1:10 – 2:00 pm
SESSION 5:
ANKLE FUSION

Moderators:

Jeffrey E. Johnson, MD
(St. Louis, Missouri)

Richard J. de Asla, MD
(Boston, Massachusetts)
I. Three keys to success with ankle fusion
   a. Pick/Prepare the “right” patient
   b. Get the ankle straight (slight valgus, external rotation, neutral sag plane)
   c. Get the fusion healed

II. Patient selection
   a. Pain localized to ankle – use differential injection if adjacent joint arthritis suspected
   b. Be aware of co-morbidities: smoking, idiopathic/diabetic peripheral neuropathy, chronic pain, psych
      i. This is an elective procedure – expect the patient to stop smoking and optimize psych, pain and any other medical issues preop
   c. Have complete discussion of the available options for treatment of ankle arthritis in your patient
      i. Arrive at decision for ankle fusion as the best option of many, rather than “settling” for it as a salvage
   d. Don’t sell it.
      i. Create realistic expectations for final result as well as each stage of recovery
      ii. Mention all major complications (nonunion 10%, nerve, longterm adjacent arthritis – radiographic, not usually debilitating)
      iii. Takes a “year” to recover
      iv. Patients with stiff hindfoot joints will notice loss of ankle ROM much more than patients with normal hindfoot ROM
      v. Arrange interviews with satisfied (age/activity matched) former ankle fusion patients as live testimonials for patients concerned about post fusion activity level.

III. Ankle fusion techniques
   a. No/Minimal deformity – In Situ arthrodesis
      i. Mini/minimal open – minimize striping
         1. Anterolateral arthrotomy
         2. Anterior fibular resection
      ii. Arthroscopic- union rates high, technique driven
      iii. Distal tib fib and lateral gutter not fused
   b. Moderate/severe deformity with anatomic joint surfaces
      i. Maintain joint architecture to create coapted fusion surfaces which will help determine proper transverse plane rotation and coronal angulation – then make sure ankle in neutral sagittal alignment
      ii. Extensile anterolateral arthrotomy
      iii. Possible oblique fibular osteotomy above joint line
1. fusion lateral gutter
2. use fibula as additional plate
iv. Possible auxillary antero-medial arthrotomy (portal)
v. Ankle distractor – pins, lamina spreader
c. Moderate /Severe deformity with loss of anatomic joint surfaces
i. Use flat cuts with or without interpositional bone graft
   1. Adding bone to fill defect technically easier than flat cuts
   2. Adding bone avoids shortening, maintains soft tissue tension
   3. Limited data suggests fusion rate minimally affected with interpositional allograft bone graft (Kleiber, et al, 2011)
      a. 19 patients 89% union rate
      b. 9.5 mm avg. maximum graft width
ii. Create stable surfaces on axial load
iii. Significant talar bone loss requires TTC fusion
iv. Careful attention to alignment since congruity of anatomic joint surfaces not able to guide the reduction

IV. Techniques to enhance fusion rate
a. Patient factors
i. Quit smoking at least 1 month preop
ii. Avoid NSAIDs until fusion healed
iii. Non weightbearing compliance
iv. Short leg cast rather than walker boot (at least first 6 weeks)
v. Authors preference: 6 weeks Non WB cast, 4 weeks WB cast, then boot
b. Joint preparation
i. Thorough debridement - maximize joint fusion surface area
ii. Surface preparation: drilling (leave filings), osteotome feathering
   1. Power tools can remove excessive bone and burnish or cause thermal necrosis
iii. Slot graft technique for “spanning” fusion (Klein, et al 2011)
   1. Allograft bone impacted into “slot” prepared across fusion site
   2. May improve rigidity of construct
   3. May improve fusion rate (77% union in high risk group)
c. Joint fixation
i. Compression lag screws in different planes ( 2-3 screws)
ii. Additional plate fixation
   1. Anterior plating increased construct stiffness by a factor of 3.5, 1.9, and 1.4 for the sagittal, coronal, and torsion modes, respectively. (Tarkin, et al 2007)
iii. Avoid subtalar joint penetration with hardware
   1. Take multiple C-arm obliques intraop to confirm proper screw placement
d. Adjuncts for difficult cases
i. Iliac crest bone marrow aspirate may help when added to cancellous allograft to fill voids when needed.
ii. Autograft ICBG
iii. BMP – off label usage
References

1:25 – 1:40 pm  
SESSION 5:  
What is going on biomechanically in a diseased ankle?  

Richard J. de Asla, MD  
(Boston, Massachusetts)

Ankle Kinematics  
Richard J. de Asla, M.D.  
Co-Director, Foot & Ankle Division  
Massachusetts General Hospital

Wikipedia...  
Kinematics: Is the branch of classical mechanics... that describes the motion of bodies and systems without consideration to the forces that cause the motion.

