Department of Surgery, Division of Organ Transplantation, Northwestern University Transplant Outcomes Research Collaborative

Leveraging CT reports for Risk Stratification in Patients with Cirrhosis: a Machine-Learning approach.

Alexander Huang[1], Praneet Polineni[1], Jonathan Jung[1], Matthew Antalek[2], Ulas Bagci[2], Amir Borhani[2], Daniela P. Ladner[1]

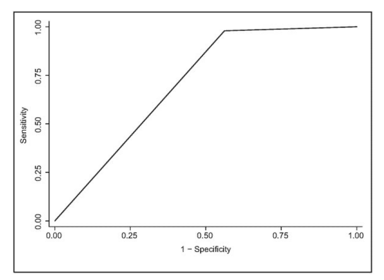
[1]NUTORC, Northwestern University Feinberg School of Medicine, [2]Department of Radiology, Northwestern University Feinberg School of Medicine

Background

Cirrhosis of the liver affects millions of adult Americans and is implicated in over 100,000 hospitalizations and over 50,000 deaths each year.

Accurate identification of cirrhosis in electronic health records (EHR), using International Classification of Disease (ICD) codes, has limited success, potentially leading to delays in Hepatocellular Carcinoma (HCC) screening.

A deep-learning model can predict cirrhosis and recommend screening, leading to early preventive care.



ICD-code based classification of cirrhosis has limitations. C-statistic = 0.72

Research Objectives

1. Develop a neural net that can accurately distinguish radiology findings and diseases states of cirrhosis from other organ systems.
2. Implement a deep learning model to classify patients at risk of cirrhosis.

Methods

A retrospective study was performed using data from all adult patients (>18yo) within Northwestern Medicine's Enterprise Data Warehouse between 2014 – 2022 who had an abdominal CT and a consent indicator in the medical record.
Text from radiology-reports were vectorized through the Word2Vec algorithm (Figure 2).
Comparisons of the word-similarity were evaluated using T-SNE projection (Figure 3)
Data was split into train:test:validation sets (70:20:10). Highly specific cirrhosis ICD-codes were used as positive control (> 98% specificity). Non-cirrhosis radiology reports were used as the negative outcome. Chart-review of 150 radiology reports was preformed by two clinicians (Cohen's kappa coefficient (κ = .96) and used as validation set to test model predictive capability. Remaining 480 of 630 currently under review (Figure 1).
The area under the receiver operator characteristic curve was utilized to evaluate the model. The effectiveness of the deep learning model was compared against ICD-code classifications (Figure 4).

