Breakout Session 4: Track A

Development of an AI / ML-Ready Knee Ultrasound Dataset in a Population-Based Cohort

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Development of an AI/ML-ready knee ultrasound dataset in a population-based cohort

NOT-OD-22-067

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Presented by: Dr. Katherine Yates, UNC Rheumatology fellow

Johnston HEALTH County STUDY

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Value to the field

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- Systematically performed studies are needed to inform broader use of ultrasound (US) for knee osteoarthritis (OA)
- US is safe, accessible, and efficient, bridging the gap between limited information on x-ray and more expensive MRI for OA
- Demonstrating the utility of US as an assessment tool **before disease is detectable on radiographs**, is crucial

Parent R01 summary

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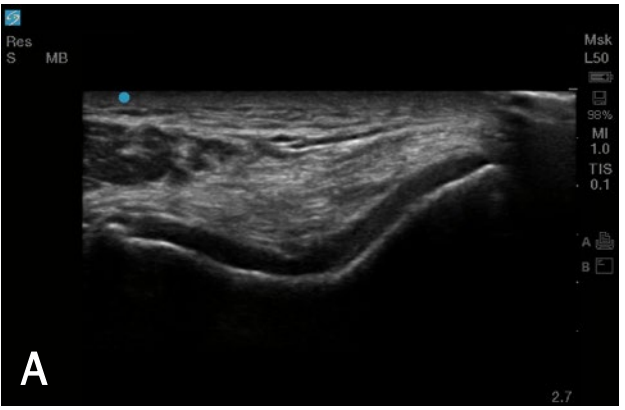
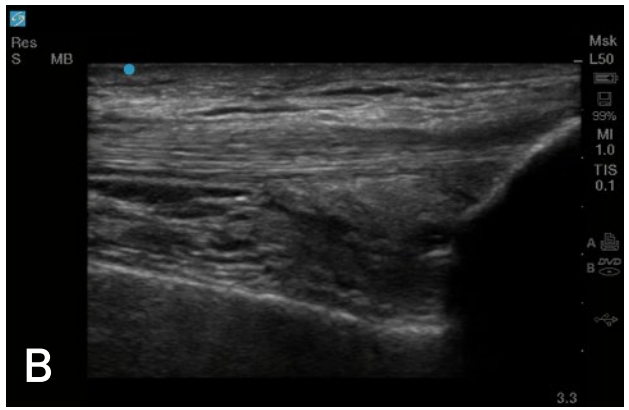
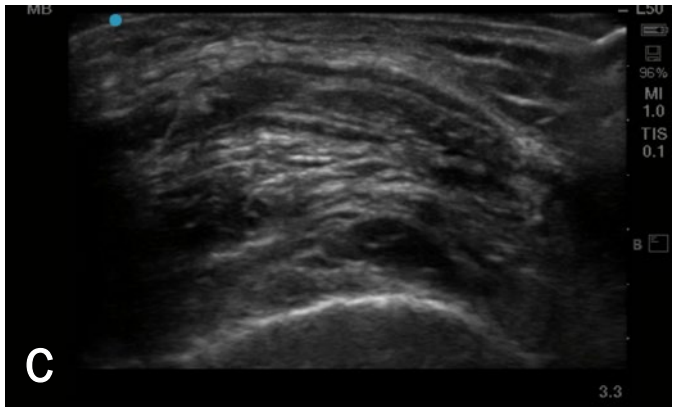
- Obtain standardized US and radiography in the diverse population-based Johnston County Health Study (JoCoHS)
- Aim 1: determine the population prevalence of knee US features (i.e., cartilage and meniscal damage, synovitis/effusion, calcium crystal deposition, popliteal cysts and osteophytes)
  - overall and in key subgroups by age, sex, race/ethnicity, and symptom status
- Aim 2: quantify associations between US features and radiographic findings and symptom scores overall and in key subgroups
- Aim 3: apply novel machine learning methodologies to a) develop an overall US score for symptomatic KOA and b) identify the contribution of US variables to phenotypes relevant to KOA based on general health, physical activity, and functional assessments

