A scalable and accurate deep learning approach

Predictive modeling with EHR data

Why bother using a deep learning approach?

Tl;dr

- Desire: predictive statistical modeling
- Current implementation disadvantages:
  - Labor-intensive
  - Discards majority of information from patient data
- Proposal:
  - Predict multiple medical events on full raw EHR records with a deep learning approach
- Outcome:
  - Deep learning approach outperformed traditional models

Comparison

Predictive model

- Each prediction requires a custom dataset
- Unscalable due to number of predictors → limitations
- 80% pre-processing
- No (semi-)structured & text simultaneously (statistical model)

Deep learning

- Can handle “messy” data
- No specification of predictors required → feature learning
- Uses a new data structure (FHIR)
- Scalable

Feature learning

Set of techniques used to automatically discover representations for feature detection / classification

Feature detection: categorize a new observation into an existing set

Pattern recognition: computers can do this better

3 architectures, 4 tasks, multiple time points → ensemble learning

Neural networks

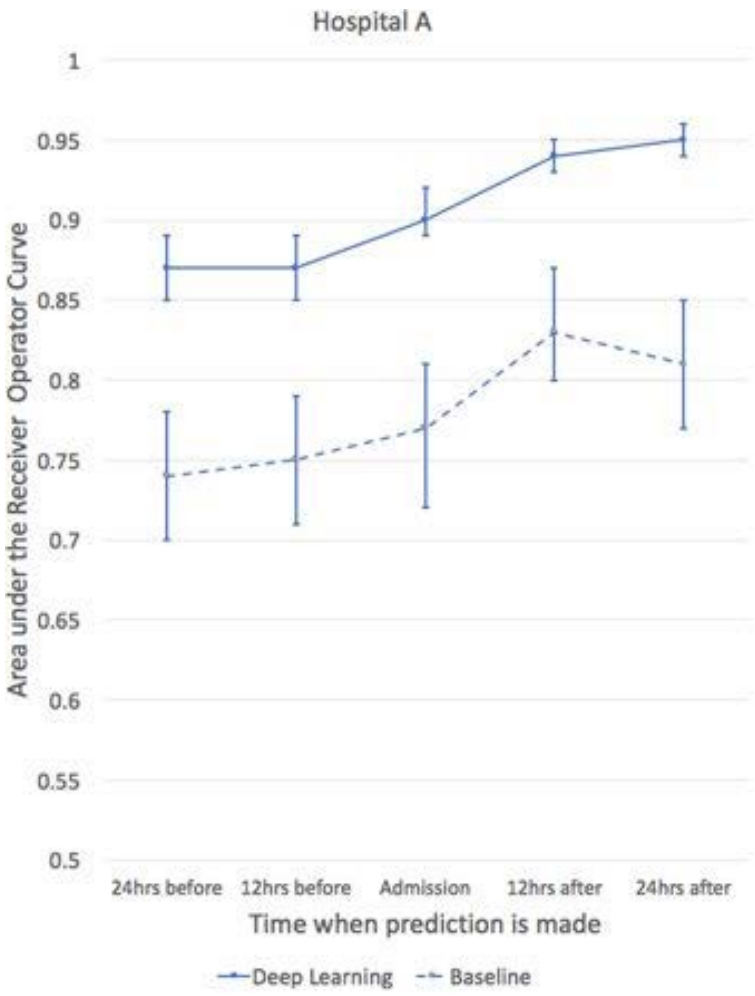
- Recurrent neural networks (long short-term memory (LSTM))
  - Uses feedback connections → sequences of data
  - Consist of: a cell, an input gate, an output gate and a forget gate.
- Attention-based TANN
  - Attention used to determine important data points
- A neural network with boosted time-based decision stamps
  - Boosting by combining weak classifiers (small correlated classifier)
- Ensemble learning, a supervised learning algorithm

