Kidney biopsy classification using shear wave elastography and machine learning techniques

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Background, Motivation, and Objective:

End-stage renal disease can rapidly deteriorate the ability of the body to sustain homeostasis. Kidney transplant is the preferred treatment because it provides a better survival rate and quality of life than dialysis. Renal biopsy, using Banff classification features, is the gold standard for diagnosis of allograft health, but it is an invasive procedure that can cause complications, and so, cannot be used frequently. An alternative to biopsy could be noninvasive imaging such as shear wave elastography (SWE) that can potentially assess changes in renal allografts directly related to pathological processes. Elastic mechanical properties have been found to be sensitive to the presence of interstitial fibrosis (ci) while viscoelastic parameters were sensitive to interstitial inflammation (i) processes and tubular atrophy (ct).

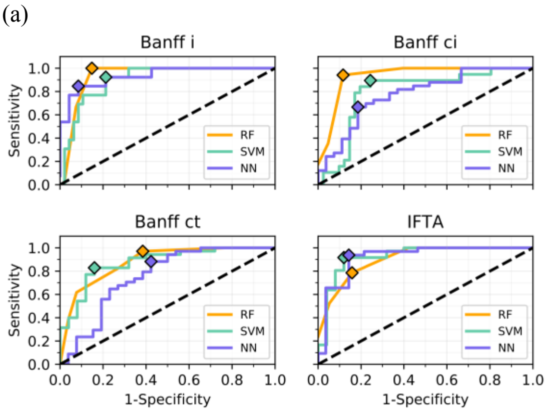
Statement of Contribution/Methods:

In this study, 97 patients with renal transplants had SWE scans performed right before their routine protocol biopsy procedure. Neural networks (NN), support vector machine (SVM) classifier and random forest (RF) were optimized using nested K-fold cross validation and compared to assess their capabilities to predict Banff biopsy scores (i, ci and ct and ci with ct (IFTA)) with the rheological and physiological features obtained during their routine evaluation. The parameters obtained from the SWE measurements included elastic properties such as group velocity, shear modulus, and viscoelastic properties such as phase velocity and attenuation at frequencies 100-300 Hz, Kelvin-Voigt fractional derivative model fitting, tubule/vessel direction, and biomarkers such as serum creatinine. The area under the receiver operating characteristic (AUROC) curve, sensitivity and specificity were used to evaluate the models' performance.

Results/Discussion:

The results are summarized by Figure 1(a) with ROC curves and the point maximizing Youden's index. Predictability was highest for IFTA (ci + ct) and i, while it was the worst for ci alone, with AUROC of 0.80 or below for SVM and NN. Random Forest had the best classification performance for i and ci, with AUROC at 0.93. SVM and NN showed best performance for i and IFTA, with AUROCs above 0.90. Given the small number of subjects, the current results show the elevated clinical potential of elastography techniques for frequent noninvasive evaluation of renal allografts.

(a)



(b)

		Sensitivity	Specificity	AUROC
i	RF	1.00	0.85	0.93
	SVM	0.92	0.79	0.90
	NN	0.85	0.91	0.93
ci	RF	0.94	0.88	0.93
	SVM	0.89	0.76	0.80
	NN	0.67	0.81	0.78
ct	RF	0.97	0.62	0.88
	SVM	0.83	0.84	0.87
	NN	0.78	0.71	0.79
IFTA	RF	0.79	0.84	0.90
	SVM	0.92	0.88	0.93
	NN	0.94	0.86	0.92

Figure 1 – The test dataset prediction ROC curves for each biopsy Banff score and machine learning model are presented by (a). Values of sensitivity and specificity calculated from ROC plots using maximum Youden's index are depicted as diamonds for each machine learning model. The sensitivity, specificity and AUROC values found are summarized in the table above (b).