An Outcome-weighted Collaborative Network for Modeling Patient Satisfaction in the Emergency Department

§Matthew B Carson, PhD[1], Stephanie Gravenor[2], Young Ji Lee, PhD, RN[1], Denise Scholtens, PhD[1], Conor Frailey, PhD[1], Nicholas D Soulakis, PhD[1]

[1] Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago IL

[2] Department of Emergency Medicine, , Feinberg School of Medicine, Northwestern University, Chicago IL

Aims

- To identify **business-as-usual care and associated activities** in the NMH Emergency Department
- To determine **the degree of interaction between care providers**, **the degree of potential collaboration**, and **how well providers are connected with each other**.

Introduction

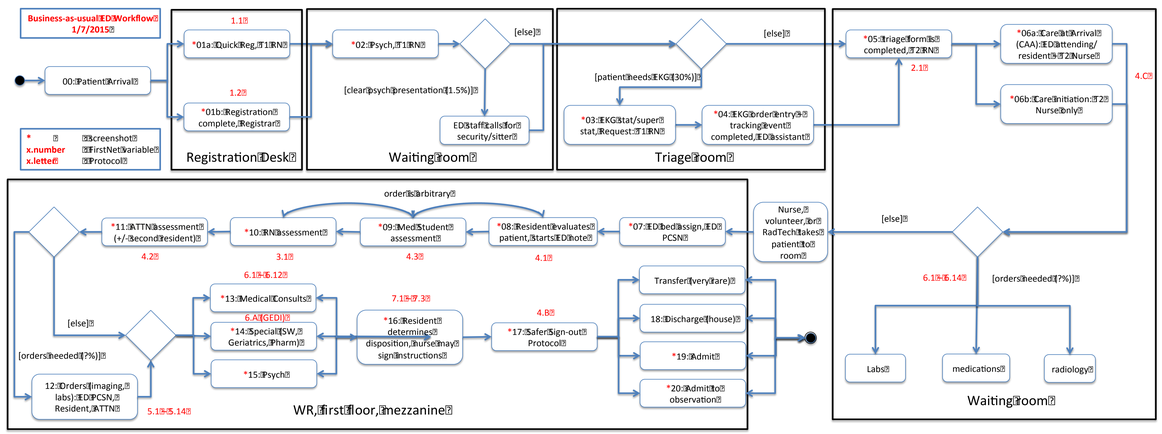
- **Care events for even simple patient encounters may involve several providers and several care events**
- **Operational attempts to maximize efficiency while maintaining quality care from the patient perspective require understanding complex, non-linear relationships.**
- **A graph model can help to identify collaboration between care providers**

Methods

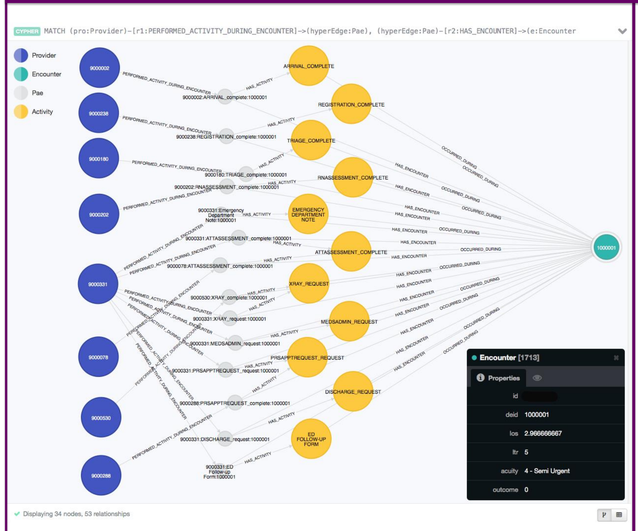
- **Identified business-as-usual workflow in the ED**
- **Extracted ED encounter and provider data from the Northwestern Medicine Enterprise Data Warehouse (NMEDW)**
  - **3,014 encounters, 753 providers, 30 positions, 27 activities, 41,851 individual provider actions**
  - **Outcome: LTR+ (1783), LTR- (1230)**
- **Developed a graph database using Neo4j**
- **Created and analyzed**
  - **Provider activity network**
  - **provider collaboration network with edge weight is a *Satisfied Shared Patient Index*:**

$$SSPI = \frac{|SSP_A \cap SSP_B| \;/\; |SSP_A \cup SSP_B|}{|SP_A \cap SP_B| \;/\; |SP_A \cup SP_B|}$$

