.89 mm/day). Mean consolidation index was 33.7 days/cm (range, 23.7–49.6 days/cm), and mean maturation index was 16.6 days/cm (range, 10.4–20.6). Mean duration of follow–up after index surgery was 18 months (range, 9–66 months). We observed six adverse events: two complications, three obstacles, and one problem. Also, there was one mortality unrelated to the surgery. Two complications were observed: one infection after lengthening that resolved with irrigation and debridement at another facility and a sciatic nerve stretch injury resulting in neuropathic pain that persisted post lengthening. Three obstacles occurred: a delayed union (treated with bone marrow aspirate concentration), a delayed malunion with broken hardware (treated with repair of delayed malunion, new osteotomy to achieve lengthening goal, and a new nail), and broken hardware secondary to the patient deliberately over lengthening (treated with a static nail and ORIF). The one problem that occurred was a mechanical problem with the external remote controller during lengthening that resolved before treatment ended. All patients achieved their lengthening goals except for one patient (0.5 cm short of proposed goal).

What are your conclusions?
Lengthening is not traditionally considered in older patients. The distraction rate, consolidation rate, and number of adverse events reported in the geriatric population appear to be similar to that of the general population.

The Accuracy of Blocking Screw–Assisted Intramedullary Nailing for Limb Lengthening and Deformity Correction

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What was the question?
Historically, blocking screws (Poller screws) have been used to assist in the acute reduction of fractures during intramedullary nailing (IMN). However, there is little literature published on the use of blocking screws in deformity correction and limb lengthening. The "reverse rule of thumbs" is a helpful guideline when placing blocking screws in IMN–assisted limb reconstruction. The following questions were asked about the accuracy of deformity correction using this technique.
1) Does the use of 2 or more blocking screws improve accuracy?
2) Does placing the blocking screws 2 cm or less from the osteotomy site improve accuracy?
3) Does an osteotomy site less than 10 cm from the joint line reduce accuracy despite blocking screw use?
4) Does the accuracy differ among deformity correction, limb lengthening, or deformity correction and limb lengthening?
5) Does lengthening the bone by more than 3 cm reduce accuracy?

How did you answer the question?
We conducted an IRB–approved retrospective study on 85 patients who had IMN–assisted limb reconstruction with blocking screws. These surgeries covered 3 different indications: 1) deformity correction, 2) limb lengthening, and 3) deformity correction and limb lengthening. The total number of tibias was 39, femurs 46, and combined ipsilateral tibia and femur 1. Data on the following variables were collected: number of blocking screws, distance from each blocking screw to osteotomy, distance from the joint line to osteotomy, and the amount of limb lengthening. We measured mechanical axis deviation (MAD), medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), posterior proximal tibial angle (PPTA), and posterior distal femoral angle (PDFA) pre–operatively and post–operatively. The primary outcome in tibias was the ability to obtain the desired MPTA and PPTA, and in femurs the desired LDFA and PDFA. Accuracies were reported as post–operative measurements relative to goal (median of normal limits). MAD was used to judge the accuracy of the cohort. A secondary outcome was the ASAMI score.

What are the results?
The average pre–operative MAD was 23.8 mm, and the average post–operative MAD was 9.8 mm. For our specific questions, we found:
1) The number of blocking screws, 1 versus 2 or more, did not impact accuracy in femurs nor tibias.
2) The distance of the closest blocking screw relative to the osteotomy did not impact accuracy.
3) Position of the osteotomy relative to the joint line demonstrated no difference in tibial accuracy. However, in femurs, osteotomies more than 10 cm away from the joint line had a closer post–operative LDFA relative to the goal (mean 2.4 degrees, range 0.5–8.5 degrees) as compared to less than 10 cm (4.0 degrees, 0.5–8.5 degrees) (P=0.026). There were no differences in achieving the PDFA goal in these patients with femoral surgeries.

The Accuracy of Blocking Screw–Assisted Intramedullary Nailing for Limb Lengthening and Deformity Correction *continued*

Sherif Dabash, MD

4) The type of surgery did not affect tibial accuracy but did affect femoral accuracy. Post–operative LDFA was furthest from goal in deformity correction cases and closest in lengthening ones. PDFA did not differ among surgery types.
5) The amount of lengthening, less than 3 cm versus more than, did not affect accuracy in both tibias and femurs.
ASAMI scores were excellent or good across most patients. In regard to complications, blocking screws were unable to prevent flexion in cases of tibial osteotomy with posterior cortical comminution and proximal propagation.

What are your conclusions?
Blocking screws are effective tools in correcting deformities of the lower extremity long bones as well as in preventing deformity during limb lengthening. Using the reverse rule of thumbs configuration to prevent femoral varus compensation and tibial valgus compensation is quite successful. The number of blocking screws and distance of the blocking screw to the osteotomy did not affect accuracy and can be guided by surgeon intuition. Similarly, the amount of lengthening did not impact accuracy and can be a patient and surgeon preference. However, based on our experience, we found accuracy improved when the femoral osteotomy was more than 10 cm away from the joint line.

Difficult Case Presentation

Moderator: Joseph R. Hsu, MD

Joseph R. Hsu, MD
J. Spence Reid, MD

Clinician Scholar Career Development Program Presentation

Wendy Ramalingam, MD

Session V: Trauma I

Moderator: Stephen M. Quinnan, MD

The Utility of Routine Cultures in Low Risk Nonunion Surgeries

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What was the question?
Common orthopaedic practice is to culture every nonunion even in the setting of non–elevated inflammatory markers. While studies have suggested treating surprise positive cultures, others have shown significant complications of that antibiotic treatment. Our goal is to evaluate if there is a benefit to culture and treatment in patients with low pre–test probability of infection undergoing nonunion surgery.

How did you answer the question?
We conducted a retrospective study of patients treated for nonunion between 2015–2017 in a large healthcare system (n=56). We excluded patients with elevated inflammatory markers (n=22), signs of clinical infection (n=15), or history of infection at that site (n=11). Demographic information, injury characteristics, presence of intraoperative cultures, rate of union, and post–operative infections were documented.

What are the results?
24 patients were eligible for the study (presumed aseptic) and included in analysis. Half of the patients received routine intraoperative cultures (n=12, 50%). There were no differences between the groups in age, gender, smoking status, or diabetes. The overall post–operative positive culture rate was 16%. The rate of infection in the group without intraoperative cultures was 0 ompared to a presumed 33% in the group where routine cultures were obtained and subsequently treated. Overall union rate was 85 t last follow up with a union rate of 100% in the non–culture group and 75% in the culture group ($p = 0.487$).

What are your conclusions?
Our preliminary data suggest that in patients without risk factors there is no benefit of obtaining routine cultures during nonunion surgery. Although not statistically significant, continuing to explore this question with a larger sample will be important for weighing risks and benefits of intraoperative cultures in nonunions with low pre–test probability.

ON Path: Outpatient Nonunion Pathway: Surgical Tactic and Pathway

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What was the question?
Despite modern operative techniques, non–unions still remain challenging to manage. Furthermore, they have a debilitating impact on patient quality of life leading to reported outcome scores significantly lower than population norms. Traditional tactics for nonunion surgery, while typically successful, involve significant surgical dissection and length of stay. Our study investigates a pathway approach to treating long bone non–union successfully in an outpatient setting.

How did you answer the question?
The Outpatient Nonunion pathway is utilized to allow for successful non–union treatment as an outpatient procedure. Patients are risk stratified based on medical co–morbidities to be treated as an outpatient at a one day surgery center or in the main hospital. The Pathway pre–operative phase involves opioid tapering (if needed), discussion of cognitive, physical, and pharmaceutical multimodal pain management, and counseling that the patient will go home the same day or following morning. The surgical tactic includes minimally invasive hardware removal and revision implant placement. Preparation of the non–union site is performed through a small incision with flouroscopic and tactile feedback (palpation). Allograft is used to mitigate donor site morbidity and applied through a metal tube with an impactor. Appropriate clinical follow–up for bone healing was defined as six months.

What are the results?
There were a total of 44 non–union surgeries done through the outpatient non–union pathway between the 2013 and 2018. Of these, 15 (34%) were femur, 18 (41%) were tibia, and 11 (25%) were humerus non–unions. 27 (61%) were atrophic, 5 (11%) are hypertrophic, and 8 (18%) are oligotrophic non–unions. The average length of time for the procedure is 151.5 minutes for tibia, 160.4 minutes for femur and, 163.2 for humerus fractures (p=0.72). The average length of stay is 0.5 days for femur fractures, 0.4 days for tibia, and 0.6 days for humerus fractures (p=0.67).
35 (80%) patients are at least six months from injury or have completed clinical follow–up. 28 (80%) of these patients have achieved union (n=19 (68%) within 6 months; n=9 (32%) after six months). On average, union was achieved at 6.9 months. The remaining 4 (13%) patients are have not achieved union, but are still in clinical follow up. The remaining patients are still early in their post–operative period (n=9), were lost to follow–up (n=2), or underwent an amputation due to recalcitrant osteomyelitis (n=1). The overall rate of complications is 13.6% (n=6 patients). Complications included infection (n=5), repeat surgeries (n=5), readmission (n=4), and hardware failure (n=2). There were 9 emergency room visits among 5 patients. 7 of the 9 emergency room visits were shared between 3 patients who have a history of polysubstance abuse and psychiatric disorder. Visits were for pain (n=5), infection (n=3), bleeding at surgical site (n=1), abscess (n=1), and post–surgical fall (n=1).

