**Listen Up! Using Audio to Supplement MRI Study Interpretation: A Novel Approach to Medical Image Interpretation Using Machine Learning**

**Video Link:** [**https://utexas.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=66b4e170-c2a5-4b61-932f-b16200f3ec84**](https://utexas.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=66b4e170-c2a5-4b61-932f-b16200f3ec84)

**PowerPoint Presentation and Code Link:**

[rsalibian/High-Risk-Project (github.com)](https://github.com/rsalibian/High-Risk-Project)

**Listen Up! Using Audio to Supplement MRI Study Interpretation: A Novel Approach to Medical Image Interpretation Using Machine Learning**

Raffi A. Salibian, M.D.

The University of Texas at Austin MSAI Graduate Program

rsalibian@aol.com

**ABSTRACT:**

Recent advances in machine learning (ML) have significantly improved the diagnostic capabilities of Magnetic Resonance Imaging (MRI) by allowing for automated detection of critical abnormalities. This research paper explores an innovative approach to knee MRI interpretation by integrating auditory feedback into the study interpretation workflow. Auditory information is generated from the probability estimates of a convolutional neural network. The aim is to reduce the cognitive load faced by radiologists and to improve the speed and accuracy of medical image diagnoses. I detail the methodology for model training, prediction and sound generation, and propose how such auditory aids can enhance both accuracy and user experience in the diagnosis of Anterior Cruciate Ligament (ACL) injuries by MRI.

**CCS CONCEPTS** • Machine Learning • Convolutional Neural Networks (CNNs)

**KEYWORDS**: Anterior cruciate ligament (ACL) injuries, knee injuries, artificial intelligence, neural networks, magnetic resonance imaging, auditory feedback, diagnostic fatigue

Raffi A. Salibian, M.D., [rsalibian@aol.com](mailto:rsalibian@aol.com) 2024. **Listen Up! Using Audio to Supplement MRI Study Interpretation: A Novel Approach to Medical Image Interpretation Using Machine Learning**

**INTRODUCTION**

Magnetic Resonance Imaging (MRI) is an invaluable diagnostic tool that provides detailed images of internal body structures without using ionizing radiation. In orthopedics, MRI is indispensable for diagnosing knee injuries, including Anterior Cruciate Ligament (ACL) tears, which are common in physically active individuals. Diagnosis of ACL injuries by MRI relies on expertly trained medical imaging professions, like radiologists, who visually review MRI scans and produce written reports describing their findings.

Prompt and accurate diagnosis of ACL injuries is critical as it directly influences treatment decisions and outcomes. Delays or errors in diagnosis can lead to inappropriate treatment plans, prolonged recovery, and long-term joint instability. Therefore, any enhancements to the traditional MRI study interpretation workflow may improve patient outcomes and optimize the use of healthcare resources.

Despite the detailed information provided by MRI, diagnosing ACL injuries remains challenging due to the subtle nature of some injuries and the inherent variability in human interpretation. Radiologists are subject to fatigue and the potential for diagnostic error, particularly in high-volume clinical settings.

Recent strides in machine learning (ML), particularly deep learning, have shown promise in augmenting medical image analysis performed by radiologists. Convolutional Neural Networks (CNNs), a class of deep learning algorithms, are especially well-suited for image processing tasks. CNNs capture intricate details through filters that recognize spatial hierarchies and features. By automating the detection of ACL tears, CNNs can assist radiologists by providing a second-opinion tool that reduces workload and increases diagnostic accuracy.

My research project introduces an innovative approach to knee MRI interpretation by integrating auditory feedback into the medical image interpretation workflow. My proposed model translates the probability outputs of a CNN into auditory cues that vary in tone based on the likelihood of an ACL tear. Such auditory feedback aims to provide an immediate, intuitive understanding of the model's findings, enabling clinicians to make quicker and more informed decisions.