Overview
- Foot and ankle probably the least studied of the kinematic systems
- Difficult
  - 26 bones
  - 39 joints
  - Small motions
  - Coupled motions

Overview
- Cadaveric studies are the most numerous
  - Loads are estimated
  - No muscle contraction
  - Tibia either fixed or free
  - Soft tissue response

Overview
What we do...
- Combined dual-orthogonal fluoroscopic and MR imaging technique
  - In vivo
  - Allows for weight bearing
  - Can measure ligament lengths and cartilage contact
  - Non-invasive
  - Physiologic Motion

**Dual-orthogonal Fluoroscopic System**
- Two fluoroscopes positioned in orthogonal planes
- Fluoroscopic images are captured simultaneously

**Methods**
- Sagittal plane magnetic resonance (MR) images acquired with subjects supine

**3-D anatomic models of the ankle joint complex (AJC) are reconstructed from MR images** (3D SPGR, TR~48 ms, TE~4.3 ms, Flip angle 45°, FOV=16x16 cm²)
- AJC defined as the bony geometry of: tibia, fibula, talus, and calcaneus
- Solid modeling software (Rhino3D, Seattle, Wash)

**MRI 3-D Reconstruction**
**Methods**

- The 3-D AJC MRI model and the fluoroscopic images are imported into the solid modeling software
- The geometry of the fluoroscopic system is recreated virtually in software
- Calibration data

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**AJC Kinematics**

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**Discussion**

Once the model is created...
- Measurements in 6 degrees of freedom
- Changes in ligament length
- Cartilage contact area

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**Coordinate System**

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**AJC Kinematics**

Initial Study...
- 5 healthy ankles were investigated
- 4 males and 1 female
- Age 32-43
- No current symptoms or previous surgery

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**Methods**

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**AJC Kinematics**

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**Discussion**

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**Coordinate System**

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**AJC Kinematics**

Initial Study...
- 5 healthy ankles were investigated
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Ankle Kinematics

Study the effect of tibiotalar osteoarthritis on six degrees of freedom (6DOF) kinematics of the ankle joint complex (AJC) in vivo.

Ankle Kinematics

Compared two groups:
- Healthy subjects without arthritis
- Subjects with post traumatic DJD
- Combined dual fluoroscopic and MRI technique used.

Tibiotalar Joint

Subtalar Joint
**Tibiotalar Joint**

Mid-Stance to Toe Off

- ER(+) t(–)
- DF(+)/PF(–)
- EV(+)/INV(–)

**Subtalar Joint**

Mid-Stance to Toe Off

- ER(+)/IR(–)
- DF(+)/PF(–)
- EV(+)/INV(–)

**AJC Kinematics**

- Accuracy
  - 0.1 mm
  - 0.1 degree
  - Very good inter-observer reproducibility in the knee

**Ankle Kinematics**

Coupled motion between the tibiotalar and subtalar joints observed in normal subjects was largely not demonstrated in patients with posttraumatic tibiotalar osteoarthritis.

**Thank You!**
SESSION 5: ANKLE FUSION

Moderators:
Jeffrey E. Johnson, MD (St. Louis, Missouri)
Richard J. de Asla, MD (Boston, Massachusetts)

SESSION 5: 1:40 pm

Nonunion Risk Assessment in Foot & Ankle Surgery: Proposing a New Predictive Risk Assessment Model

Presenting
Gowreeson Thevendran, Dip. Sports Med (Ed), FRCS (Tr&Orth) (Vancouver, British Columbia, Canada)
Calvin Wang, MD; Alastair S.E. Younger, MBChB, FRCSC; Stephen J. Pinney, MD, FRCSC

Summary
Quantitative risk assessment for nonunions will enable more objective patient assessment prior to foot and ankle arthrodesis surgery. Currently, patient assessment is subjective and hence highly variable. We propose a novel risk score that can be utilised to better evaluate patients, surgical outcomes and research the use of bone grafts.

Introduction
The management and research of nonunions is compromised as the relative and cumulative risk of nonunion from multiple factors has not been described. This study aimed to develop and validate a nonunion risk score assessing multiple risk factors. This score can be utilised in the treatment of fractures and fusions to estimate non-union risk. The score can be used to determine the need for bone graft and bone graft substitutes, the risk of surgery and to research outcomes for bone grafts and bone graft substitutes.

Methods
From a survey of international experts in foot and ankle surgery we were able to stratify and weight various proposed nonunion risk factors into 3 nonunion risk categories: (1) greater risk, (2) similar risk, (3) lower risk than smoking 1 pack/day. We propose utilizing the weighted score of each of these individual risk factors as a component of the total nonunion (TN) score for an individual patient. In this study, we retrospectively validated this score on two distinct cohorts of procedure matched patients from an end-stage ankle arthritis database: a) 22 cases of ankle and hindfoot fusion nonunions and b) 40 cases of fully united ankle and hindfoot fusions. This dataset of 62 patients served as validation data in the statistical analysis which included descriptive statistics, univariate and multivariate analysis.