What are your conclusions?
The use of the outpatient non–union pathway in selected patients is safe and has similar efficacy to traditional tactics.

Prospective Observational Study of an Integrated Therapeutic InitiatiVe for Extremities (POSITIVE): Implementation of an Integrated Orthotic and Rehabilitation Program in the Civilian Setting

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What was the question?
The Intrepid dynamic exoskeleton orthotic (IDEO) and Return to Run (RTR) pathways currently utilized in the military have been demonstrated in literature to facilitate return to duty, recreation and physical activity and decrease pain in high functioning patients who have sustained high energy lower extremity trauma. A recent study has also demonstrated that the processes and outcomes are translatable across military settings, however, to date there is no evidence on implementation of this pathway in the civilian setting. We sought to evaluate the feasibility of implementation of a similar, Return to Performance (RTP), pathway at a high volume, level I civilian trauma center.

How did you answer the question?
Institutional electronic health records, physical therapy referral and prosthetic referral were queried to identify patient who had been evaluated through the RTP pathway. A large, national prosthetic and orthotic company was utilized for brace manufacture and fitting. Physical therapy services were provided in the outpatient setting.

What are the results?
The RTP pathway has been fully operational for three years. There was a two year run in period for initial training of therapists and prosthetists and logistic implementation at our institution. 30 patients have received braces and therapy through the RTP pathway. All expenses for prostheses as well as therapy sessions have been covered by insurance. 32 prosthetists have been trained locally in the fabrication of the brace with an additional 70 trained at the brace manufacturers most recent national meeting. 13 physical therapists have been trained to perform functional rehabilitation through the RTP pathway.

What are your conclusions?
Implementation of the Return to Performance pathway can be translated and scaled to the civilian setting. The study has successfully replicated the brace fabrication and therapy requirements necessary for optimal outcome in the RTR pathway. This provides evidence that the process can be de–centralized and the benefits of dynamic bracing in high functioning patients following lower extremity trauma can be translated to the civilian population.

Intentional Temporary Deformity in Type IIIIA and IIIB Tibia Fractures with Hexapod Frame to Assist in Soft Tissue Coverage

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What was the question?
Open tibia fractures continue to be a challenge for both osseous and soft tissue reconstruction. Free tissue transfer has been an important advancement in providing coverage for these injuries. Unfortunately, this technique is demanding on both patient and surgeon and often not available outside of academic medical centers. In certain traumatic situations, there exists the combination of soft tissue and osseous injury that will allow the tissue envelope to be closed without tension by the temporary creation of a deformity through either the fracture or an osteotomy. In this technique, a hexapod frame is applied and a unique deformity is created and the soft tissue envelope is closed (with or without a STSG). Following healing of the soft tissue, but prior to osseous union, the deformity is slowly corrected such that anatomic alignment is achieved and the the limb is reconstituted without the need for a free tissue transfer or muscle flap. Specific injury characteristics to allow this technique to be employed have not been described. This study retrospectively reviews the use of this technique at two academic centers

How did you answer the question?
Eleven patients were identified over a 15 year period in which this technique was employed. Inclusion criteria was the presence of an open type IIIA or IIIB tibia fracture with the application of a hexapod frame in the acute phase of care and the temporary creation of a deformity to assist in soft tissue closure. Following IRB approval, retrospective data was abstracted and entered into a common RedCap database for analysis.

What are the results?
The mean age at injury was 47 (20–70 yrs). There were 8 men (73%) and 3 women. Smokers comprised 36% of patients. Average BMI was 33 (25–48). The most common fracture location was the distal 1/5th of the tibia (46%) followed by the proximal 1/5th (27%). Extension into either the plateau or pilon were common. The fracture orientation was usually oblique(27%) or comminuted(63%). Bone loss exceeded 2 cm in 55% of patients. The soft tissue wound averaged 7 cm in length (2–30cm), and 5 cm in width(3–28 cm) and was transversely oriented in 73%. The deformity created was varus (80%), apex posterior (45%), internal rotation 27%, and shortening 2mm. The time from soft tissue closure to initiation of deformity correction average 31 (16–61) days and the deformity was corrected over 22 (14–46) days. A corticotomy was performed in 64% outside the zone of injury. Time in frame averaged 295 (157–421)days. Two patients failed primary closure and required additional soft tissue procedures (1 STSG and 1 free flap).

What are your conclusions?
The technique of acute deformity creation in selected open tibia fractures allows tension free soft tissue closure and limb salvage particularly in situations where free tissue transfer is either not available or the patient is not a candidate. The most common presentation is a patient with a comminuted fracture and a transverse open wound on the anteromedial face of the distal 1/5th of the tibia. Varus, apex posterior angulation and internal rotation is the most common created deformity to close this defect.

Plate Assisted Bone Segment Transport Utilizing a Magnetic Intramedullary Limb Lengthening System: Five Patients

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What was the question?
Is plate–assisted bone segment transport using a magnetic intramedullary limb lengthening device effective as treatment of segmental bone defects of the tibia, and can it be performed in the antegrade and retrograde direction?

How did you answer the question?
Plate assisted bone segment transport (PABST) was performed on five patients (4 men, 1 woman) with a Gustilo–Anderson type IIIB tibia fracture by a single orthopaedic surgeon at our institution. The average patient age at time of surgery was 45 (range = 23–76), average defect size was 5.63 cm (range = 2.25–9 cm), and average follow–up is 509.2 days (range = 177–1201 days). Bone segment transport was done in both the antegrade (N = 3) and retrograde (N = 2) direction for distal and proximal tibial defects, respectively.

What are the results?
All patients have successfully salvaged their post–traumatic lower limb. A plastic surgeon was required in all cases to perform complex closure as these injuries are highly associated with significant soft tissue damage. Three patients have achieved complete union and two patients continue to progress toward union. Technical pearls include: placement of a blocking screw can prevent nail drift, screw placement in the transport segment should be placed nearest to the docking site to reduce segment drift, and careful pre–operative planning is essential to select nail length with adequate stroke. Complications resolved included: infection in one case requiring antibiotic bead placement, delayed union requiring exchange nailing and/or bone grafting, and intra–operative fractures during corticotomy.

What are your conclusions?
PABST is an effective means of limb salvage and treating post–traumatic segmental bone defects in the tibia. The ability to perform retrograde and antegrade transport offers increased usability of the intramedullary limb lengthening system in addressing tibial bone defects. Technical pearls learned can be valuable to surgeons considering PABST for bone defects.

Plate Assisted Bone Segment Transport in the Femur Using a Magnetic Internal Lengthening Nail

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What was the question?
Can an all internal technique of bone transport be used to successfully reconstruct traumatic segmental bone defects in the femur?

How did you answer the question?
A retrospective review of four patients who had an average segmental bone defect of 9 cm (range 6.5–10 cm) treated with a plate assisted bone segment transport using a magnetic internal lengthening nail combined with a lateral locking plate is reported. Patients were treated in a staged fashion with the osteotomy and placement of the internal lengthening nail performed approximately one month after open reduction and internal fixation of the open distal femur fractures. At the time of docking, patients had their lengthening nail exchanged for a trauma nail and progressed to full weight bearing. The patients were followed until they were fully ambulatory without any aids with an average follow up of 16 months (range 11–19 months).

What are the results?
There were no nonunions and no infections. All fractures and osteotomy sites healed without the need for additional unplanned procedures. Limb lengths were within 2 cms of the oppostite lower extremity and coronal alignment was also within 5 degrees of contralateral extremity. Knee range of motion averaged 3–115 degrees. No patient required ambulatory aids for walking.
Complications included one nail that had to be revised from antegrade to retrograde due to inability of the remote control to activate the magnet in the nail because of patient obesity and large amount of soft tissue.

What are your conclusions?
We describe a useful technique in the reconstruction of segmental defects in the distal femur resulting from trauma. Successful treatment of defects of at least 10 cms can be obtained with this technique without the need for an external fixator. No nonunions of the docking site or distraction site were observed and excellent alignment was also noted. We feel this is an attractive all internal technique for the treatment of segmental defects in the femur.

Single– versus Double–Level Corticotomy for the Treatment of Segmental Tibia Bone Defects Using the Balanced Cable Transport and Then Nailing Method

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What was the question?
The management of segmental bone loss resulting from high–energy tibia fractures and their sequelae remains a challenge even with modern techniques. Our group has previously described our treatment protocol for segmental tibia bone defects using circular external fixator with a balanced cable bone transport and then intramedullary nailing (BC–TATN) method. For patients that have massive segmental defects >10cm, we have used two–level corticotomies in order to decrease external fixation and healing time. This study looks to answer the question about difference in healing rate and external fixator time comparing single versus double–level corticotomies with this method.

How did you answer the question?
After institutional review board approval, a retrospective review was performed at a single university level 1 trauma center. We identified 37 patients that were treated with the BC–TATN method. For this study, we excluded patients that had not yet completed healing resulting in a final cohort of 23 patients. We defined healing as radiographic healing with 3 bridging healed cortices together with independent ambulation without assistive devices. Because of our data distribution and number of patients, nonparametric statistics were used for this analysis.