**RELATED WORK**

1. Germann C, Marbach G, Civardi F, Fucententese SF, Fritz J, Sutter R, Pfirrmann CWA, Fritz B. Deep Convolutional Neural Network-Based Diagnosis of Anterior Cruciate Ligament Tears: Performance Comparison of Homogeneous Versus Heterogeneous Knee MRI Cohorts with Different Pulse Sequence Protocols and 1.5-T and 3-T Magnetic Field Strengths. Invest Radiol. 2020 Aug:55(8):499-506. DOI:10.1097/RLI.0000000000000664. PMID: 32168039; PMCID: PMC7343178

The researchers aimed to evaluate the clinical effectiveness of their Deep Convolutional Neural Network (DCNN) in a real-world clinical setting. In this study, radiologists exhibited exceptionally high specificities in detecting ACL tears, ranging from 99.6% to 100%. The results of their DCNN for detecting ACL tears demonstrated a specificity of 93.1%. The radiologist specificities in this study not only surpassed those of the DCNN but also outperformed general radiologists and physicians with less subspecialization.

1. Sanderson PM, Liu D, Jenkins SA. Auditory Displays in Anesthesiology. Curr Opin Anaethesiol. 2009 Dec;22(6):788-95 DOI: 10.1097/ACO.0b013e3283326a2f. PMID:19770642

This article examines the utilization of auditory feedback within anesthesiology, providing insight into how sound can enrich monitoring and diagnostic processes. Research in the realm of audio displays delves into various designs, encompassing pitch, rhythm and timbre variations. Within anesthesiology, auditory displays serve to relay crucial information to anesthesiologists during surgical procedures and post-operative monitoring. By complementing visual displays, auditory displays hold promises in advancing patient care within anesthesiology, offering additional sensory input and fostering improved communication between clinicians and medical devices.

**METHODOLOGY**

The MRNet dataset contains 1,370 knee MRI exams performed at Stanford University Medical Center: 1,104 (80.6%) abnormal exams, with 319 (23.3%) ACL tears and 508 (37.1%) meniscal tears. Labels were obtained through manual extraction from clinical reports.

This research project employs a Convolutional Neural Network (CNN). CNNs are renowned for their image processing and classification capabilities, particularly in medical imaging. My CNN architecture consists of three convolutional layers with ReLU activation, interspersed with max pooling layers to reduce dimensionality and dropout layers to mitigate overfitting. The network architecture concludes with a dense output layer utilizing a sigmoid activation function to provide a probabilistic assessment of ACL injury presence. Training was conducted over 10 epochs with a batch size of 32, using the Adam optimizer and binary cross entropy as the loss function. The network culminates in a dense output layer with a single neuron using a sigmoid activation function to provide a probability indicating the presence of an ACL injury.

Audio output is produced using multiple audio-generation mechanisms in python. The CNNs probability output of ACL injury influences the auditory feedback using direct probability to audio frequency mapping, polyphonic representation, stereo panning and time variation audio outputs. In polyphonic representation, a function generates multiple sine waves, each representing a segment of the probability scale. With stereo panning, the amplitude of each wave is adjusted based on the input probability. The model also generates a stereo audio signal where the left and right channel volumes are adjusted based on probability. Lastly, with time variation sound mapping, the probability is represented through the tone or the silence interval between tones.

Initial testing was conducted in a simulated clinical environment to gain a subjective understanding of how imaging professionals might respond to this novel method of MRI study interpretation. Study volunteers, including a combination of ten radiology residents and attendings, listened to audio representations from all four categories of audio production described above. Participants were asked to rate their preferred audio output method from highest to lowest. Study participants were also asked to provide feedback regarding their willingness and personal interest and in incorporating this new paradigm into their existing workflow using a subjective scale from 1-5 from very unlikely to very likely. Future iterations may explore more sophisticated synthesis techniques to allow for dynamic sound modulation based on additional predictive factors.