Results
The mean score in the control group was 6.6 and in the case group was 13.5. A two-tailed t-test showed a statistical difference between the two groups, with a confidence level p < 0.001. Data reliability was tested using the Pearson correlation coefficient and showed an excellent intraclass correlation coefficient for the various risk factors ranging 0.90 to 0.97 and interclass correlation coefficient ranging from 0.80 to 0.93. A Receiver Operating Characteristic (ROC) Curve was plotted to demonstrate the discriminatory potential of this risk scoring system. The area under the curve was 0.77 with a confidence interval (0.64 – 0.88). A predict model using multivariate logistic regression analysis with nonunion as the dependent variable, when adjusted for age and gender as covariates, suggests the lack of fusion site stability and a raised body mass index were significantly predictive of nonunion.
Conclusion
Quantitative risk assessment is a novel and valuable tool to better estimate the degree of patient risk and allows for peri-operative management and risk modification to be tailored for each individual to minimize the risk of nonunion. For the future, the advent of a risk score will also aid comparing different patient groups when assessing the efficacy of nonunion interventional modalities in the literature.
Anterior and Inferior Widening of the Ankle Mortise with Varus of Tibial Plafond in Varus Ankle Osteoarthritis on Three Dimensional Computed Tomography

Presenting
Jiyong Ahn, MD (Seoul, Korea)
Jonghoon Jang, MD; Chulhyun Park, MD; Woo-chun Lee, MD

Background:
Present understanding of the morphology of the ankle mortise is based on the plain radiograph. Because plain radiograph cannot show the depth of a deformity, it may be overshadowed by normal area even though there is a deformity in a part of an object. Three dimensional change of ankle mortise is not known. A hypothesis was formulated that there may be a deformity of the anterior part of the medial malleolus and medial aspect of the tibial plafond in varus ankle OA. The purposes of this study were to investigate the three dimensional change of ankle mortise by analysis of three dimensional computed tomography (3D CT) and the relationship between the findings on 3D CT and the findings on plain radiographs.

Methods:
This study includes the images on 3D CT of 101 patients with varus ankle osteoarthritis who had undergone surgical treatment at our hospital from August 2007 to April 2011. The patients included fifty-nine women and forty-two men with mean age of 58.7 years (range, 35 to 81). Severity of osteoarthritis was staged using modified Takakura classification. The patients had no history of fracture around the ankle. Osteoarthritis associated with paralytic disorders or generalized inflammatory disease was excluded. The 40 ankles which had undergone 3D CT examination for other reason than osteoarthritis were used as a control group in which joint space was normal. The control group included eleven women and twenty-nine men with mean age of 24 years (range, 16 to 41). Ankle mortise was assessed on axial, coronal and sagittal planes using 3D CT. On axial plane CT images, an angle subtended by articular surface between medial malleolus and lateral malleolus was measured and named as anterior opening angle (AOA). Inter-malleolar index (IMI) was measured as suggested by Christopher et al. Correlation between the AOA and IMI has been investigated. On coronal plane CT images, angles between the medial and lateral malleolar articular surface were measured and named as inferior opening angle (IOA). An angle between the tibial axis and the articular margin of the medial malleolus on plain weight-bearing anteroposterior radiograph (TMM) was measured and correlation between the IOA and TMM has been investigated. For coronal plane analysis of the tibial plafond, The angles between tibial plafond and vertical line were measured were named as anterior and posterior CT-TAS of tibial plafond. Correlation between these angles and TAS angle on plain radiograph has been investigated. On sagittal plane CT images, an angle between tibial articular surface and vertical line was named as CT-TLS of tibial plafond (CT-TLS). TLS measured by plain radiograph was compared to CT-TLS on medial, middle and lateral aspect of the tibial plafond. All parameters were compared between control group and patients, and compared among the different stages of OA.

Results:
AOA was significantly greater in patients than control group (p<0.001). However there was no significant difference of AOA among each radiographic stage. IMI was significantly greater in patients group than control group. IMI correlated moderately strongly to AOA (r=0.590, p<0.001).
Mean IOA and TMM were significantly greater in more advanced stages (stage 3 and 4) of osteoarthritis than control group and earlier stage (stage 2) of ankle osteoarthritis (p<0.001). IOA correlated
moderately ($r=0.521$, $p<0.001$) to TMM. The TAS on plain radiograph was similar to the mean posterior CT-TAS. Mean CT-TLS of tibial plafond (CT-TLS) on each area was not significantly different between control group and patients ($p=0.242$). The CT-TLS of tibial plafond has a tendency to decrease from lateral to medial side ($p<0.001$). TLS on weight-bearing plain radiograph correlated moderately ($r=0.571$, $p<0.001$) to CT-TLS of tibial plafond.

**Conclusions:**
Anterior and inferior widening of the ankle mortise and varus of tibial plafond were demonstrated on three dimensional computed tomography in varus ankle osteoarthritis.

**Key words:** three dimensional change, 3D CT, ankle osteoarthritis