What are the results?
Our cohort includes 8 patients that were treated using two corticotomies, and 15 with a single corticotomy. Of the patients that had two corticotomies, 4 (50%) had proximal metaphyseal and shaft corticotomies and underwent tandem proximal to distal transport. Four (50%) had proximal metaphyseal and distal metaphyseal corticotomies and underwent converging transport. Of the patients that had a single level corticotomy, 13 (87%) had a proximal metaphyseal corticotomy. Two (13%) patients had shaft corticotomies. Median (interquartile range) bone defect was 13.8 (13.1–18.7) and 7.3 (5.6–9.4) for double and single level corticotomy patients, respectively. External fixation time was 139 (107–181) days for double–level, and 119 (98–161) days for single–level corticotomy. External fixation index was 9 (8–12) days/cm for double–level, compared to 12 (12–22) days/cm for single–level corticotomies (p=0.01). Healing time was 265(225–366) days four double–level, and 272(253–316) days for single–level corticotomy. Healing index was 19 (16–20) days/cm for double level, compared to 35(31–40) days/cm for single level corticotomies (p=0.001). The docking sites healed faster than the regenerate bone by a median of 42 (30–70) days.

What are your conclusions?
BC–TATN provides a reliable and safe treatment strategy for segmental tibial bone loss associated with severe open fractures, infected nonunions, and osteomyelitis. Double level osteotomy performed with BC–TATN significantly decreases the external fixation and bone healing index and compares very favorably to historical cohorts of multifocal transport with traditional circular external fixation. BC–TATN with double–level corticotomy is more technically challenging than single–level corticotomy but given its substantial advantages should be considered in the treatment of patients with larger segemental tibial bone defects.

Balanced Cable Transport with Circular External Fixation and Then Nailing for Segmental Tibia Bone Defects

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What was the question?
Is cable bone transport and then immediate intramedullary nailing (CB–TATN) effective in the treatment of tibia bone defects?

How did you answer the question?
After institutional review board approval, a retrospective review was performed at a single university level 1 trauma center. We identified 37 adult patients that underwent CB–TATN. Of these, 20 have completed 1–year follow up. We defined healing as radiographic healing with 3 bridging healed cortices together with independant ambulation without assistive devices.

What are the results?
Seventeen (85%) patients had defects from severe open tibia fractures (AO/OTA 42), 2 (10%) from tibial septic nonunion, and 1 (5%) from osteomyelitis. 10% of our patients were smokers. Average follow up time was 16 months (12–43 months). The average bone loss was 11.6 cm (6–24). 13 (65%) patients had a single level osteotomy and 7 (35%) had multifocal transport. Average frame time was 115 days (74–314). Average healing time was 281 days (197–477), with an average healing index of 0.9 months (28 days) per cm bone loss. Fracture union rate and healing of regenerate bone was 100%. One patient developed a deep infection 6 months after healing and required debridement, nail removal, and intravenous antibiotics with no further sequelae or limitations at final follow–up. Alignment data at healing revealed an average medial proximal tibia angle of 86.7 (84–90), medial distal tibia angle of 89.8 (87–92), proximal posterior tibia angle of 79.2 (77–81) and anterior distal tibia angle of 80.4 (77–84). The incidence of malalignment greater than 5 degrees was 0%.

What are your conclusions?
Balanced cable transport with circular fixation followed by intramedullary nailing provides a reliable and safe option to treat tibial bone loss associated with severe open fractures, infected nonunions, and osteomyelitis. The results of the CB–TATN method reported here show an outstanding success rate with a dramatic decrease in external fixator and bone healing index over more traditional methods of distraction osteogenesis. These differences indicate that the CB–TATN method may represent a new gold standard in tibial bone defect reconstruction with distraction osteogenesis.

Alessandro Codivilla Presentation

What Limb Trauma Patients can Teach Surgeons – Lessons from the Boston Marathon Bombing

Patrick Downes, PsyD

Jessica Kensky, RN

Poster Session

Please visit the posters in the back of the meeting room.

An author will be available to answer questions/discuss the research.

Poster # 1

Patient Guided Physical Therapy in Internal, Motorized, Femoral Lengthening

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What was the question?

Motorized lengthening nails have improved the limb lengthening patient experience and result. Patients with congenital limb length discrepancies have a risk of knee joint subluxation during lengthening. The knee can be temporarily protected from subluxation by spanning the joint with external fixation. However, an ideal protocol for preventing knee subluxation during motorized internal limb lengthening is still not well established. Various intensive regimens have been advocated to maintain knee joint position and motion during limb lengthening. A less intensive approach to physical therapy has evolved at our institution for patients undergoing lengthening, consisting of teaching simple isometric and stretching exercises with an emphasis on maintenance of knee joint extension prior to hospital discharge, thereafter using a knee immobilizer to assist static knee extension. We now examine the results of this protocol by evaluating post–lengthening range–of–motion (ROM) as well as the incidence of knee subluxation, or need for formal physical therapy, in order to answer:
Can a self–driven stretching and strengthening home therapy program lead to maintenance of knee motion following limb lengthening in patients with congenital limb length discrepancies and prevent knee subluxation and/or dislocation?

How did you answer the question?

We conducted a retrospective chart review to identify patients who had undergone femoral lengthening with an intramedullary, motorized nail between 2008 and 2018, for any diagnosis. We excluded patients who had acquired forms of limb length discrepancy. In cases of multiple lengthenings, only the first was included for this analysis. All patients were given instructions post–operatively on the use of a knee extension splint, quadriceps strengthening exercises and hamstring stretching exercises to be done independently and at home. Baseline demographic, clinical, and radiographic data was obtained from initial review, review at conclusion of lengthening, and at last followup (minimum 6 months). Paired t–test was used to compare pre–operative and final followup motion; p value $< .05$ was considered significant.

What are the results?

Data was available for 27 femoral lengthenings (diagnosis: 18 congenital femoral deficiency, 4 hemihypertrophy/atrophy, 4 idiopathic). One patient underwent bilateral femoral lengthenings. Five patients were diagnosed pre–operatively with knee instability. Average pre–operative leg length discrepancy (LLD) was 43 mm (Range: 0 – 85 mm). Average length achieved was 37 mm (15 – 60 mm). At the conclusion of lengthening, flexion was reduced by an average 34% (0 – 67%); additionally, four patients developed flexion contractures of 10, 10, 17 and 30 degrees. At final follow–up, average knee extension was 0 degrees (±1 degree) and knee flexion was 136 degrees (±7 degrees). There were no statistically significant differences between pre–operative and final follow–up knee extension ($p=.21$) or flexion ($p=.54$). There were no knee subluxations. One patient regained less than 90% of pre–operative range (78%).

Patient Guided Physical Therapy in Internal, Motorized, Femoral Lengthening

continued

What are your conclusions?

Our approach to physical therapy during lengthening resulted in no knee contractures or subluxations. All patients experienced a reduction in flexion during lengthening, and then achieved near–full motion by one year. All but four patients maintained full knee extension without ongoing physical therapy visits. This approach is less resource intensive than formal physical therapy programs but demands careful preoperative and in–hospital postoperative therapy guidance as well as surgeon surveillance at each postoperative visit. Further research into patient satisfaction, and examination of subsequent lengthening procedures is required.

Poster # 2

Applications of Ultrasonography in Limb Lengthening and Reconstruction

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What was the question?
Ultrasound technology offers multiple benefits including cost effectiveness, portability and lack of radiation. It allows for a wide range of diagnostic and therapeutic applications to musculoskeletal health. We examined the utility of ultrasound in the field of limb lengthening and reconstruction (LLR), believing that the technology's ability to improve surgical safety and improve diagnostic accuracy has a large potential to improve patient outcomes and satisfaction.

How did you answer the question?
A literature review was performed to determine the musculoskeletal applications of ultrasound that could be applied to LLR. Additionally, five cases are presented to highlight the various diagnostic and therapeutic functions of ultrasonography in LLR.

What are the results?
Many widely accepted uses of ultrasonography for musculoskeletal pathologies have diagnostic and therapeutic utility in LLR. Diagnostic purposes include non–invasive assessment of regenerate bone quality, size, and shape. Additionally, practitioners can estimate biomechanical properties of the regenerate. Therapeutic benefits include localization of anatomic structures, enhancing bone formation with the use of low intensity pulsed ultrasound bone stimulation, and assisting in needle guidance for percutaneous injections or biopsies. Exemplary cases from our institution are highlighted.

What are your conclusions?
Ultrasound can be effectively utilized for both diagnostic and therapeutic purposes in LLR. Its portability and cost effectiveness pose a great asset to those practitioners who are trained in the techniques to utilize the technology properly. Often there is a high radiation burden for patients undergoing LLR, so the ability to use a radiation–free modality is attractive as a means to improve the safety profile of treatment. More research is required to determine the reliability of this technology and its users in its applications for LLR.