Figure 1. Defining the Cohort

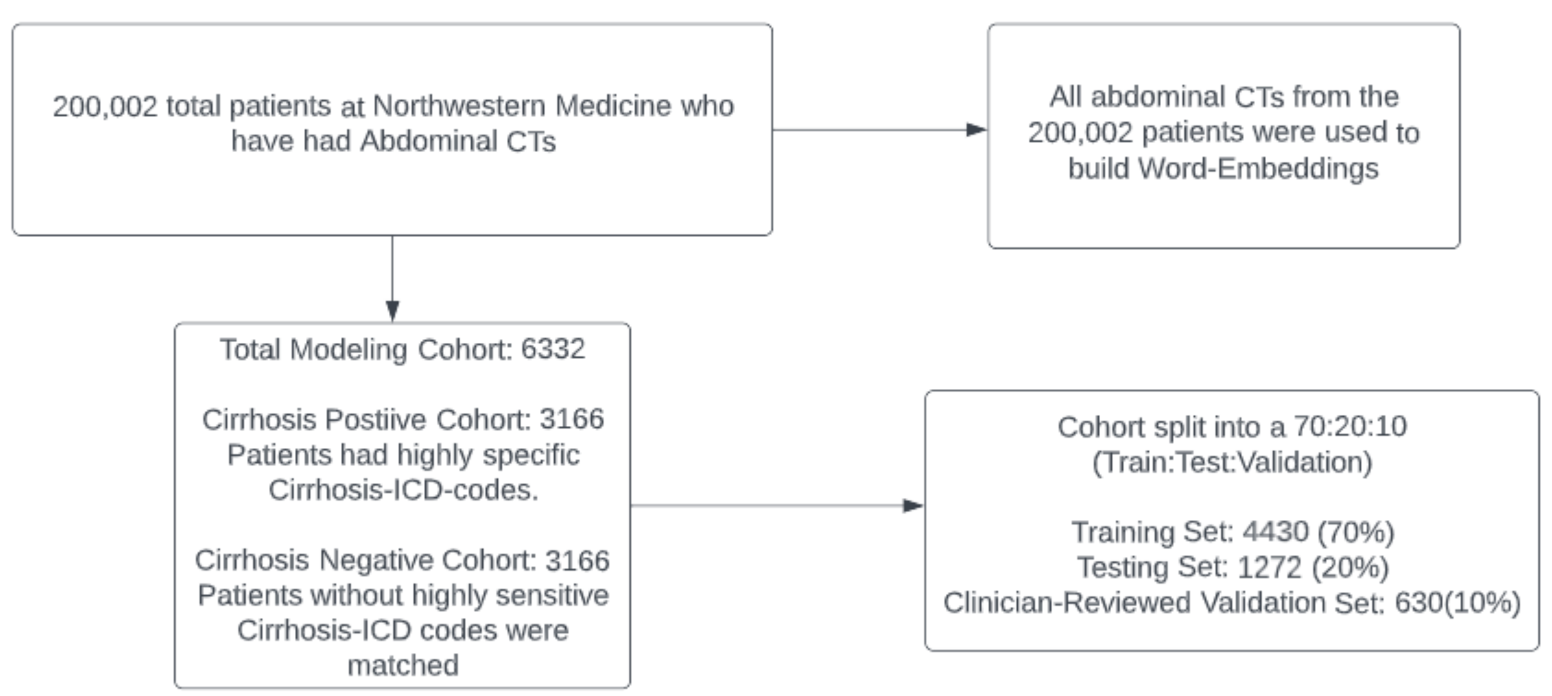