Emergency Department Workflow



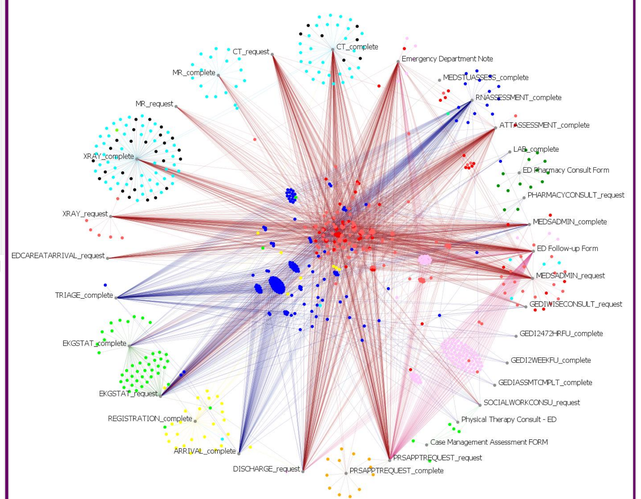
Graph Database



- **A Neo4j graph database query example showing one encounter with associated providers and their activities**
  - **Properties of the encounter node are shown in the black box**
  - **The Pae nodes (Provider – Activity – Encounter) allowed us to represent particular instances of activities during a specific encounter**
- **Advantages of the graph data model over the relational model**
  - **data is implicitly connected so queries are much faster**
  - **highly flexible due to lack of table structure**
  - **Both nodes and relationships can have properties**

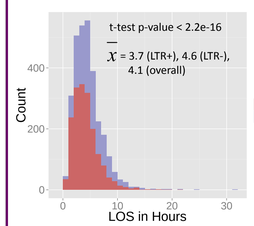
Provider-Activity Network

- **Activities (grey nodes, clockwise from the bottom left ordered by their occurrence in the ED workflow) and the providers who performed them at least once in our data set are shown below**
- **Providers are colored by position Physician: dark red, Res/Fellow: salmon, Med Student: pink, Nurse: blue, ED assistant: light green, Pharmacy: dark green, RAD: light blue, ED reg: yellow, PRS: orange, UR/QA: green, Reg/Sched SU: black**
- **The number of activities vary widely across provider types, with nurses, physicians, and res/fellows performing the largest number of activities**
- **Some provider types (e.g., nurses, in blue) are divided into communities based on activity types**

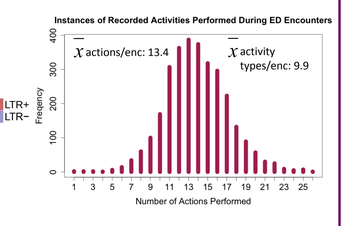


Results

LTR is related to LOS



# of provider actions is norm distributed

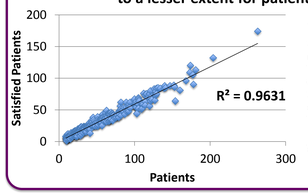


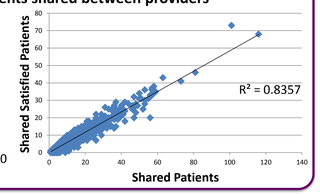
The average number of providers involved in each encounter: 7.7

Highlights of the Collaboration Network

- **A high level of collaboration among providers**
  - **Average node degree: 59**
  - **Average Path length: 2.1**
  - **The top 7 highest degree providers are residents**
- **Only a moderate tendency for collaborating provider pairs to share other collaborating partners (clustering coefficient = 0.59)**
- **The low network density (0.107) reveals that far less collaboration exists in reality than is theoretically possible**
- **Closeness: Top 8 are residents**
- **The top 5 highest betweenness providers are nurses, indicating that they act as a bridge between at least two groups of providers**

The number of satisfied patients scales with total patients seen; the same is true to a lesser extent for patients shared between providers





Conclusions

- **There were large variations in network statistics among providers of different types, highlighting their unique contributions to the collaboration process**

Acknowledgements

Supported in part by the Clinical and Translational Science Award (CTSA) award UL1RR025741 from the National Center for Research Resources - transitioned to the National Center for Advancing Translational Sciences (NCATS).

§Corresponding author

Matthew Carson, matthew.carson@northwestern.edu