Poster # 3

X–Ray Calibration for Orthopedic Procedures

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What was the question?
Radiographic measurements are used pre–operatively for planning of surgical deformity correction and post–operatively for monitoring of the correction. Correct measurement of any object on an x–ray image is difficult as a 3–dimensional anatomic structure is projected to a planar film. The resulting 2–dimensional image is magnified, and the true anatomic sizes are distorted. Therefore, x–ray images need calibration for proper measurements. Most often used calibration marker is a radiopaque ball of known diameter which is placed at the level of anatomical object. The purpose of our study is to evaluate if there are any changes in measurements when the x–ray marker is positioned away from the center of the x–ray beam. And to evaluate the capability of a newly introduced x–ray marker to allow for accurate calibration of x–ray images.

How did you answer the question?
Two different x–ray markers were used in this study: metal spheres with diameter of 25 mm (M1) and radiopaque adhesive disks with inner diameter of 20 mm and outer diameter of 30 mm (M2). Four spheres and four discs were affixed to radiolucent templates with 6 cm distance from the center of each marker. Radiographs of these templates were taken with an x–ray beam centered at the middle of one marker at the edge of the template. X–rays were repeated with the templates positioned at 0, 10, 20, and 30 cm elevated away from the x–ray cassette. Synapse digital radiology system was used to measure the diameter of the discs and spheres. The x–rays were also printed, and digital handheld calipers were used to repeat the measurements. Three measurements for the diameter of each marker were taken for both the printed and the electronic version by three examiners. Four M2 markers were also attached to x–ray detectable plastic cylinder 15 mm in diameter and 240 mm in length. All markers were attached in the same plane and x–rays were taken at different angles of the plane of the markers (at 0, 30, 60, and 90 degrees). One x–ray image was also taken with the M1 markers adjacent to the cylinder as a control. These x–ray images were loaded into a HEX–Ray module of the TL–Hex planning software (Orthofix, Inc. Lewisville, TX, USA) and cylinder length was measure after calibrating the image using markers.

What are the results?
The results of the Intraclass Correlation Test, comparing accuracy of measurements of different readers, demonstrated that there was no significant difference in measurement between the three examiners. There was also no difference in measuring the sizes on paper or using Synapse digital radiology system. When compared projection sizes of the centered markers to ones positioned away from the center – the slight increase is size was noted for both M1 markers (up to 4.43 ± 3.19%) and M2 markers (up to 1.85 ± 1.8%). These changes were not statistically significant and were actually within the measurement errors. Comparison of calibration methods using M2 at different rotation angles vs. M1 showed difference from 0.7% to 1.3% (or max up to 3.1 mm for the 240 mm long cylinder). Which was within measurement error between raters (1.2%). Circle calibration tool of the HEX–Ray software was used for the calibration – as it allowed for easy positioning of the circular projection of the M1 marker and elliptical projection of the M2 marker within the circle tool. Rotation of the M2 markers did not affect the calibration accuracy.

X–Ray Calibration for Orthopedic Procedures *continued*

What are your conclusions?

Positioning markers away from the center of the x–ray beam results in slight increase of the size of their projection. However, the resulting change in size is lesser than the measurement error. Therefore, positioning markers within 18 cm from the center of the x–ray beam should not affect the precision of the calibration. X–ray calibration with the newly introduced radiopaque disk markers has the same accuracy as the known spherical markers. Nevertheless, disk markers are easier to handle and attach to the patient limb.

Poster # 4

Establishment of an Accurate and Precise Alternative Intraoperative Technique for Determination of Femoral Anteversion

Benjamin Yao, BA, Don Li, MS, Jonathan Cui, MD, Havalee Henry, MD, Vineet Tyagi, MD, Joseph Bagrit Kahan, MD, MPH, Allen Daniel Nicholson, MD, Brian G. Smith, MD, Raymond W. Liu MD, Daniel Roy Cooperman, MD
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What was the question?

Accurate femoral version can be determined in the operating room using a C–arm, if it is possible to identify the bicondylar plane described by Murphy et al. (JBJS 1987) and the angle at which the femoral neck intersects it. The bicondylar plane is determined by superimposing the most posterior aspects of the medial and lateral femoral condyles. We developed a modified C–arm technique where a perfect knee anteroposterior (AP) is determined, the femur is rotated until a lateral view of the proximal femur produces a neutral neck, and then the rotation of the C–arm used for the perfect knee AP produces the degrees of version. This study tests the ability to accurately and precisely assess intra–operative femoral anteversion through this modified C–arm technique compared to the modified Ogata–Goldsand biplanar imaging technique.

How did you answer the question?

To study the ability of an observer to determine when the femoral neck is level to the ground, 72 cadaveric femurs were photographed proximally with the bone rotated to versions ranging from –20 to + 20 degrees in 5–degree increments. These were arranged in a grid layout and validated through three–fold randomization and blinding. Five investigators selected the orientation that they believed to be closest to neutral (0 degrees) femoral version. Then, five full–size cadavers were examined in a surgical suite. The femoral version of each full–size femoral cadaver was estimated utilizing the modified C–arm technique and the modified Ogata–Goldsand technique, with the Kingsley and Olmsted anatomical technique as the gold standard.

What are the results?

In determining neutral femoral neck, observers were able to determine 0 degrees of version accurately with the average absolute deviation 4.4 degrees (SD 2.4 degrees). There was minimal systematic bias in the selections with –1.8 degrees aggregate average deviation from true neutral. Intraclass correlation coefficient = 0.91 for intraobserver and 0.79 for interobserver comparisons. The modified C–arm technique produced an average measurement deviating 1.45 +/– 5.2 degrees from the true value. The modified Ogata–Goldsand technique had an average measurement deviating –0.5 +/– 3.6 degrees from true angles. Intraclass correlation coefficient was 0.82 for different observers and 0.81 for average measured values for the modified C–arm technique, versus 0.78 and 0.89 for the modified Ogata Goldsand technique.

Establishment of an Accurate and Precise Alternative Intraoperative Technique for Determination of Femoral Anteversion *continued*

What are your conclusions?

We show that observers can accurately perceive when a femur neck is parallel to a virtual floor. Furthermore, there are no systematic biases towards version with tight standard deviations on all predictions, and there is excellent intra and interobserver agreement in the perception of neutral femoral version. Additionally, we show that utilization of the modified C–arm technique is comparable to the modified Ogata–Goldsand technique. The relatively simplicity of the modified C–arm technique versus the modified Ogata–Goldsand technique makes this modified C–arm technique a reasonable option for measuring intraoperative femoral version.

Poster # 5

Alternative Tibial Osteotomy Technique

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What was the question?
Tibial osteotomies using the drill hole and osteotome method are commonly performed from an anterior approach. When using this approach, iatrogenic damage to the anterior tibial periosteum is often unavoidable which may lead to an anterior defect in the subsequent regenerate bone. The approach also forces the surgeon to direct the osteotome in an anterior to posterior direction. This places the posterior neurovascular structures at risk to injury if the osteotome is inadvertently advanced too deep. Finally, the approach requires the C–arm to be placed in the lateral position to monitor the depth of the osteotome penetration. Is there an alternative tibial drill and osteotome method that avoids these concerns?

How did you answer the question?
An alternative surgical technique was developed using two small incisions. A 5 mm incision is made over the anterior crest of the tibia. A drill bit (3.8 or 4.8 mm) is then carefully directed anterior to posterior parallel to the lateral cortex of the tibia to create a bicortical drill hole. The drill is then withdrawn from the posterior cortex and re–advanced slightly medial to the first exit hole creating a second posterior hole. This is repeated two more times until the final hole is through the posteromedial corner of the tibia. This pattern of drilling uses one anterior entry hole to produce a total of four posterior cortex holes. A second 5–10 mm incision in the skin at the same level is made at the posteromedial edge of the tibia. The drill is directed straight medial to lateral parallel to the posterior cortex to create a bicortical drill hole. A second bicortical drill path is made parallel to the first holes in a medial to lateral direction. Using the second medial entry hole the drill is angled anteriorly and a hole is made in the anterolateral corner of the tibia. Finally, the skin can be retracted posteriorly and a unicortical hole can be made in the posteromedial tibia. With the limb elevated on towels, the osteotome is used to pass from medial to lateral through the medial incision. The medial cortex of the tibia is cut next, aiming from posterior to anterior. At this point, a twist of the inserted osteotome should be sufficient to break the tibia.

What are the results?
This technique has been performed on over 20 consecutive tibial osteotomy patients, both in the metaphysis and the diaphysis. The technique avoids elevating the anterior periosteum and directs the osteotome posterior to anterior away from the neurovascular structures. The C–arm does not need to be placed in the lateral orientation to visualize the osteotome path. There were no neurovascular injuries or skin healing issues using this technique. Bone formation and healing was excellent in all cases without an anterior defect.

What are your conclusions?
This abstract describes an alternative tibial osteotomy technique that can be performed quickly and safely using a minimally invasive approach. By creating circumferential drill holes, there is a decreased tendency to cause spikes or large irregularities at the osteotomy site. The osteotome is never directed towards the neurovascular structures and preliminary data shows reliable anterior bone healing. This osteotomy technique can be used as an alternative to the anterior approach.

Poster # 6

Limb Lengthening Reactivation with "Sleeper" Nails

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What was the question?
Magnetic intramedullary lengthening nails have been proven effective for limb lengthening. Patients with large discrepancies may require more than one lengthening treatment. The authors present a case series of magnetic lengthening nails that lengthened, were deliberately stopped for a prolonged period, and then were re–activated for a second lengthening. We term this sequence the "sleeper" nail strategy.