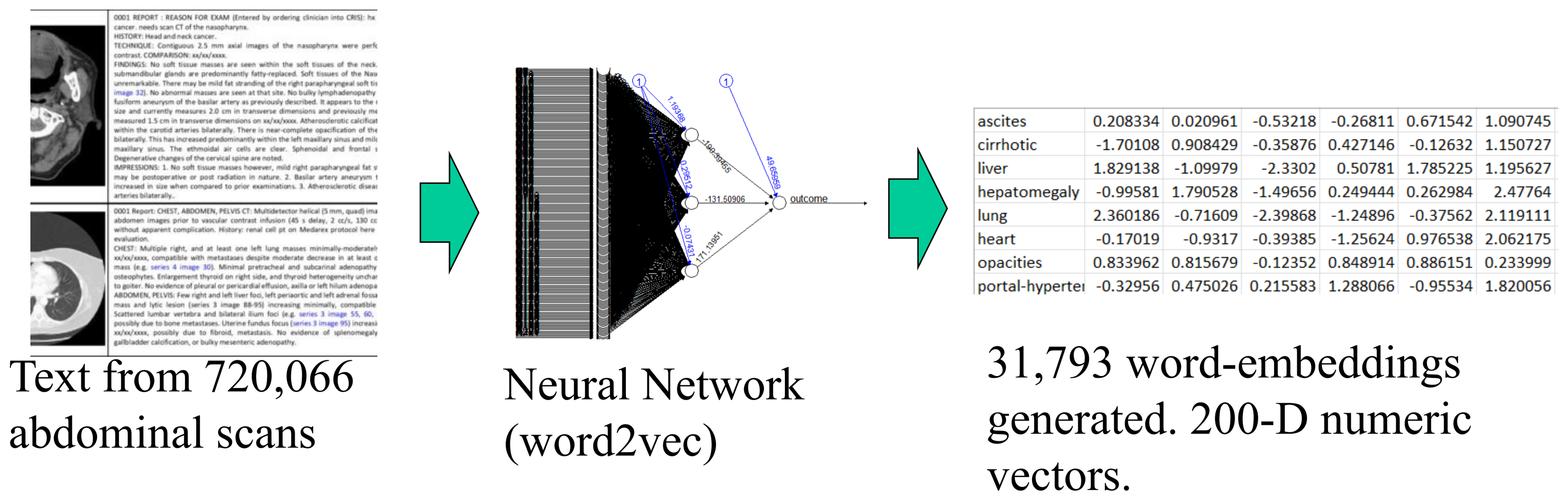
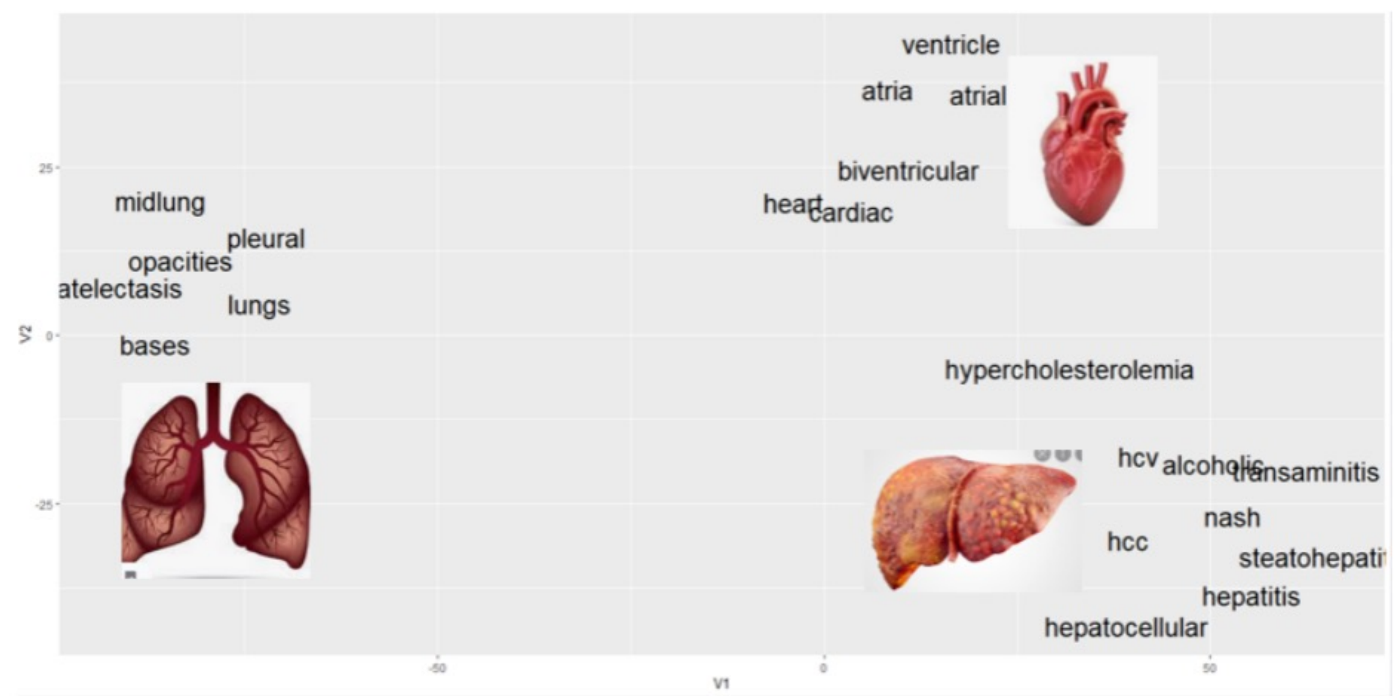


