AMPLIFYING INTELLIGENCE IN HEALTHCARE PATIENT FLOW EXECUTION
GOALS

Showcase how applied intelligence can increase hospital bed availability and care quality

Present the solution with a strong business oriented vision

Share lessons learned and success factors for applying AI in health industry
WELCOME!

AMPLIFYING INTELLIGENCE IN HEALTHCARE PATIENT FLOW EXECUTION

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Albert Einstein Jewish Hospital

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Accenture Latin America
Purpose, Mission, Vision, Precepts and Values

Overview

1. Purpose
   Deliver healthier lives by handing a drop of Einstein to every citizen.

2. Mission
   To offer excellence in the field of healthcare, education, and social responsibility, as a way of highlighting the Jewish community’s contribution to Brazilian society.

3. Vision
   To be a leader and an innovator in medical and hospital care, a reference in managing knowledge, and recognized for its commitment to social responsibility.

4. Precepts
   Mitzvah (Good Deeds)
   Refuah (Health)
   Chinuch (Education)
   Tsedakah (Social Justice)

5. Organizational Values
   - Honesty
   - Truthfulness
   - Integrity
   - Diligence
   - Competence
   - Fairness
Einstein Hospital Key Figures
Operations Overview

Private System
- 640 beds
- 3.28 length of stay
- 32,884 surgeries
- 5,1 mi exams
- 55,8k hospital leaves
- 28,2k hospital leaves
- 4,237 births
- 8,498 births
- 340,5k ED cases

Unified Health System (Public)
- 11,174 surgeries
- 339,3 appointments
- 675,5k appointments
- 730,3k ED cases¹
- 8,498 births
- 81,5% occupation rate
- 86,2% occupation rate²

Hospital Municipal Dr Moysés Deutsch
- 240 beds
- 5,51 length of stay

Hospital Municipal Vila Santa Catarina
- 174 beds
- 5,68 length of stay

¹ HMMD + UPA Campo Limpo ² HMVSC e HMMD
Hospital experienced a margin deterioration despite of significant revenue growth captured.

**Business Context**

**Operational Efficiency Burning Platform**

- **2007-10 Period**
  - **Health Market**
    - +10.6mi new private customers
  - **Volume Growth**
    - +31% revenue increase
  - **Margin Loss**
    - -6.9p.p. EBTIDA reduction

**Call for Action**

Increase operational efficiency to reduce investments on capacity expansion

No significant improvement of average length of stay indicator

Operational Beds: 499, 493, 523, 577, 614
PATIENT FLOW MANAGEMENT PROGRAM
"Managing patient flow is one way to improve health services. Adapting the relationship between capacity and demand increases patient safety and it is essential to ensure that patients receive the right care, at the right place, at the right time, all the time."
PATIENT FLOW MANAGEMENT PROGRAM

Program Drivers and Principals

Increase capacity availability

Deliver high care quality standards

Maximize patient experience

Program Principals

Break Silos
Systemic Vision
Scientific Evidence
Data Reliability
Process Review
KPIs Monitor
PATIENT FLOW MANAGEMENT PROGRAM

Program Organization

The program aimed to eliminate waste of time and resources among the patient flow through a process optimization oriented methodology.

Phase 1
- Process mapping
- Process decoupling among emergency, elective and outpatient
- Future state design

Phase 2
- Multidisciplinary team formalization
- Process gaps confirmation
- Prioritization plan

Phase 3
- Action plan building
- KPIs and indicators confirmation
- Detailed workplan and follow up

27 operational areas involved
+70 team members accountable
548 actions implemented
70 KPIs and indicators monitored daily
PATIENT FLOW MANAGEMENT PROGRAM

How we measure success

The reduction of average length of stay increase bed availability, increase patient safety and postpone investments on capacity expansion.

97 virtual beds added to serve patients
HOW TO CONTINUE CREATING VIRTUAL CAPACITY AND ENSURING HIGH CARE QUALITY STANDARDS?
APPLIED INTELLIGENCE FOR PATIENT FLOW

Solution's Components Prioritized

PROBABILITY OF ER ADMISSION

25% of bed demand comes from ER

Anticipate visibility of ER demands for capacity planning

business reason

component objective

OPTIMIZED PATIENT ALLOCATION

First bed specialty allocation reduced length of stay

Maximize patient allocation in first bed specialty
Variables from every patient stage in ER are ingested and used...