How did you answer the question?
Lengthening was deliberately terminated short of overall target length in three patients (six segments: bilateral femoral, bilateral tibial, and 2 unilateral femoral lengthenings). Etiologies were hypochondroplasia (1 case) and congenital femoral deficiency (2 cases). The hypochondroplastic patient with four–segment lengthening developed bilateral progressive knee flexion contracture and peroneal nerve symptoms, which prompted program termination. Preconsolidation and joint instability halted lengthening in the remaining two patients with congenital femoral deficiency. All magnetic lengthening devices had a residual stroke capacity after the first lengthening and remained in the limb. After a period of dormancy, new osteotomies were made and the same nails were reactivated for a second lengthening.

What are the results?
Reactivation of nails was successful in all three patients. Average residual stroke capacity was 3.25 cm. The intraoperative distraction tests were positive in all cases. Implant–related complications were not encountered during any of the second lengthenings. The mean length achieved post–reactivation of nails was 3 cm (range, 1–5 cm). During the second–stage consolidation phase, bending was seen in one tibial nail (valgus) and one femoral nail (varus). These two cases required conventional intramedullary nail exchange with intraoperative temporary external fixator application.

What are your conclusions?
The concept of "sleeper" magnetic lengthening nails was shown to be effective in these three patients. Candidate magnetic lengthening nails must have an adequate lengthening reserve. Nails with signs of impending failure should not be reactivated. Patients must be informed regarding the possibility of magnetic mechanism failure and subsequent need for insertion of a new, substitute magnetic lengthening nail. "Sleeper" magnetic nail lengthening may shorten the operative time and reduce the overall procedure cost by sparing the need for insertion of a new magnetic lengthening nail.

Poster # 7

Preliminary Report on a Method of Assessing Functional Hip Motion

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What was the question?
Pediatric outcomes measures for hip procedures have been difficult to establish, and need to be fundamentally different from those devised for adult hip procedures. Adult hip scales are primarily evaluate outcomes for total hip replacements and focus largely on the patient's symptomology, and not a functional range of motion. Pediatric hip pathologies in arthrogryposis are congenital, either dislocations or contractures, and are rarely painful during childhood. Evaluating activity limitations in pediatric hip conditions, before and after surgical treatment is also a less reliable outcome measure compared to adults. Many conditions are treated in infancy, before full acquisition of milestones, making functional comparisons infeasible. Also, children usually are less impeded by physical impairments than adults, attempting to adapt to their circumstances in order to participate. The existing pediatric outcomes scales, such as the PODCI, are very useful but do not evaluate the global improvement in hip motion after hip reconstruction in the child. Can we develop a hip scale focused on infant and pediatric hip conditions, that is centered around the subject's functional range of motion, resulting in a single, comparable value? Such a value will allow pre– to post–operative comparisons, or comparisons between subjects.

How did you answer the question?
We will present preliminary work on a method to assess the total or global range of motion of the hip, then use it to assess motion before and after a treatment, thereby judging the effectiveness of a treatment. We created a model to graph hip range of motion in three dimensions, with the axes of flexion–extension, abduction–adduction, and internal–external rotation in the X–Y plane. Connecting the data points on the 3 axes creates a "radar" or "spider web" plot. Normative data was used to create an ideal or standard hip plot. This standard was made three dimensional, with the Z–axis, projecting perpendicularly, emanating up from the point corresponding to 30° of flexion, all other axes neutral (the most functional position for a fused or immobile hip). The resulting 3 dimensional graph is tent–like. A subject's hip motion is plotted on the same radar plot, and projected straight up, intersecting the "roof of the tent". The volume of standard hip graph captured by the outline of the subject's plotted hip data is expressed as a percentage of the entire volume underneath that standard hip graph, i.e. a percentage of "functional hip motion". Comparisons of the percentage of "functional hip motion" before and after a treatment would be meaningful in understanding how much a given surgical intervention improves a patient's global hip motion range, which can then be compared a patient's functional abilities over time. We compared pre– and post–operative values of functional hip motion of patients with arthrogryposis who underwent reorientational osteotomies of the femur, for hip contractures. We also compared pre– and post–operative measures of patients with arthrogryposis who underwent open reduction of their dislocated hips.

What are the results?
For the 53 patients who underwent reorientational osteotomies, with full pre–operative functional hip scores were 42% +/– 11%, which improved to 54% +/– 20%, post–operatively ($p = 0.0001$). For the 9 patients who underwent open reduction of their hips, the pre–operative and post–operative values did not change (45% +/– 18 nd 42% +/– 18%, respectively, $p = 0.63$).

What are your conclusions?
This model for a functional hip score appears to provide the desired results, a single value that can be compared between the pre– and post–operative states of the hip. In the case of the reorientational osteotomy for arthrogryposis, the data suggests that the child's hip motion is placed into a more functional sphere, whereas in the hip dislocation patients, the small decrease in the functional motion value does not reach statistical significance, although it is a very small sample size. We hope to continue to refine the model, and work towards validating it.

Poster # 8

Humerus Lengthening

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What was the question?
The ystem is a fully implantable device based on an external computerized control unit and a wireless energy transmission to a motorized distraction nail. The system was used in our Center for more than 1500 lengthening of femur and tibia. What are the indications for the use of the system in the humerus and which results can be expected?

How did you answer the question?
The humerus as the best healing bone in the human body is suitable for lengthening with a nail as well but the indications are rare in comparison with the lower legs. Especially when driving a car or when working on a tablet length discrepancies of the arms of more than 4–5cm may cause severe hardening of the cervical muscles and induce chronical pain in the upper spine. We have used the device in 5 cases for humerus lengthening. The nail was inserted in all cases from proximal. The mean age of the patients was 34 years. No patient was lengthened before with an external device. The mean lengthening amount was 58mm (55–100). In one case the system was exchanged to reach the desired length (40mm + 60mm).

What are the results?
Lengthening was done as usualy with 1mm/day in 3 steps each 90 seconds and was completed in all cases as planned. The bone healing was circular around the nail and very fast. The arm was used functionally without any restrictions after wound healing beside carriing havy load until the bone seems to be strong enouph. There was no infection, no radial nerve irritation and no chronical shoulder pain. The system was removed in 3 cases in an average of 15 months (12–18) the other 2 nails will be removed sone as well.

What are your conclusions?
The preliminary results of our 5 cases demonstrate, that the device is not only a favourable option for lengthening the lower leg but also advantageous for lengthening the humerus. In some cases especially in achondroplastic patients the initial length of the humerus may be too short to allow the insertion of a regular nail and custom made implants may be needed. In comparison with the use of external fixators the functional outcome, the comfort of treatment and the cosmetic result is amazing.

Poster # 9

Complex Femur Problems and the Monolateral Rail: A Power Tool in Times of Despair

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What was the question?
Is the monolateral rail an effective tool for femur reconstruction?

How did you answer the question?
After institutional review board approval, a retrospective review was performed at a single university level 1 trauma center. We identified 8 patients that underwent reconstruction with the Modular Rail System (MRS) monolateral rail external fixator from January 2009–January 2019.

What are the results?
Our cohort includes 8 patients with femur problems treated with a monolateral external fixator. Median age was 43(30–58). Two (25%) patients were smokers. Four were treated for deep infections/osteomyelitis, 3 patients were treated for malunions with shortening, and one was treated for lengthening due to acquired leg length discrepancy. The median lengthening was 9 (6–13) cm. Four patients were converted to a nail, 3 patients continued in the fixator until healing, and 1 patient was converted to a nail/plate combination. For the 5 patients that were converted to internal fixation, the median frame time was 91(30–147) days, with a median time to healing of 191 (90–295) days. For the 3 patients that were allowed to heal in the frame, the median frame time was 326 (307–422) days, with a median time to healing of 316 (302–393) days. Five patients (63%) had complications requiring further surgery after frame removal, including 3 patients with deep infection requiring debridement and/or removal of hardware to achieve cure, 1 patient with a persistent infection decided to change plans for an above knee amputation during treatment, and one patient had a stiffening screw placed at the fracture site after initial callous formation.

What are your conclusions?
The monolateral frame is a powerful and useful tool to treat complex pathology in long bones. Treatment strategies that involve conversion to internal fixation significantly shorten time in the external fixator, but were associated with a significantly increased risk of complications.

Poster # 10

Long–Term Alignment After Balanced Cable Transport with Circular External Fixation and Then Nailing for Segmental Tibia Bone Defects

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What was the question?
Is circular fixation with bone transport and then nailing is a reliable and effective method to treat significant bone defects after tibia fractures? This study presents the alignment data of our treatment protocol including the use of balanced cabler transport and then immediate intramedullary nailing (BC–TATN) for the treatment of tibial bone defects.

How did you answer the question?
After institutional review board approval, a retrospective review was performed at a single university level 1 trauma center. We identified 51 adult patients that underwent reconstruction with a cable transport. Of these, 37 patients were treated with our BC–TATN method. We measured coronal and sagittal alignment using the method described by Paley in the immediate postoperative period, and at 3, 6, and 12 months.

