Developing an AI Model to Identify Malignancy Results on Imaging Reports to Delay Release to the Electronic Patient Portal

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2023 Radiological Society of North America Conference
November 26-30, 2023
## Summary of the Laws on Imaging Result Release

<table>
<thead>
<tr>
<th>21st Century CURES Act</th>
<th>SB1419</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal law</td>
<td>California state law</td>
</tr>
<tr>
<td>Took effect 10/2020</td>
<td>Enacted 10/2022, Took effect 01/2023</td>
</tr>
<tr>
<td>Immediate release of results to electronic patient portal</td>
<td>Imaging scan results that <strong>reveal a new or recurrent malignancy</strong> shall not be released to the patient portal until discussion with the patient by a healthcare professional</td>
</tr>
</tbody>
</table>

### Goal
- Have a consistent, reliable automated flagging workflow that complies with both state and federal regulations

### Solution
- Create an AI/NLP program to automatically analyze imaging reports and determine which to be held or released to patient portal
• Dictate phrase ‘SB1419’ at the bottom of the IMPRESSION section of the report.

• EHR will analyze for phrase dictated in reports from different reporting platforms (i.e. PowerScribe, CareConnect, and MagView)

• Manual flagging of reports to be held is onerous, prone to inconsistency, and difficult to standardize
Automated Workflow with AI: Overview

- Pre-existing malignancy classification schemes (i.e. BI-RADS, LI-RADS)
  - Positive defined as > 50% probability of malignancy on malignancy classification schemes (i.e. BI-RADS $\geq 4$, LI-RADS $\geq 4$)
  - Pre-selected 12 most common keyword stems: Malignant, Cancer, Neoplas, Tumor, Carcinoma, Metastatic, Metastas, Lymphoma, Sarcoma, Leukemia, Melanoma, Lymphoproliferative
  - Training dataset labeled by physician informaticists was used to train the deep neural network (DNN) model
Data Preparation for Hybrid Machine Learning Model

Data Collection
- MagView
- Radiant
- CareConnect
- Epic

Radiology applications sending real-time data to EHR CareConnect

Data Cleaning
- Handling rich text formats
- Removing appendixes

Data Engineering
- Normalize the text vocabulary
- Case folding - reduce all letters to lowercase
- Lemmatization - reduce inflected words to root words
- Removing stop words
- Tokenization using n-gram
- Term Frequency-Inverse Document Frequency: evaluates the frequency of words to determine its relevance in a given document

Exploratory Data Analysis
- Daily volume of reports
- Distribution of imaging reports

Data Splitting
- Development Set 75%
- Test Set 25%
- Labeled data n=2,677

Pre-Modeling Phase
- Deep Neural Network Modeling Phase
Model Development: NLP Deep Learning

Output:
\( y_0 \) is used for not holding reports
\( y_1 \) is used to hold the radiology reports

Deep Neural Networks’ structure is designed to learn by multi-connection of layers (each layer only receives a connection from the previous and provides connections only to the next layer).
Model Training and Validation

Prepare training dataset from reports
(12/01/2022-12/31/2022)

Apply AI model to reports
(01/19/2023-02/12/2023)
Applying AI Model

- Daily dashboard of AI model applied on reports that resulted from 01/19/2023-02/12/2023
- A total of 1,289 (2.6%) reports were positive and met the criteria for hold, with 996 reports identified from the DNN NLP and 293 reports from –RADS rule NLP, respectively.

Evaluating Performance

- Combining model output from both DNN and rule-base NLP
- Dataset: 25% of data from 12/01/2022-12/31/2022 (N=61K)

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Label Truth</th>
<th>True Negative</th>
<th>True Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>14535</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>62</td>
<td>135</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE (Recall)</td>
<td>0.8336</td>
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<tr>
<td>SP</td>
<td>0.9958</td>
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<tr>
<td>PPV (Precision)</td>
<td>0.6857</td>
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<tr>
<td>NPV</td>
<td>0.9981</td>
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<tr>
<td>ACC</td>
<td>0.9940</td>
</tr>
<tr>
<td>F1-Score</td>
<td>0.7524</td>
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Model Monitoring

System Monitoring

• CareConnect build to notify users of system failure

Performance Monitoring

• Periodically review of model performance post deployment
• Analyze for data drift or performance deterioration

Business Monitoring

• Evaluate how the model impacts the business with dashboards
EHR Workflow Integration

- Awaiting further development by Epic EHR to incorporate AI model into Radiant workflow to perform hold functionality
- Status of released or held reports visible to providers