**SCREENING**
- Patient record
- Specialty
- Vital signs
- Severity index

**1ST DOCTOR CHECK**
- Medicines
- Blood Exams
- Image exams
- Patient in Observation

**EXAM/TEST RESULTS**
- Reference tables and standards
- Test results
- Image reports

**SPECIALIST DOCTOR CHECK**
- Specialty
- Doctor

**HOSPITALIZATION**

**PREDICT ACCURATELY AS EARLY AS POSSIBLE**
...but modelling approach is based on 10' time windows.

Business Hypothesis: treatment approach evolves depending on how patient’s clinical condition respond to previews prescriptions, such as medication and exam results.
APPLIED INTELLIGENCE FOR PATIENT FLOW
Probability of ER Admission

Dataset used from new CERNER EMR:

<table>
<thead>
<tr>
<th>Count</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>66K</td>
<td>ER cases</td>
</tr>
<tr>
<td>6.5k</td>
<td>Admissions</td>
</tr>
<tr>
<td>10k</td>
<td>Types of medicines prescribed. 1.1k active principles</td>
</tr>
<tr>
<td>1.8k</td>
<td>Types of blood tests and image exams</td>
</tr>
<tr>
<td>2.5k</td>
<td>Different medical prescriptions in EMR</td>
</tr>
<tr>
<td>87</td>
<td>Different form fields</td>
</tr>
</tbody>
</table>

JANUARY TO JULY OF 2017
**APPLIED INTELLIGENCE FOR PATIENT FLOW**

**Probability of ER Admission**

The variety of features were a powerful tool against lack of historic data set.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Specialist evaluation</th>
<th>Nutrition Services</th>
<th>Pharmacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical record</td>
<td>Evaluation</td>
<td>Fasting, General, Pasty, ..</td>
<td>Medication</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>Type of Drug Administration</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient assistance</th>
<th>Screening</th>
<th>Physiotherapy</th>
<th>Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of pain level</td>
<td>Specialty</td>
<td>Respiratory Physiotherapy</td>
<td>Exams</td>
</tr>
<tr>
<td>Emergency room flow</td>
<td>Protocols (Heart Attack, Stroke, Sepsis)</td>
<td>Non-invasive ventilation</td>
<td></td>
</tr>
<tr>
<td>Observation room flow</td>
<td>Screening complaint</td>
<td>Analgesic Physiotherapy</td>
<td></td>
</tr>
<tr>
<td>O₂ saturation</td>
<td>ESI</td>
<td>Respiratory and Motor Physiotherapy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiology</th>
<th>Physiotherapy</th>
<th>Neurodiagnosis</th>
<th>Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray</td>
<td>Respiratory Physiotherapy</td>
<td>Electroencephalogram</td>
<td>Endoscopy</td>
</tr>
<tr>
<td>Tomography</td>
<td>Non-invasive ventilation</td>
<td></td>
<td>US Obstetric Transvaginal</td>
</tr>
<tr>
<td>Ultrasonography</td>
<td>Analgesic Physiotherapy</td>
<td></td>
<td>Angiography</td>
</tr>
<tr>
<td>Magnetic Resonance</td>
<td>Respiratory and Motor Physiotherapy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Cardiovascular | Respiratory Therapy | Procedures | |
|----------------|---------------------|------------|
| Electrocardiogram | Oxygen therapy | Endoscopy | |

| Cardiology | Procedures | |
|-------------|------------|
| Doppler echocardiogram | US Obstetric Transvaginal | |
| | Angiography | |
## Accuracy vs. Explainability:

<table>
<thead>
<tr>
<th>METRIC</th>
<th>MODEL</th>
<th>TRAIN 80% split</th>
<th>TEST 20% split</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACCURACY</strong></td>
<td>R.N.N.</td>
<td>92%</td>
<td>87%</td>
</tr>
<tr>
<td></td>
<td>Logistic Regression</td>
<td>80%</td>
<td>78%</td>
</tr>
<tr>
<td></td>
<td>Random Forest</td>
<td>78%</td>
<td>75%</td>
</tr>
<tr>
<td><strong>F1 SCORE</strong></td>
<td>R.N.N.</td>
<td>0.75</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Logistic Regression</td>
<td>0.61</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Random Forest</td>
<td>0.55</td>
<td>0.49</td>
</tr>
</tbody>
</table>

*R.N.N. = Recurrent neural network*
Hybrid optimization model composed by two phases:

- The first phase is a mathematical model for capacity sizing which consists of a variant of the Generalized Assignment Problem. It considers the optimal allocation of patients in the beds and also redistributes the patients among the management units in order to minimize the use of contingency.
- The second is an heuristic based on hierarchal rules to determine which beds should be used as contingency.