What are the results?
The average(min–max) medial proximal tibia angle (MPTA) was 87(85–90), 87(85–90), 86(84–89), and 86(84–89) in the immediate postoperative period and at 3, 6, and 12 months, respectively. The average(min–max) lateral distal tibia angle (LDTA) was 88(84–92), 89(83–96), 88(79–97), and 88(83–98) in the immediate postoperative period and at 3, 6, and 12 months, respectively. The average(min–max) posterior proximal tibia angle (PPTA) was 80(76–83), 80(76–85), 79(74–84), and 77(73–83) in the immediate postoperative period and at 3, 6, and 12 months, respectively. The average(min–max) anterior distal tibia angle (ADTA) was 82(77–87), 82(76–88), 82(75–89), and 82(77–88) in the immediate postoperative period and at 3, 6, and 12 months, respectively. At 1 year, The average (min–max) alignment change in the coronal plane was 2.1 (1–4) degrees in the proximal tibia and 2.8(1–7) degrees in the distal tibia. The average (min–max) alignment change in the sagittal plane was 3 (0–5) degrees in the proximal tibia, and 2.2 (1–5) degrees in the distal tibia. One patient with a very short distal tibia segment (29mm) collapsed 7 degrees into varus at the ankle from her original alignment at 1 year follow up.

What are your conclusions?
The results of the CB–TATN method reported here show that excellent alignment can be consistently obtained and maintained through the healing process. Mild drift in the sagittal plane alignment of the proximal tibia was noted in some, but was eliminated with the addition of a proximal posterior blocking screw. Change in the distal alignment was uncommon, but occurred in one patient with a very small distal segment of 29mm.

Poster # 11

Dysplasia Epiphysealis Hemimelica of the Lower Extremity: A 47–Year Multi–Institutional Review

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What was the question?

Dysplasia epiphysealis hemimelica (DEH) is an extremely rare condition and treatment recommendations vary widely. This study aims to characterize the nature of DEH of the lower extremity and correlate radiographic classification to presenting symptomatology and ultimate need for surgical intervention.
What are the characteristics and nature of DEH of the lower extremity and how can lesions be classified radiographically and symptomatically to determine a threshold for surgical intervention?

How did you answer the question?

An IRB approved multi–center, retrospective review of all patients with DEH over a 47–year period was conducted. Medical records and radiographs of all patients aged 0–25 years with DEH of the lower extremity were reviewed. Demographic data, presenting complaints, range of motion of the affected joint, treatments rendered and symptoms at final follow–up were recorded. Radiographs were reviewed to determine if solitary or multiple lesions were present within the involved joint. Lesions were classified using the Universal Classification System for Osteochondromas (UCSO). Correlative statistics were used to determine if certain presenting complaints, lesion location or radiographic classification portended the need for surgery or a pain–free outcome.

What are the results?

28 patients met inclusion criteria with an average age at presentation of 7.8 years (range 1–20 years). The ankle was the most commonly affected joint with 20/28 patients (71%) having lesions of talus, distal tibia or distal fibula. Patients with a chief complaint of pain or deformity were likely to undergo surgery while those with complaints of a mass were less likely ($p=0.03$). Ankle lesions were more likely to be managed operatively than those of the hip or knee ($p=0.018$) and of the 12 patients with talar lesions, all underwent surgical intervention. Neither the number of lesions nor lesion classification by the UCSO was predictive of surgical intervention or a pain–free outcome following surgery. Patients presenting with pain were more likely to have a pain–free outcome (11/14 patients) following surgery ($p=0.023$) while all patients presenting with deformity who underwent surgery had pain at final follow up. Overall, there was no difference in pain–free outcomes between patients undergoing surgery and those managed conservatively.

What are your conclusions?

While no single radiographic characteristic of DEH is predictive of surgical intervention or outcome, painful lesions of the ankle joint and lesions of the talus in particular were more likely to be managed surgically. Though surgical intervention does not reliably result in a pain free outcome, the operative management of painful lesions is more likely to provide a pain–free outcome than surgery for deformity or a mass. Symptomatology is more predictive of success with operative treatment of lower extremity DEH than location or lesion characteristics.

Session VI: Pediatrics I

Moderator: David Podeszwa, MD

The Use of Growth Modulation in Conjunction with Motorized, Internal, Femoral Lengthening in Patients with Congenital Femoral Deficiency

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What was the question?
Computer–assisted circular external fixation allowed for simultaneous limb lengthening and deformity correction in skeletally immature patients. Over the past two decades, internal, motorized lengthening has evolved. However, the ability of the motorized, femoral lengthening nail to correct deformity is limited. Patients with congenital femoral deficiency (CFD) may have associated lateral femoral condyle hypoplasia and have pre–existing genu valgum. In addition, femoral lengthening occurs along the anatomic axis and consequently lateralizes the mechanical axis while lengthening. We choose to prevent this lateralization and correct accompanying distal femoral deformities in skeletally immature patients with CFD with growth modulation. Therefore, we asked, does distal, femoral, medial growth modulation during motorized, internal femoral lengthening allow for prevention and correction of deformity in skeletally, immature patients with congenital femoral deficiency?

How did you answer the question?
We retrospectively reviewed all skeletally immature patients undergoing internal, motorized, femoral lengthening at our institution with congenital femoral deficiency from 2008 – 2018. From that group, we selected all patients who, in addition to femoral osteoplasty and insertion of a nail, also had temporary hemiepiphysiodesis of the involved femur performed at the index procedure. Patients were excluded if they had not completed treatment or had incomplete radiographic imaging. We also excluded patients who had additional osteotomies at the time of surgery or during the treatment period. We analyzed pre–lengthening, immediate post–lengthening and final (prior to removal of hemiepiphysiodesis plate) radiographs to determine change in mechanical axis deviation (MAD), lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA) and overall coronal femoral–tibial angle. We used the paired t–test to compare radiographic measurements.

What are the results?
Eleven limbs (ten patients) were included in the study. The mean age of the patients was 12+1 years. The mean amount of length achieved 40mm (±11mm). The average duration of lengthening was 55 days (±12 days) and mean total treatment with temporary hemiepiphysiodesis was 261 days (±113 days). The mean pre–lengthening MAD was 13mm (Range 0 – 26mm), coronal femoral–tibial angle was 5 degrees of valgus (Range 0 – 14 degrees of valgus), LDFA was 84 degrees (Range 81 – 93 degrees) and MPTA was 90 degrees (Range 85– 93 degrees). There was no statistically significant difference between preoperative and immediate post–lengthening MAD, coronal femoral–tibial angle, LDFA and MPTA. The mean final MAD was 6mm deviated from neutral alignment (±4mm), coronal femoral–tibial angle was 2 degrees deviated from neutral alignment (±2 degrees) and LDFA was 91 degrees(±3 degrees). Comparing preoperative and final measurements, there was a statistically significant change in MAD (mean 17mm of medialization, p=.0002), coronal femoral–tibial angle (mean 7 degrees of varus, p=.0002) and LDFA (mean increase of 5 degrees, p = .004). There was no statistically significant difference in MPTA (mean 0 degrees) between pre–lengthening and final measurements. All limbs were within 4 degrees of a neutral mechanical axis at the conclusion of treatment.

The Use of Growth Modulation in Conjunction with Motorized, Internal, Femoral Lengthening in Patients with Congenital Femoral Deficiency *continued*

Aaron J. Huser. DO

What are your conclusions?

The combination of the temporary hemiepiphysiodesis and internal, motorized, femoral lengthening is effective in achieving a near anatomic mechanical axis. The improvement of the mechanical axis may not be evident when the lengthening portion of the treatment is completed. However, the mechanical axis will continue to improve during and after consolidation. Additionally, the use of growth modulation was effective in preventing worsening valgus during the lengthening period in all cases. We advocate for concomitant, temporary growth modulation during internal, femoral lengthening in skeletally immature patients with congenital femoral deficiency.

Correction of the Lower Extremity Mechanical Axis Deviation in Children with Angular Deformities of the Knee treated with Guided Growth Hemiepiphysiodesis

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What was the question?
Correction rate of angular deformities around the knee following hemiepiphysiodesis has been variable in the literature. This study aims to report the rate of mechanical axis after hemiepiphysiodesis around the knee. Factors associated with differences in correction rate are also reported.

How did you answer the question?
Records of skeletally immature patients, who underwent hemiepiphysiodesis for either genu valgum or genu varum between 2004 and 2018, were reviewed. For all patients, temporary hemiepiphysiodesis was performed using tension band plating. Radiographs at preoperative visit as well as each follow up visit were reviewed. Lower extremity mechanical axis deviation (MAD) was measured on each radiograph. Last follow up was defined as 1.5 years postoperatively, or time of implant removal if correction was achieved within 1.5 years.