Figure 2. Vectorization (Conversion of Words → Numbers)



The word2vec algorithm to constructs word-embeddings (a computer's dictionary of words) based upon their context in the radiology report.

Figure 3. Visualization of Synonyms through T-SNE projection

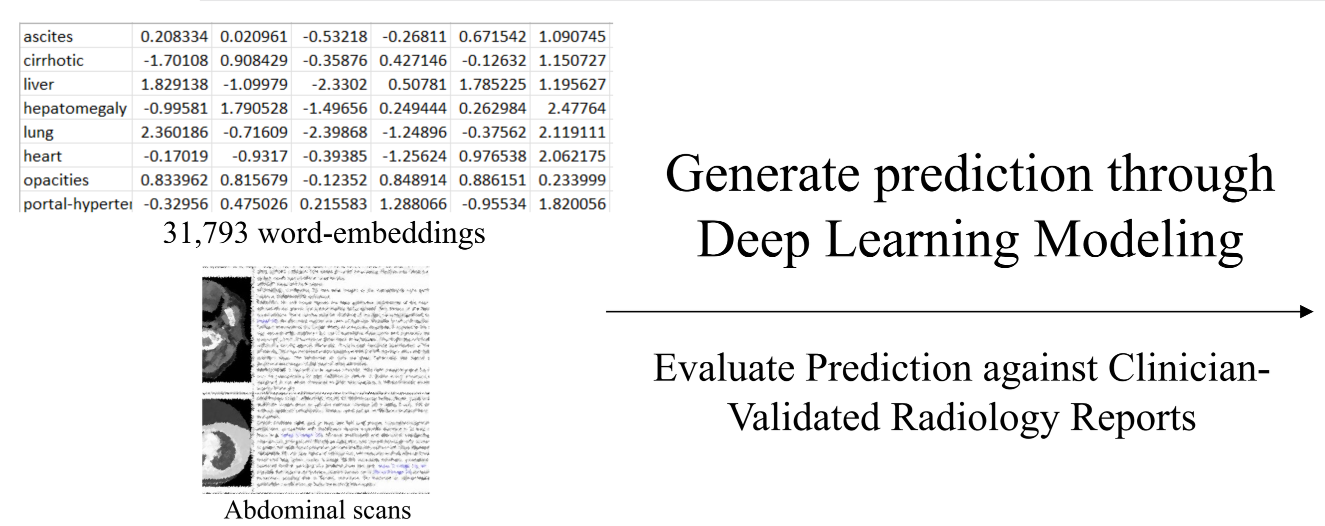


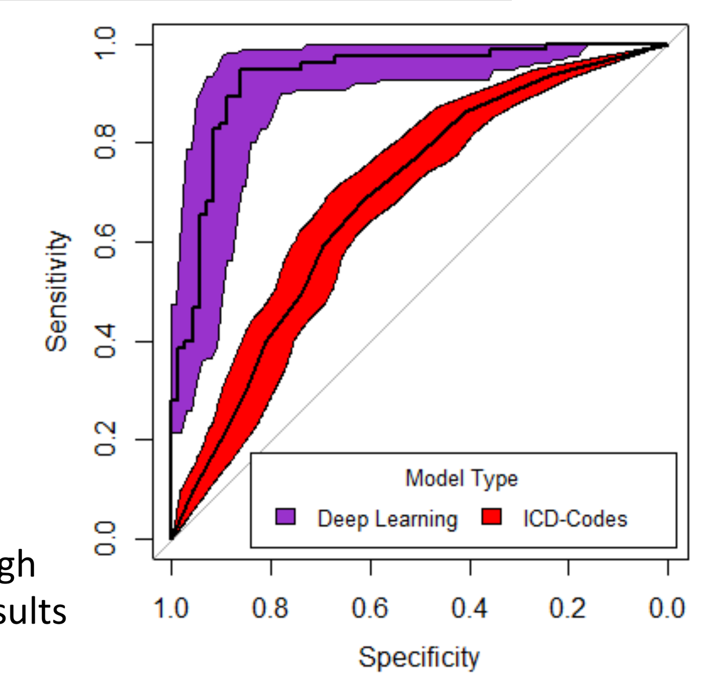
Clustering of terms that are contextually, semantically, and syntactically related are shown through the T-SNE projection.

200-Dimensional vectors projected down to a 2-Dimensional space.