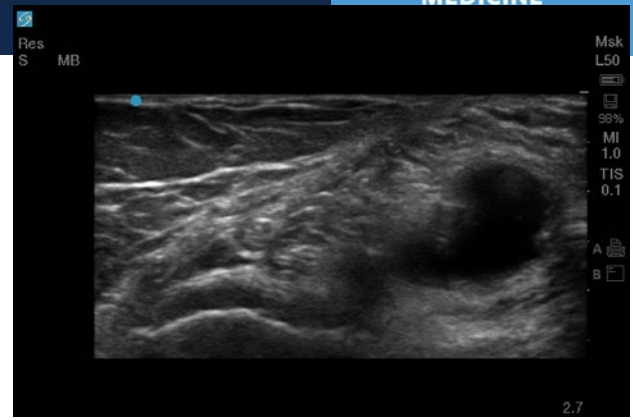
US images obtained per knee

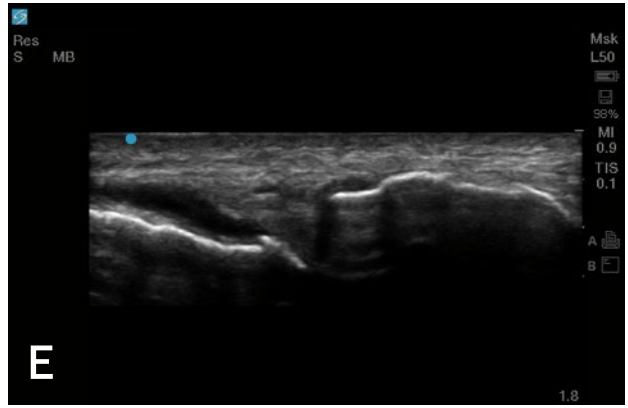
	View	Position	Structure(s) and/or pathology identified
A	**Suprapatellar**	Transverse over the distal femoral condyles, maximal flexion	Articular cartilage
B	**Suprapatellar**	Longitudinal over the distal femur and patella, 30° flexion, with and without power Doppler	Effusion/synovitis
C	**Suprapatellar**	Transverse over the distal femur, 30° flexion	Effusion/synovitis
D	**Medial**	Longitudinal at the medial femorotibial joint, 30° flexion	Osteophytes, meniscus, effusion/synovitis
E	**Lateral**	Longitudinal at the lateral femorotibial joint, 30° flexion	Osteophytes, meniscus, effusion/synovitis
F	**Posterior**	Transverse medial at the femoral condyle	Popliteal cyst

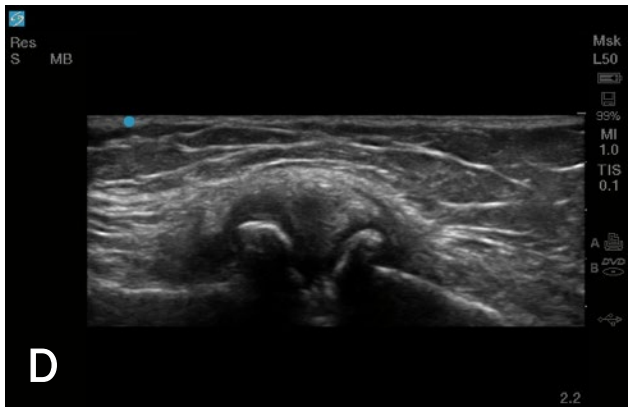












Supplement Aim 1

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- Apply state of the art DL/convolutional neural network (CNN) methods to standardized knee US images obtained in a diverse, representative cohort to determine US features that are cross-sectionally associated with a) knee pain and b) radiographic features of knee OA