What are the results?
A total of 114 patients with 180 knees were included. Mean age at surgery was 10.8 ± 2.9 (2–15) years. 84/114 (74%) patients had genu valgum and 30/114 (26%) had genu varum. The mean preoperative MAD was 23.1 degrees and corrected following hemiepiphysiodesis as described by Figure 1. Patients had different underlying etiologies of their angular deformities, and there was a significant association between the rate of correction of the MAD and the etiology of the angular deformity (Table 1) ($p = 0.04$). Patients with rickets or renal osteodystrophy had the highest rate of MAD correction (2.6 mm/month) while those with Ollier disease were found to have the lowest rate of MAD correction (0.2 mm/month). The mean rate of MAD correction was highest during the first 3 months postop and progressively decreased afterwards; however, this decline was not statistically significant ($p = 0.75$). There were no differences in the rate of MAD correction in regards to specific angular deformity (genu varum vs. genu valgum) ($p = 0.62$), magnitude of the preoperative MAD ($p = 0.37$), site of hemiepiphysiodesis (distal femoral vs. proximal tibial vs. both) ($p = 0.09$), or limb involvement (unilateral vs. bilateral) ($p = 0.42$).

What are your conclusions?
In children with angular deformities around the knee treated with guided growth hemiepiphysiodesis, the rate of MAD correction is significantly influenced by the specific etiology of the deformity. Surgeons should recognize that the rate of MAD correction will vary in children with genu valgum or genu varum depending on the etiology of their deformity, and this knowledge should aid in monitoring for deformity correction.

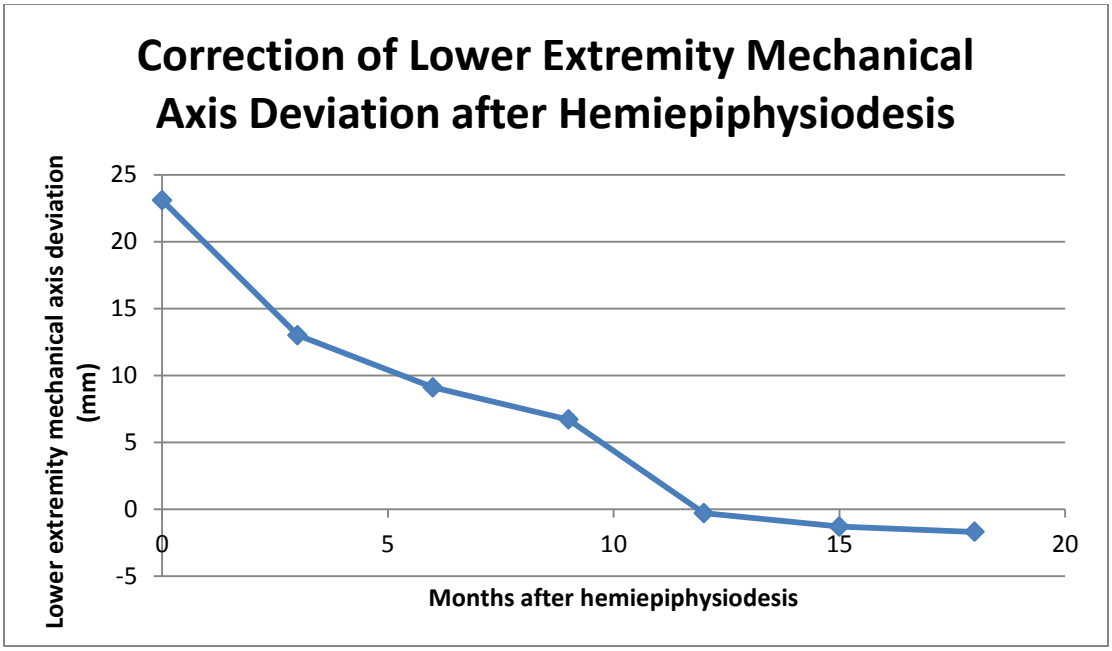

Figure 1: In children with genu varum or genu valgum that were treated with hemiepiphysiodesis, the mean preoperative lower extremity mechanical axis deviation (MAD) was 23.1 mm, and progressively improved over the treatment period. Negative values of the MAD denote that the initial deformity (either genu valgum or varum) overcorrected during the treatment period.

Table 1: Etiologies of the angular deformities in 118 patients treated with guided growth hemiepiphysiodesis

Etiology of angular deformity	Number of patients (%)	Rate of MAD correction (mm/month)
Idiopathic	61 (54%)	1.7
Multiple hereditary exostoses	14 (12%)	1.3
Blount's disease	14 (12%)	1.8
Rickets or renal osteodystrophy	10 (9%)	2.6
Skeletal dysplasia	5 (5%)	1.1
Various syndromes*	4 (4%)	2.0
Malunion	3 (3%)	2.1
Ollier disease	2 (2%)	0.2
Fibrous dysplasia	1 (1%)	0.8

*Velocardiofacial syndrome (n=1), Lenz Majewski syndrome (n=1), Beal's syndrome (n=1), NOMID syndrome (n=1)

Foot Height Difference Does Contribute to Ultimate Leg Length Discrepancy in Fibular Hemimelia Patients

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What was the question?
Fibular hemimelia is a congenital disorder of unknown etiology that leads to a spectrum of deformities within the lower limb. Two of the major issues include limb length inequality and abnormalities of the foot and ankle, including missing lateral rays, ankle valgus, and tarsal coalitions. Treatment algorithms for fibular hemimelia usually address limb length and foot differences separately. Surgical procedures that are performed to assist in equalizing limb length difference at skeletal maturity rely on predictive methods such as the multiplier method and Mosely straight–line graph. The multiplier method takes into account foot height difference only if "entire leg" is selected in the algorithm. While it is recognized that foot hypoplasia exists and can result in a foot height difference in fibular hemimelia, the amount of foot height difference is not well–described. The purpose of this study was to determine the accuracy of measuring foot height difference in patie!
nts with fibular hemimelia on full length radiographs and to investigate the amount of foot height difference as it relates to total limb length inequality in the fibular hemimelia population.

How did you answer the question?
A retrospective review at a single institution was performed for patients with a diagnosis of fibular hemimelia treated between January 2008 – January 2018. Patients were excluded if there was an additional skeletal dysplasia diagnosis, bilateral fibular hemimelia, or inadequate radiographs. The foot height inequality was calculated as the difference between the tibial plafond heights of the affected and non–affected sides on the radiographs. Additionally, bilateral femur and tibia lengths and total leg length differences were calculated. Descriptive analysis was performed.

What are the results?
26 patients with fibular hemimelia were evaluated over a ten–year period at a tertiary children's hospital. Of these, 10 met inclusion criteria. Four were excluded due to bilateral fibular hemimelia, one had proximal femoral focal deficiency, and eleven had inadequate radiographs. There were six left and four right fibular hemimelia cases. Results showed seven Achterman–Kalamchi Classification 1A, two 1B, and one type 2. All where type 1 Birch. Every patient had a calculated foot height difference (ranging from 0.2 cm to 1.6 cm). Five patients had a foot height difference more than 1 cm. The average foot height difference was 1 cm and the average leg length difference was 4.7 cm.

What are your conclusions?
The foot height difference can be calculated using the differences in the tibial plafond measurements on a standing limb radiograph. All patients had a calculated foot height difference. Foot height differences associated with fibular hemimelia need to be taken into account when looking at leg length difference.

Comparison of the White–Menelaus and Anderson–Green Predictions of Growth Remaining in the Distal Femur and Proximal Tibia

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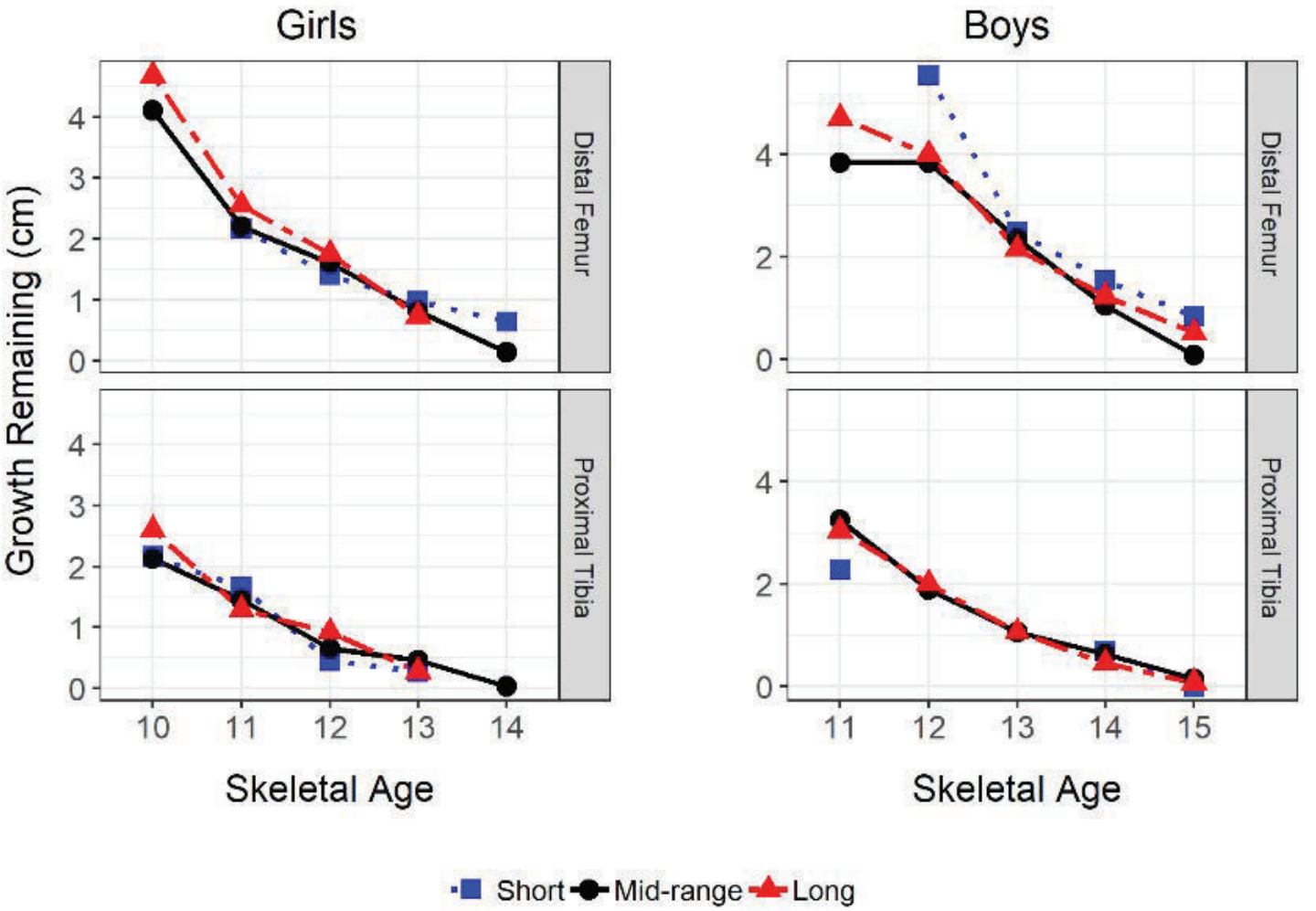
What was the question?
Our previous report showed that White–Menelaus arithmetic method more simply and accurately predicted tibial and femoral remaining growth than the Anderson–Green growth remaining charts and other derived methods. Current study aimed to determine the reason for disparate predictions of growth remaining by these two main methods in a cohort of patients treated at our institution by epiphysiodesis.

