Applications of AI to Ultrasonography

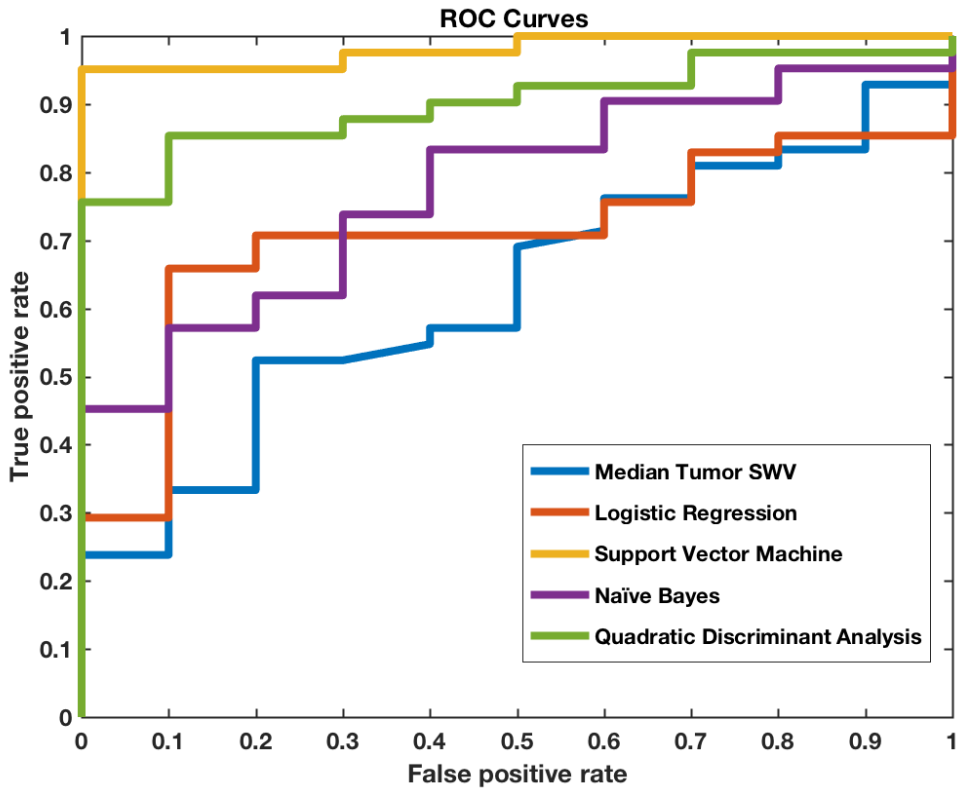
Hersh Sagreiya, MD

Assistant Professor of Radiology, University of Pennsylvania

Evolving Role of Artificial Intelligence in Radiological Imaging

Renal Lesion Characterization on Initial Ultrasound

- Angiomyolipoma (AML) is the most common benign solid renal neoplasm and renal cell carcinoma (RCC) is the most common malignant one. Incidentally seen on US.
- Although often characterized by subsequent CT/MRI, can measurements from US shear wave elastography passed to machine learning (ML) allow better characterization on initial US?
- 52 solid renal neoplasms assessed prospectively.
- 30 measurements of US shear wave velocity from the tumor, cortex, and medulla served as inputs to ML.
- 4 ML algorithms: logistic regression, Naïve Bayes, QDA, and SVM used to predict RCC vs. AML. Baseline comparison: median tumor SWV.
- Performance assessed with leave-one-out cross validation.
- SVM performed best (AUC = 0.98), median tumor shear wave velocity performed worst (AUC = 0.62). Using the DeLong method, this difference is statistically significant ($p = 2.8\ e^{-4}$). Difference between SVM and all other algorithms is also significant.