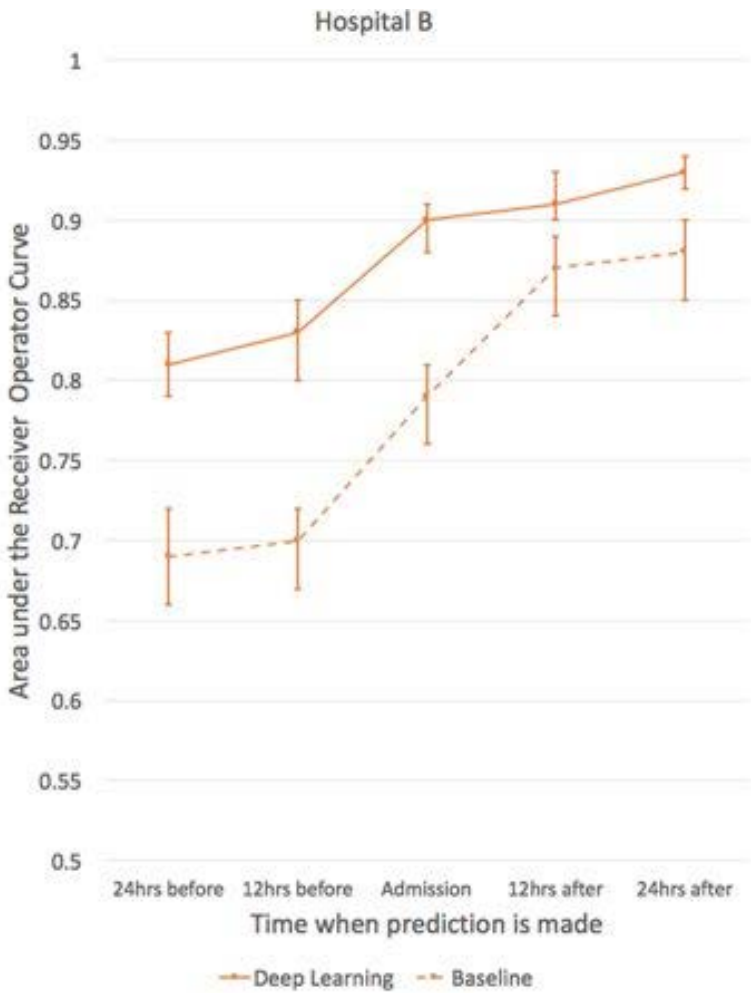
- All supervised learning: development (80%), validation (10%), and test (10%) sets.

Results

- Accuracy for mortality rate prediction: .95 vs. .85
- Reduced false alerts: 7.4 vs 14.3
- 24-48h earlier for same accuracy

- Unexpected readmissions prediction: .77 vs .70
- Long stay prediction: .86 vs .76