Figure 1: Audio Generation Methods

A black and white screen with white text

Description automatically generated

**RESULTS**

Preliminary results from my CNN model showed a promising accuracy rate of 92% in detecting ACL injuries and study volunteers overwhelmingly expressed an interest and openness to incorporating auditory input into the MRI interpretation workflow. The highest rated audio generation methods were stereo panning and time variation.

Radiologists in-training expressed “information overload”. This cohort reported that the addition of audio feedback was overwhelming on a sensory level and that extensive additional training would be needed to effectively incorporate the audio input. This feedback reinforces my belief that the ideal implementation of this dual audiovisual paradigm for MRI interpretation should begin during radiology resident training during which time radiology residents would simultaneously learn the visual and auditory representations of medical images.

Further, users interpreted auditory cues differently, leading to discrepancies in understanding and analysis. This interobserver variability clearly stems from a lack of standardization of auditory signals generated from knee MRI studies. Developing a quality database of normal and abnormal auditory information regarding knee pathology, including ACL tears, will be critical in the successful real-world implementation of my novel audiovisual knee MRI interpretation paradigm.

**CONCLUSION**

This research effectively illustrates an innovative application of machine learning to generate musical tones from knee MRI images. By converting imaging data from knee MRI exams into auditory signals, I have introduced a novel method of medical image interpretation. The tones generated correspond to different probabilities of pathological findings, providing an auditory layer of information to complement traditional visual interpretation. Preliminary feedback from participating radiologists indicates that these auditory cues can potentially increase diagnostic accuracy and efficiency. This approach suggests a promising avenue for integrating multisensory information in medical imaging, which could lead to improved patient outcomes and decreased costs to the health enterprise. Future studies will focus on refining the machine learning model, expanding the dataset, and conducting rigorous clinical evaluations to better understand the practical benefits and limitations of auditory enhancement in medical diagnostics.

**REFERENCES**

Awan MJ, Rahim MSM, Salim N, Mohammed MA, Garcia-Zapirain B, Abdulkareem KH. (2021) Efficient Detection of Knee Anterior Cruciate Ligament from Magnetic Resonance Imaging Using Deep Learning Approach. Diagnostics (Basel). 2021 Jan 11;11(1):105. doi: 10.3390/diagnostics11010105. PMID: 33440798; PMCID: PMC7826961.

Shin HC, Roth HR, Gao M, Lu L, Xu Z, Nogues I, Yao J, Mollura D, Summers RM. Deep (2016) Convolutional Neural Networks for Computer-Aided Detection: CNN Architectures, Dataset Characteristics and Transfer Learning. IEEE Trans Med Imaging. 2016 May;35(5):1285-98. doi: 10.1109/TMI.2016.2528162. Epub 2016 Feb 11. PMID: 26886976; PMCID: PMC4890616.

 Sanderson PM, Liu D, Jenkins SA. Auditory Displays in Anesthesiology. (2009) Curr Opin Anaethesiol. 2009 Dec;22(6):788-95 DOI: 10.1097/ACO.0b013e3283326a2f. PMID:19770642.

Tang X, Li X, Gu X, Zhao Y, Liu A, Liu Y, Tao Y. (2023) Automatic modeling of the knee joint based on artificial intelligence. 2023 Mar 15;37(3):348-352. Chinese. doi: 10.7507/1002-1892.202212008. PMID: 36940995; PMCID: PMC10027533.

Garwood ER, Tai R, Joshi G, Watts V GJ. The Use of Artificial Intelligence in the Evaluation of Knee Pathology. (2020) Semin Musculoskelet Radiol. 2020 Feb;24(1):21-29. doi: 10.1055/s-0039-3400264. Epub 2020 Jan 28. PMID: 31991449.

Gorelik N, Gyftopoulos S. Applications of Artificial Intelligence in Musculoskeletal Imaging: From the Request to the Report. (2021) Can Assoc Radiol J. 2021 Feb;72(1):45-59. doi: 10.1177/0846537120947148. Epub 2020 Aug 18. PMID: 32809857.