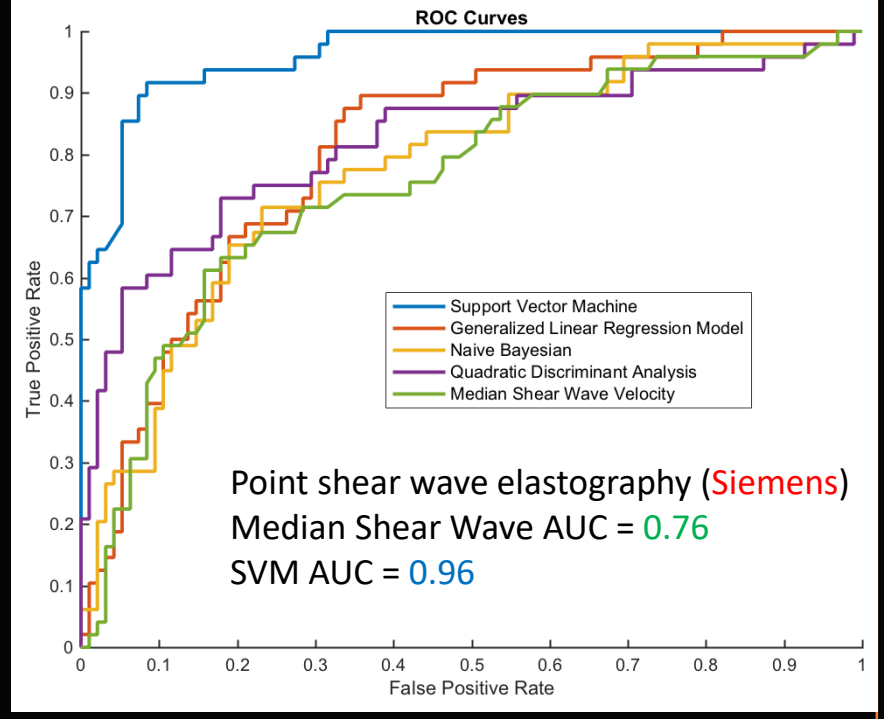


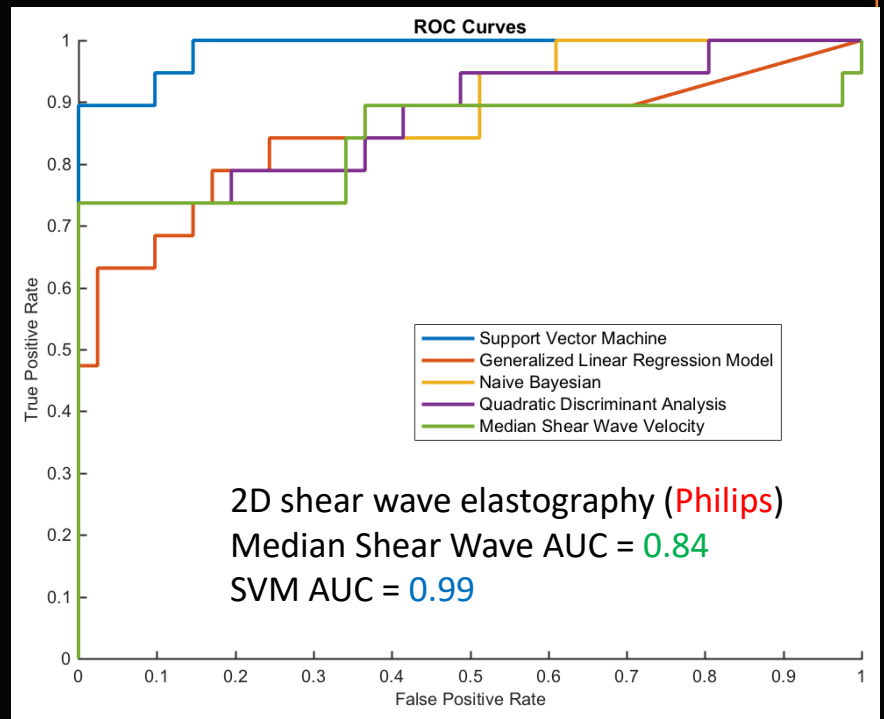
Sagreiya, H., Akhbardeh, A., Li, D., Sigrist, R., Chung, B., Sonn, G., Tian, L., Rubin, D.L., Willmann, J.K. (2019). "Point Shear Wave Elastography Using Machine Learning to Differentiate Renal Cell Carcinoma and Angiomyolipoma." Ultrasound in Medicine and Biology, 45(8):1944-54.

