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A Novel Methodological Framework for the Analysis of Health Trajectories and Survival Outcomes in Heart Failure Patients

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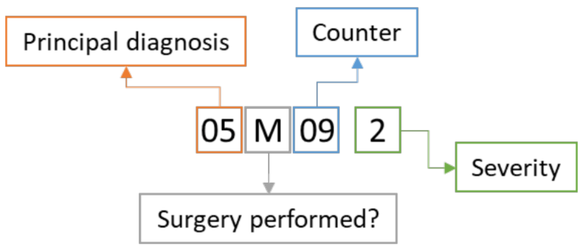
CONTEXT & OBJECTIVES

Motivating example

- Heart failure (HF) is common amongst **elderly** patients and associated with a **high mortality rate** *[Farré 2017]*
- Chronic HF is often accompanied with **repeated hospitalizations** and is the condition with **highest 30-days re-hospitalization rate** *[Constantinou 2021]*

Figure 1. ICD-10 architecture



Available data

- The **EGB** (*Echantillon Généraliste des Bénéficiaires*) is a random sample representative of the **French health insurance databases** and provides **in-hospital electronic health records**
- **International Classification of Disease** (10th edition (ICD-10)) is used to establish **primary and associated diagnoses** of hospitalizations (Figure 1)

Study objectives

- Identify frequent care sequences in HF patients in France
- Investigate associations with mortality

METHODOLOGICAL FRAMEWORK

Identify similarities from care pathways using clustering

Input – Care pathways (examples in Table 1), excluding factors like gender and age

Methodology

- Defining the appropriate distance metric to quantify the distance between two patients' care pathways, based on Levenshtein distance with weighted components of the ICD-10 codes. For two ICD-10 codes A and B:

Table 1. Three patients and their care pathways

Patient	hospit_course
P0	05K051,05M042,05M16T,05M09T,05M092,05C191,…
P6	02C05J,02C05J,05M093,04M132,05C222,23M103
P8	11M041,06C194

$$D_{ICD10}(A,B) = \omega_1 * lev(A_{0:2}, B_{0:2}) + \omega_2 * lev(A[2], B[2]) + \omega_3 * lev(A_{3:5}, B_{3:5}) + \omega_4 * lev(A[5], B[5])$$

→ We then compare the i^{th} ICD-10 code of a patient with the $(i-1)^{th}$, i^{th} and $(i+1)^{th}$ ICD-10 codes of another patient, compute the distances and keep the minimum to get the distance between two patient sequences.

- K-medoids algorithm used to group data points into k clusters. Two hyperparameters require settings and are under constraint:
  - Ω the weights of the distance metric, with $0 \leq \omega_4 \leq \omega_3 \leq \omega_2 \leq \omega_1 \leq 100$,
  - $k \in [2,20]$ the number of clusters.

Extract frequent care pathway patterns using sequential pattern mining

Input – Subset of items (ICD-10 code), event sequence (ordered list of ICD-10 codes)

Methodology – PrefixSpan algorithm was retained and uses the concept of "prefixes" to efficiently search for frequent patterns in a sequence database *[Pei 2001]*

Clinicians' interest in survival analysis to predict the survival probability of a specific HF patient

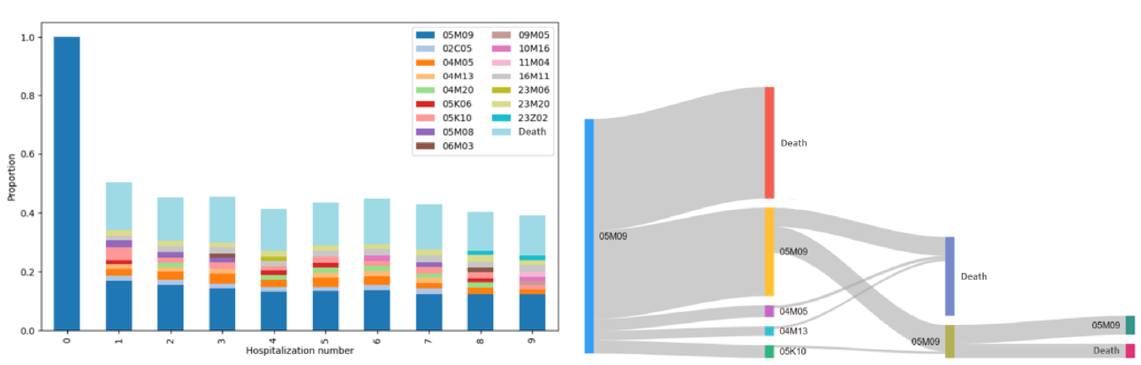
Input – Survival time and status (dead or alive), adjusted covariates

Methodology – Random survival forests and survival gradient boosting algorithm (hyperparameter tuning conducted*) [Ishwaran 2008, Hothorn 2006]*, and evaluation using AIC and concordance index *[Harrell 1982]*

Outputs

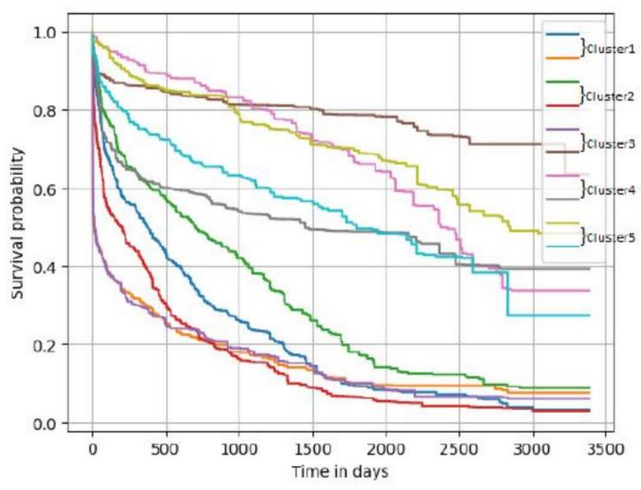
- The ten most frequent ICD-10 codes collectively accounted for approximately 50% of trajectories, indicating significant similarity in the care sequences (Figure 2)
- Common sequences leading to death are '05M09' for HF hospitalization, '04M05' for pleurisy, and '04M13' for pulmonary edema and respiratory distress
- Different survival trajectories from the 5 cluster s obtained (Figure 3)
- Aging and prolonged hospital stays are also impactful risk factors

Figure 2. Key figures for Cluster 1



(a) Frequent ICD-10 codes (b) Sankey diagram

Figure 3. Survival predictions in clusters with best and worst scenarios



DISCUSSION & CONCLUSION

- Our approach is **simple** and easily **accessible**
- While our focus has been on the HF patients, our approach is **adaptable** and **can be extended** to other clinical problematics and populations

Perspectives

- Include **up-to-date methodologies with NLP and embedding techniques** to extract event more relevant information from ICD-10 codes
- Include **risky patterns** identified as covariates in survival models

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https://github.com/Kirscher/TextMining_Parcours_de_soin