Optimization model for the allocation of patients in the beds, considering the business restrictions and maximizing the allocation in the 1st specialty to increase the quality of care.

The challenge for this model is to provide rapid response and high solution adherence. A mathematical model was used to improve the adherence and guarantee the optimality of the solution and the techniques such as data pre-processing and problem reduction based on business rules were applied to increase the speed of response.
APPLIED INTELLIGENCE FOR PATIENT FLOW
Connecting Accuracy to Business Results

94% global accuracy and .72 F1 score
89 minutes anticipated patient admission

94% allocation in first bed specialty
6% reduction of length of stay

3,28 average length of stay in 2018
## Data Integration

<table>
<thead>
<tr>
<th>Emergency Department</th>
<th>Case Doctor</th>
<th>Image Exams</th>
<th>Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital Signs</td>
<td>Complaints</td>
<td>Blood Tests</td>
<td>ER Vacancy</td>
</tr>
<tr>
<td>Complaints</td>
<td>Prescriptions</td>
<td>Blood Tests</td>
<td>ER Vacancy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient Electronic File</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Comorbidities</td>
</tr>
<tr>
<td>Admissions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hospital Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery Schedule</td>
</tr>
<tr>
<td>Surgery Status</td>
</tr>
<tr>
<td>ER Queue</td>
</tr>
<tr>
<td>Bed Status</td>
</tr>
<tr>
<td>Patient Transport</td>
</tr>
<tr>
<td>Bed Cleaning Status</td>
</tr>
<tr>
<td>Transfers</td>
</tr>
<tr>
<td>Discharges</td>
</tr>
</tbody>
</table>

## Probability of ER Admission Engine

- **Propensity Score**
  - Deep Learning Algorithm based on Recurrent Neural Network

## Optimized Patient Allocation Engine

- **Bed Programming**
  - A Hybrid Optimization Model for bed programming
- **Patient Assignment**
  - Math algorithm based on assignment class solution

## Business Rules and Operational Parameters

<table>
<thead>
<tr>
<th>Bed &amp; Patient Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed Specialty</td>
</tr>
<tr>
<td>Specialty Backup</td>
</tr>
<tr>
<td>Contingency Units</td>
</tr>
<tr>
<td>Bed Case Restrictions</td>
</tr>
<tr>
<td>Transport SLA</td>
</tr>
<tr>
<td>Cleaning SLA</td>
</tr>
<tr>
<td>Transfers SLA</td>
</tr>
<tr>
<td>Bed Leave SLA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Optimization Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor Ranking</td>
</tr>
<tr>
<td>Case Priority</td>
</tr>
<tr>
<td>Entry Door Criticity</td>
</tr>
<tr>
<td>Capacity Balancing</td>
</tr>
<tr>
<td>Planning Horizon</td>
</tr>
<tr>
<td>Contingency Usage</td>
</tr>
<tr>
<td>Bed Waiting Time</td>
</tr>
</tbody>
</table>

## Capacity Control Tower

- Capacity Planning
- Real Time Bed Assignment
- Capacity Real Time Control
- Capacity Control
- Capacity Control
APPLIED INTELLIGENCE FOR PATIENT FLOW

Lessons Learned

1. Manage project with a partnership mindset.
2. Create a multidisciplinary committee with physicians, nurses and support areas representatives.
3. Don’t underestimate the complexity of operational adoption.
4. Reserve enough time for intensive test cycles to fast refine models.
5. Act in favor to a data/analytics mindset.
6. Communicate a new supporting decision tool rather than a replacing decision tool.
7. Create new data collection instruments to enrich your dataset for models’ improvement.
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