Standardized Hepatic Fibrosis Grading

- Liver cirrhosis leads to > 1 million annual deaths.
- Liver stiffness (fibrosis), which eventually leads to cirrhosis, can be monitored noninvasively using ultrasound elastography (USE).
- Different vendors use different cut-offs for clinically significant fibrosis based on pathology (which is invasive).
- Is it possible to standardize fibrosis grading via technologies from different vendors with magnetic resonance elastography as the reference standard, using ML with US shear wave data as inputs?
- 123 patients imaged with Siemens USE and MRE (upper right), 60 imaged with Phillips USE and MRE (lower right).
- Comparisons: median shear wave velocity (current standard), logistic regression, Naïve Bayes, QDA, SVM.
- 2-fold cross-validation.

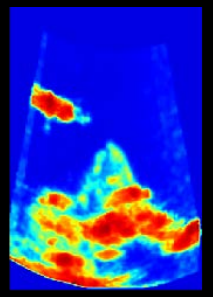
Durot, I., Akhbardeh, A., Sagreiya, H., Loening, A.M., Rubin, D.L. (2020). "A New Multi-Model Machine Learning Framework to Improve Hepatic Fibrosis Grading Using Ultrasound Elastography Systems from Different Vendors." Ultrasound in Medicine and Biology. 46(1):26-33.

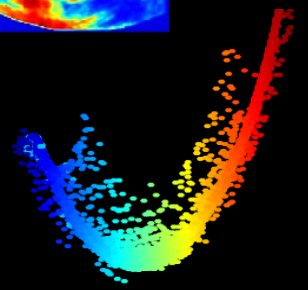




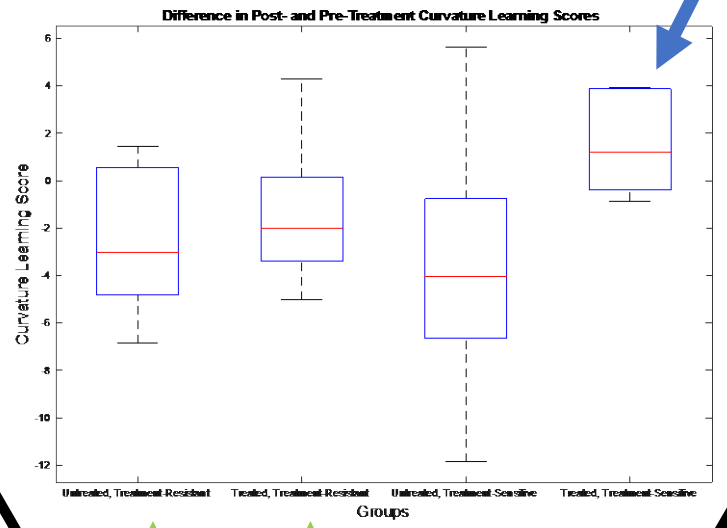
Early Cancer Treatment Response

- Is it possible to identify tumors responding to chemotherapy using contrast enhanced ultrasound before there is a change in tumor size, the current basis of RECIST measurements?
- Applied curvature learning, an unsupervised learning technique, to detect changes in tumor perfusion before there was a change in tumor size.
- Dataset: Response of tumor in mice to anti-angiogenesis agent bevacizumab.
- Method: non-linear dimensionality reduction (diffusion maps), mapping complex data into a 2D embedded space (heat map).
- Embedded image is mapped to a scattergram.
- Changes in these color classes over time on a given imaging day were compared to changes pre-treatment and post-treatment to create a tumor score.
- Compared distribution of tumor scores between the treated, treatment-sensitive group and all others (Wilcoxon rank-sum).





Treated-Treatment Sensitive Group



Controls: Untreated or Treatment-Resistant

Significant difference in curvature learning score between treated, treatment-sensitive group and control groups (**p = 0.0051**).

Anomaly Detection with US Images

Using anomaly detection from US cine images of thyroid cancer to detect abnormal frames.

Technique detects outliers that differ from the rest of the data.

Will employ generative adversarial networks (GANs).

GAN: generator creates synthetic data and discriminator distinguishes real vs. synthetic data. With training, generator creates better images and discriminator improves.

Once trained, when new samples are presented, if a good representation of the sample is not found in the latent space of the generator, it is deemed anomalous.