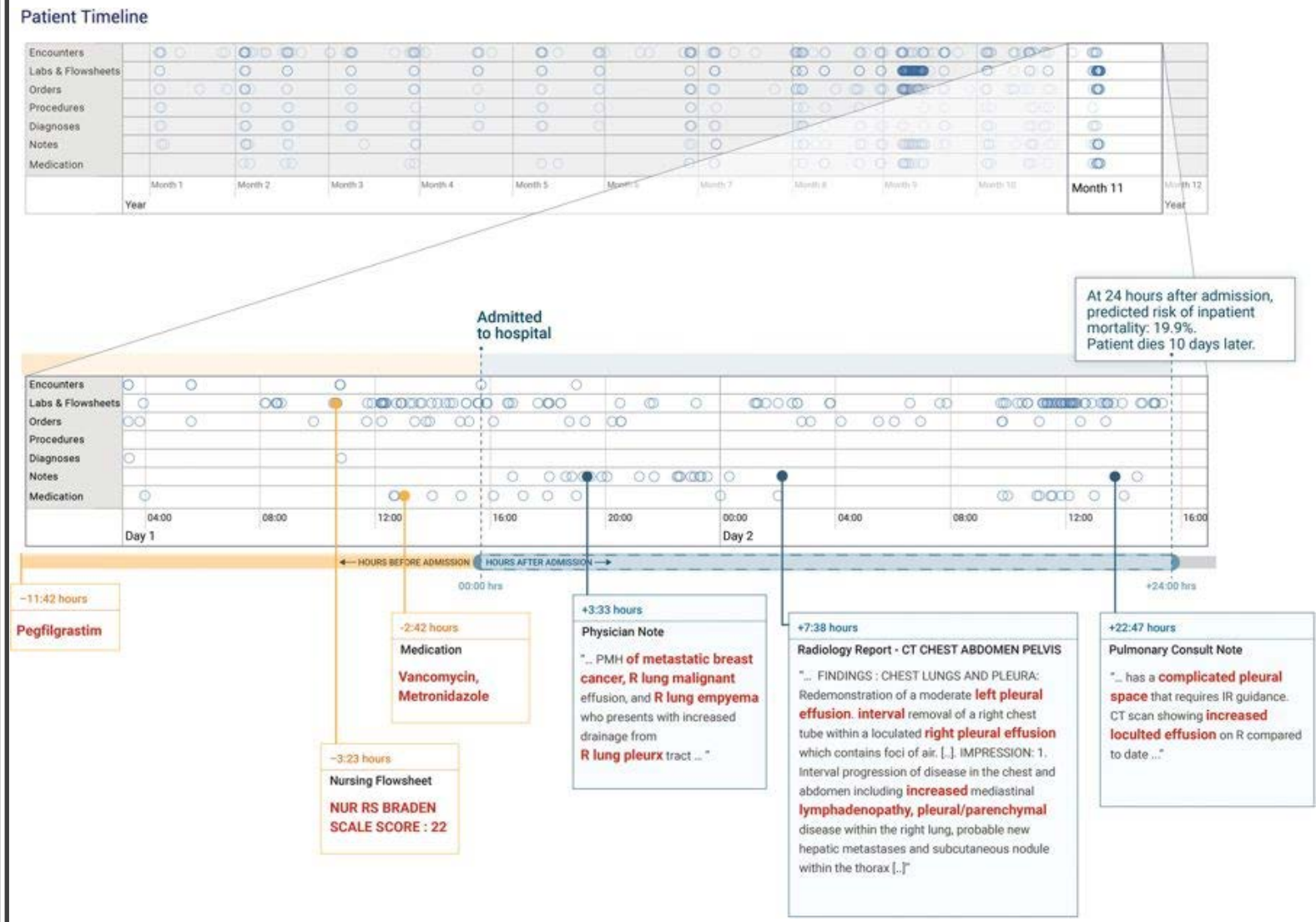




Dataset & method

- Average admission: 137,882 tokens per patient
- Increase until discharge: 216,744 tokens
- 46,864,534,945 tokens of EHR data in total
- All information in the EHR up until the moment of the prediction was used
- Real-time prediction (2ms)

Case study


Patient Timeline
Encounters
Labs & Flowsheets
Orders
Procedures
Diagnoses
Notes
Medication
Month 1
Month 2
Month 3
Month 4
Month 5
Month 11
Month 12
Year
Year
Admitted to hospital
At 24 hours after admission, predicted risk of inpatient mortality: 19.9%.
Patient dies 10 days later.
04:00
08:00
12:00
16:00
20:00
00:00
04:00
08:00
12:00
16:00
Day 1
Day 2
HOURS BEFORE ADMISSION
HOURS AFTER ADMISSION
00:00 hrs
+24:00 hrs
−11:42 hours
Pegfilgrastim
−3:23 hours
Nursing Flowsheet
NUR RS BRADEN SCALE SCORE : 22
-2:42 hours
Medication
Vancomycin, Metronidazole
+3:33 hours
Physician Note
"... PMH of metastatic breast cancer, R lung malignant effusion, and R lung empyema who presents with increased drainage from R lung pleurx tract ... "
+7:38 hours
Radiology Report - CT CHEST ABDOMEN PELVIS
"... FINDINGS : CHEST LUNGS AND PLEURA: Redemonstration of a moderate left pleural effusion. interval removal of a right chest tube within a loculated right pleural effusion which contains foci of air. [..]. IMPRESSION: 1. Interval progression of disease in the chest and abdomen including increased mediastinal lymphadenopathy, pleural/parenchymal disease within the right lung, probable new hepatic metastases and subcutaneous nodule within the thorax [..]"
+22:47 hours
Pulmonary Consult Note
"... has a complicated pleural space that requires IR guidance. CT scan showing increased loculted effusion on R compared to date ..."

Verdict

- Generic data processing pipeline without manual feature harmonization on EHR data
- Effectiveness in a variety of prediction problems

- Do you see any privacy risks that these kinds of deep learning algorithms can induce?
- What are the steps one can take to prevent overfitting on the training dataset of the hospitals at hand?
- The study has a retrospective design, what other study design would you use to allow random assignment of users? What would be the control group?
- Do you think this deep-learning with EHR can replace decisions of physicians in future? Or are the physicians still needed for the “humanity perspective”?
- Could deep learning methods also be used during the treatment phase?
- Apart from the algorithm that is used, which model do you think would have been more accurate?
- Accuracy of the test is mentioned in the paper! However, I would love to know what the value of false positive rate was? → 7.4
- The paper is very promising, are there any future plans (for adoption/implementation) with these techniques?
- Would it be ethical to use the algorithm for decision making?
- If the algorithm would be implemented, how could it improve the healthcare process?

- Do you think the algorithm could be easily changed in order to predict other things than mortality for a patient such as complications or others problems ?
- How can you explain the fact that this new way of working is way better than the usual one for prediction?
- What other data points do you think can be added to the existing ones (at admission, 24 hrs after admission, at discharge)?
- What would be the recommendations for a hospital trying to implement this deep learning algorithm with respect to the data gathering and availability?
- Are there ethical objections to using black-box model predictions in clinical decision making?
- In which clinical scenarios a Deep Learning data analysis approach is expected to yield the best results?
- This Deep Learning approach was successful evidently because the generation of healthcare data as mentioned by the authors is quite sub-optimal. Do you know of any specific examples that demonstrate this?

- Do you think the predictions made, based on the deep learning model, is trustworthy?
- What are the economic benefits of being able to predict in an accurate way risk of patient mortality, readmission probability, etc?
- How well can the FHIR integrate with a traditional healthcare approach?
- How could this study be replicated if the data is not available? What would you recommend in that case?
- What is the biggest challenge in the process of obtaining valuable information from EHRs?
- What is the main benefit of the developed EHR deep learning algorithm over existing ones? (besides precision?)