Initial approach

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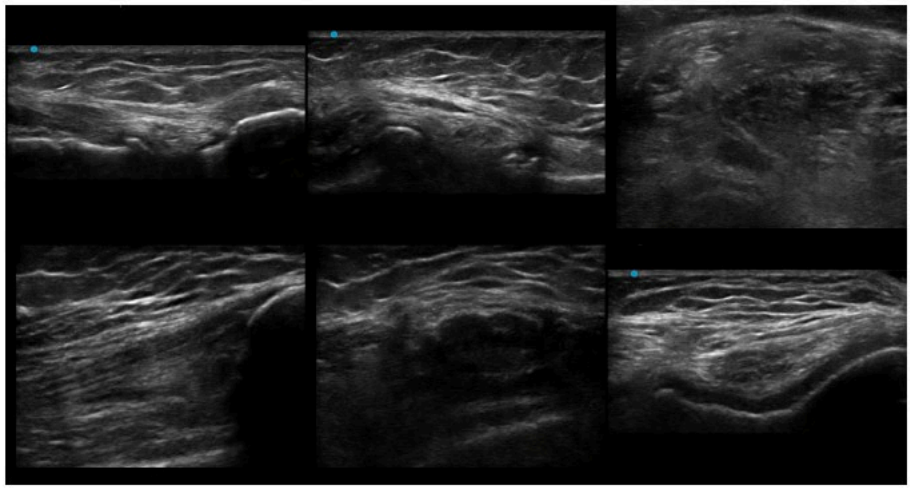
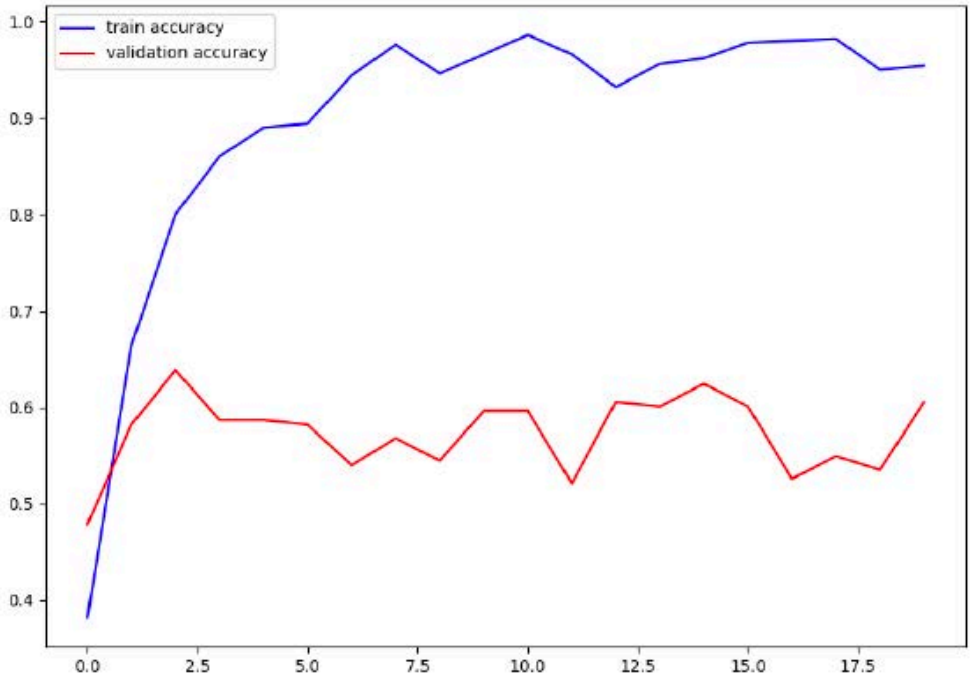
- Combine images into one composite per knee
- Pretrained models: VGGNet, ResNet, etc.



- Result: overfitting



Data augmentation with pretrained models

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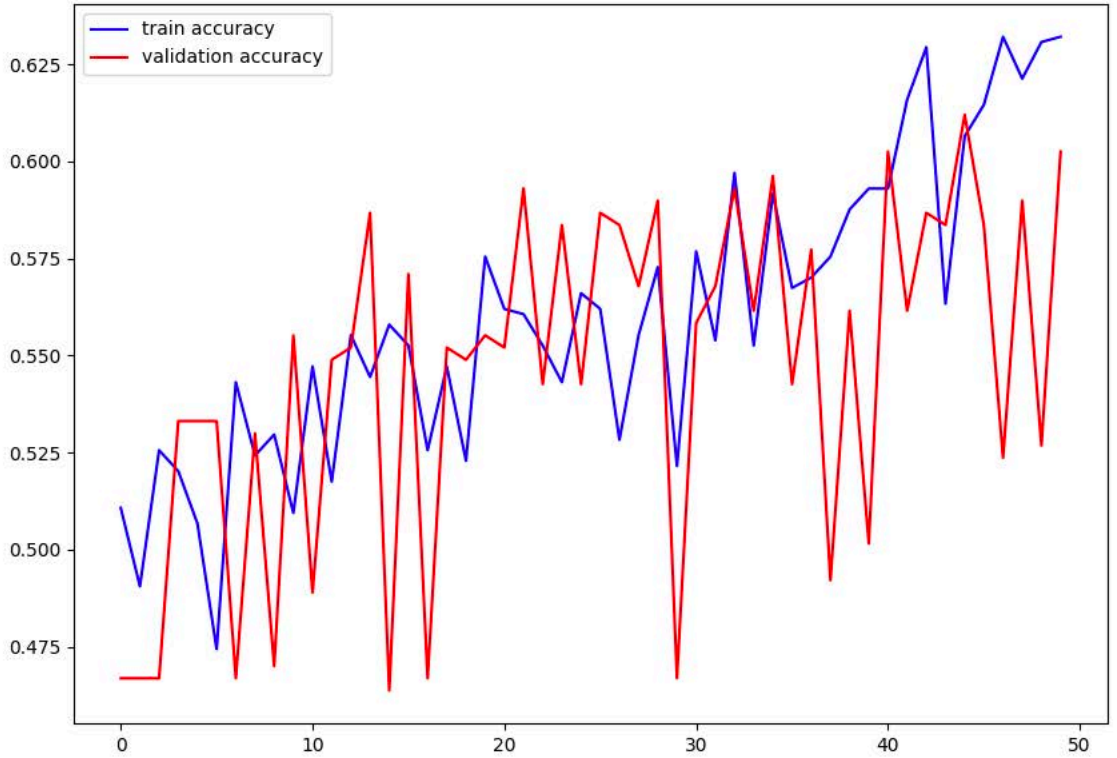
- Generative adversarial networks to increase number of (pseudo) images
- Build models for images separately
- Horizontal flips, random sharpness, denoising
- Perspective transformation