How did you answer the question?
From a database of 863 patients who had undergone epiphysiodesis of the distal femur and/or proximal tibia, we identified all un–operated healthy leg segments (both short and long sides) followed to maturity. For the Anderson–Green method, we consulted their femoral and tibial length charts, characterized preoperative segment length ranging from –2SD to +2SD as short, mid–range, and long; and calculated residual growth using their growth–remaining charts. For the White–Menelaus method, we multiplied years of growth remaining (16–age for boys; 14–age for girls) by 0.952 (distal femur) or 0.635 (proximal tibia). We used skeletal and chronological ages for both methods and compared the amount of growth that actually occurred to the amount predicted by each method.

What are the results?
441 healthy segments (201 femora and 240 tibiae) in 221 patients (105 males and 116 females) between age 9–16 were analyzed. During that time period, the distal femora and proximal tibiae grew their same respective amounts (0.95 and 0.625) per year of skeletal growth, irrespective of gender or percentile length of the segment at the time of surgery. There was no or an inverse relationship between segmental length at the time of epiphysiodesis and mean growth remaining. Skeletal age (using the Greulich and Pyle atlas) was a more accurate predictor of growth remaining than chronological in most cases.

What are your conclusions?
In children of epiphysiodesis age (older than 9 in girls, 11 in boys), the amount of growth remaining in the distal femur and/or proximal tibia is relatively constant (per the White–Menelaus method), and Anderson–Green assumption that the amount of growth remaining is correlated to percentile segment length is more likely erroneous. For the purposes of surgery timing, we recommend skeletal age for the prediction of lower extremities growth remaining.


Girls
Boys
Growth Remaining (cm)
Distal Femur
Proximal Tibia
Skeletal Age
Short
Mid-range
Long

Session VI: Pediatrics II

Moderator: Jill C. Flanagan, MD

Proximal Tibia Vara is a Hidden Deformity in a Subset of Patients with Congenital Posteromedial Bowing of the Tibia

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What was the question?
Congenital posteromedial bowing (CPB) presents with an oblique plane diaphyseal bow that slowly improves and leg length discrepancy (LLD). We observed that some patients with CPB develop compensatory proximal tibial varus (PTV). What is the incidence of PTV in patients with CPB?

How did you answer the question?
We conducted a retrospective review of children with CPB at our institution from 2007 until 2017. Full length anteroposterior and lateral views of the tibia/fibula were analyzed.

What are the results?
We identified two frontal plane deformity patterns: double–level deformity (proximal varus, diaphyseal valgus) and single–level diaphyseal valgus. Both had recurvatum of the diaphyseal segment. Nine of 18 patients diagnosed with CPB had not yet been recommended for surgery, and none of those had PTV deformity. Average age of remaining 9 patients who had been recommended for surgery was 6.7 years (range, 1.4–17.5 years). Three of the 9 patients also had PTV deformity (10°, 10°, and 9°). Two of the three patients underwent double–level osteotomies with gradual deformity correction. The third patient is planning to undergo proximal tibial guided growth. Average oblique plane posteromedial deformity of the three patients with PTV was 28.9° (standard deviation [SD] 9.2°) and for the six patients without PTV was 25.3° (SD 10.6°). Average LLD of three patients with PTV was 5.5 cm (SD 2.6 cm) and for six patients without PTV was 3.8 cm (SD 1.2 cm).

What are your conclusions?
Children with CPB of the tibia should be evaluated for PTV so that this “hidden” deformity can be addressed when developing a treatment plan. The treatment plan can then include PTV treatment (double–level osteotomy or combined osteotomy plus guided growth strategy). Failure to recognize PTV deformity may lead to residual mechanical axis deviation (varus) after correcting the posteromedial bow.

Current Use of Patient–Reported Outcomes in Pediatric Limb Deformity Research

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What was the question?
Patient–reported outcome instruments are critical to evaluating natural history and treatment effects but have not been well studied in pediatric limb deformity. The goal of this study was to identify and assess the most commonly used patient–reported outcomes in pediatric limb deformity research across a representative sample of the recent orthopaedic literature.

How did you answer the question?
A review was performed from January 1, 2016 to December 31, 2018 in 5 pediatric orthopaedic journals previously identified as having the greatest impact: Journal of Pediatric Orthopaedics, Journal of Pediatric Orthopaedics B, Journal of Children's Orthopaedics, The Journal of Bone and Joint Surgery American Volume, and The Bone and Joint Journal. Clinical research studies involving pediatric population, operative management of limb deformity, and patient–reported outcome measures were collated. Exclusion criteria were as follows: studies evaluating fewer than 10 patients, non–operative treatment of limb deformity, studies based exclusively on soft tissue surgery, hand and foot deformity studies, and studies on only adult patients or reporting only pain visual analogue scale. Patient–reported outcomes were reviewed.

What are the results?
The initial search of 3,489 publications found 127 clinical articles involving operative management of pediatric limb deformity. Thirty–three studies (26%) met inclusion criteria, in which a total of 23 different patient–reported outcomes were used. An average of 1.3 patient–reported outcomes were reported per study (range 1–3). The various patient–reported outcome tools were separate based on whether or not they were validated in children, and are listed in the table. No outcome instrument was used by more than five different studies in this review, and no instrument validated in the pediatric population was used by more than three different studies.

What are your conclusions?
Patient–reported outcomes currently used in pediatric limb deformity research are highly heterogeneous. We found no validated instrument specifically designed for use in pediatric limb deformity. There is a need to develop an appropriate tool that is reliable, valid, and responsive and could serve as a primary instrument for researchers investigating pediatric limb deformity.

Syme Amputation: Is there an Ideal Limb Length Discrepancy?

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What was the question?
Syme Amputation (SA) is performed for a number of indications in a pediatric population. SA often affords a very low limb length discrepancy (LLD), and is also purported to allow weight bearing without a prosthesis. Low LLD is useful for ambulation without a prosthesis, but can be restrictive when fitting modern prostheses. Our research focuses on the frequency of ambulation without a prosthesis in SA patients, and their functional outcomes based on LLD: Is there an 'ideal LLD' in this cohort?

How did you answer the question?
A survey was distributed to persons living with SA. Recruitment occurred via hospital database and electronic advertising. An illustration was designed to allow participants to classify their LLD by zone in relation to their non–amputated limb. In addition to demographic data, two validated outcome measures were collected: The Trinity Amputation and Prosthesis Experience Scales – Revised (TAPES–R), and the Locomotor Capabilities Index–5 (LCI–5).

What are the results?
47 persons living with SA participated. Average age at amputation was 3.7 (0.5– 14.1 years), and at survey completion 15.8 (1.7 – 60.3). Five of the described "zones" of LLD were represented. Average LCI–5 score was 52.6 of a maximum of 56, similar across all zones. TAPES–R ARS demonstrated 'least restriction' in Zone E participants. Ability to walk without a prosthesis was lower in those partipants over 11 years, when compared with those under 11 (33% vs 56% in own bedroom, respectively), as well as being heavily dependent on walking environment.

What are your conclusions?
Our study found no trend indicating that a very low LLD was functionally optimal, and indeed found participants with a moderate LLD (Zone E) had the least restriction. Our study demonstrates that ambulation without a prosthesis depends on environment and rates decrease significantly into adulthood. Optimal care should not focus simply on 'preserving length', but rather length modulation in parallel with a nuanced understanding of actual daily activities and prosthetic options.