Distances between words on this plane represent differences in contextual, semantic, or syntactic meaning of words.

Figure 4. Deep Learning Model vs ICD-code classification of Cirrhosis.





We can leverage the word-embeddings ("dictionary") to make predictions through deep learning ("read the report and classify as high or low risk for cirrhosis). Results validated against human-chart review (C-statistic 0.93)

Table 1: Model Comparison

Method	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio	C-Statistic
Deep Learning Model	92%	89%	8.4	0.1	0.93
ICD-Codes	69%	74%	2.7	0.4	0.72

The deep learning model outperforms ICD-codes in risk-stratification of patients with cirrhosis, outperforming ICD-codes in sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and the C-Statistic.

Results

A deep learning model using word-embeddings and gradient-boost classification utilized the vectorized text to predict whether patients were at risk for cirrhosis (sensitivity = 92%, specificity = 89%, C-statistic = 0.93, positive-likelihood ratio = 8.4, and negative-likelihood ratio = 0.09).

When using deep learning compared vs using ICD-codes alone to identify patients with cirrhosis, the C-statistic improves from 0.72 to 0.93 (Difference = 0.21, p< 0.00001)

Limitations

This study utilizes data from a single-healthcare system, further application and validation of this approach on different patient populations is necessary.

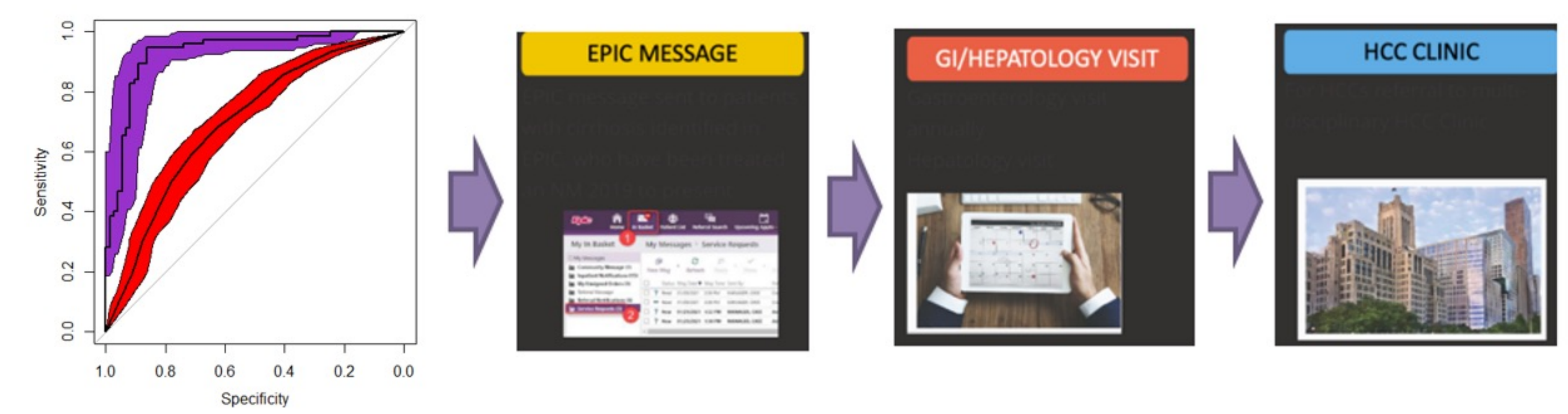
The algorithm currently only uses CT scans, utilization of MRI and Ultrasound imaging reports will be necessary to gain full understanding.

Conclusions and Future Directions

Conclusion: Deep learning models leveraging radiology-text have higher accuracy in classifying patients with cirrhosis than ICD codes associated with cirrhosis.

Future Directions: Integration of the deep learning model which can identify patients at high risk of cirrhosis into a cirrhosis care pathway allows for early preventive care (Figure 5)

Figure 5. Cirrhosis Care Pathway



Northwestern Medicine
Feinberg School of Medicine

Northwestern University
NUTORC
Transplant Outcomes Research Collaborative