Figure 4: The affine transformation of the images of Fig.3. Points A, B, and C on the checkerboard got mapped to the corresponding arbitrary points marked with red circles. Image by the author.

- Result: inadequate accuracy



Autoencoders

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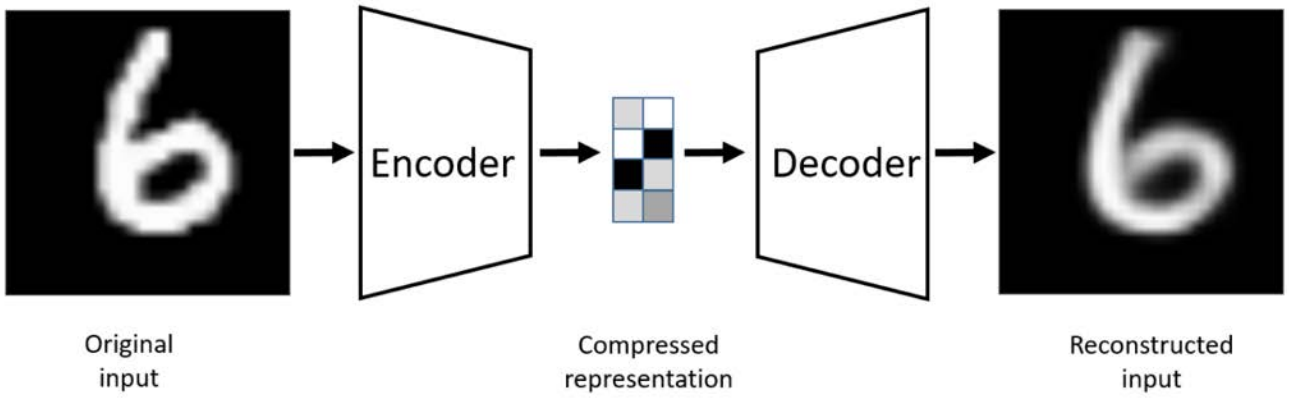
- Unsupervised
- Useful for feature extraction and dimension reduction
- Encoder compresses data; Decoder reconstructs data



Layers

- 3-4 convolutional
- Batch normalization
- Maxpooling
- Rectifier Linear Unit
- Fully connected

Autoencoders

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- Results: training loss and validation loss, unable to capture image features related to pain for classification purposes
- Need for more images (collection ongoing)

