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

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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.

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 $\kappa = .96$) 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 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 test 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).

Table 1: Model Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Likelihood Ratio</th>
<th>Negative Likelihood Ratio</th>
<th>C-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Learning Model</td>
<td>92%</td>
<td>89%</td>
<td>8.4</td>
<td>0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>ICD-Codes</td>
<td>89%</td>
<td>74%</td>
<td>2.7</td>
<td>0.4</td>
<td>0.72</td>
</tr>
</tbody>
</table>

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.

Figure 1. Defining the Cohort

Figure 2. Vectorization (Conversion of Words → Numbers)

Figure 3. Visualization of Synonyms through T-SNE projection

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

Figure 5. Cirrhosis Care Pathway