Painful knee

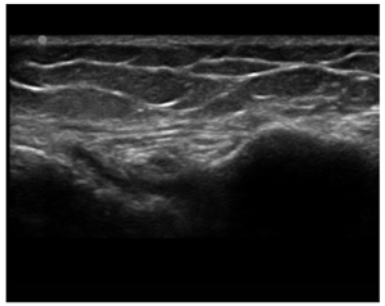


Figure 1: Original

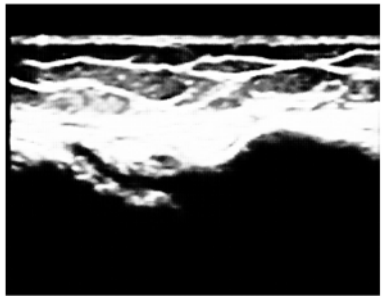


Figure 2: Reconstructed image

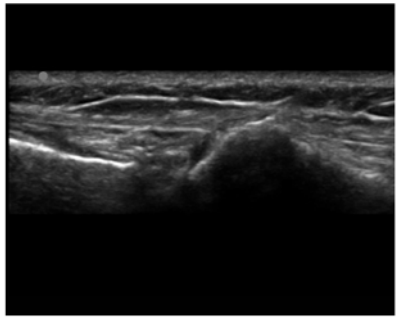


Figure 3: Original

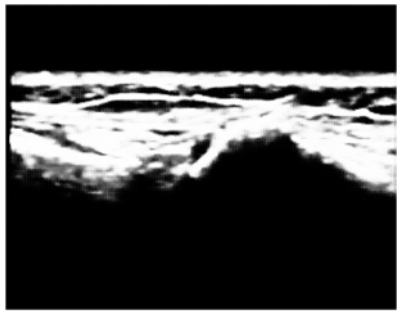
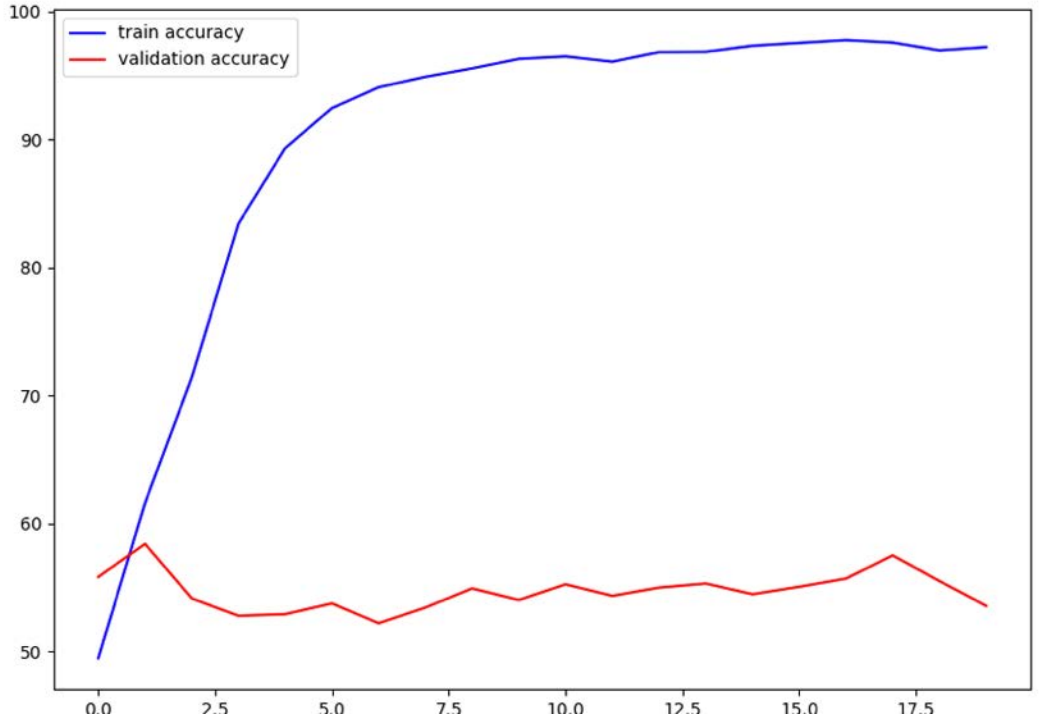


Figure 4: Reconstructed image

Non-painful knee



Supplement Aim 2

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- Optimize these US images, in direct response to NOT-OD-22-067, to be ready for AI/ML approaches by our group and others in the OA and US research communities, following the FAIR principles and improving the utility of the data for AI/ML approaches.

- Progress: images are continually uploaded to Dataverse, with ontology keywords and descriptive metadata as well as an instructional Jupyter notebook (next slide)

Johnston County HEALTH STUDY

The Johnston County Health Study More about the study can be found at https://jocohs.unc.edu/

(University of North Carolina at Chapel Hill)

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Version 5.1

Nelson, Amanda, 2023, "Development of an AI/ML-ready knee ultrasound dataset in a population-based cohort", https://doi.org/10.7910/DVN/SKP9IB, Harvard Dataverse, V5, UNF:6:e1WuNGzFGakEGlWSMnJalg== [fileUNF]

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248 Downloads

Future directions

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- We continue to collect US images in the JoCoHS, increasing the size of the dataset
- We have identified some potential external datasets for either increasing image number or eventual validation
- We will continue to explore methods for augmentation and encoding to allow for feature extraction, considering other potential outcomes

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Advancing Treatment | Finding Cures

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CDC
Centers for Disease Control and Prevention

Johnston County Health Study

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Thurston Arthritis Research Center

Core Center for Clinical Research

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