MANAGING TRANSFORMING HEALTHCARE PROCESSES in a COMPLEX BIG DATA WORLD

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Who Am I?

- Vice-Dean, Graduate Programs, Faculty of Engineering, uOttawa
- Principal Investigator, Intelligent Data Warehouse Laboratory
- www.create-best.com – Biomedical Smartphone Apps

Previously
- Enterprise BI and BPM - Ottawa, McGill, William Kaiser Hospital (Toronto)
- Startup: ESRI Canada (Ottawa Research Center)
- Startup: ProntoForms (Wesley Clover company)
- Undergrad Software Engineering, 100% COOP
- PhD Electronic Business (Engineering, Telfer, Arts)

Ancient History
- Scandinavia: Krysten Nygaard, Software Engineering
The role of **SECURITY** in *mission critical processes* is to .... **ENABLE** quicker, easier, and more effective access to **DATA** for those actors and systems which depend on it.
The Communication Revolution

- **We are at the beginning** of a third communication revolution that is transforming our world!
  - Electronic Digital Communication (~1960s, Internet, Satellites, Cellular)
  - Written Communication (~3600 BC, http://www.ancient.eu/timeline/writing/)
  - Oral Communication (maybe a million years ago?
    http://www.historyworld.net/wrldhis/PlainTextHistories.asp?historyid=ab13)

- **We are transitioning from the Industrial Age to the Information Age**
  - **Industrial Age** (Automate)
    - mass production: standardization, *repeatable processes*
  - **Information Age** (“Informate” – Big Data)
    - mass customization: constant feedback, *constant change*
Our Big Data World

- Shoshan Zuboff,
  - the duality of information technology as an informating and an automating technology
    https://en.wikipedia.org/wiki/Shoshana_Zuboff
  - Three Laws:
    Everything that can be automated will be automated.
    Everything that can be informated will be informated.
    Every digital application that can be used for surveillance and control will be used for surveillance and control.
Big Data – Original Technical Definition … Evolving

- **High Volume**
  - Terabytes of data
  - Tables/Files
  - Distributed

- **High Velocity**
  - Batch
  - Real/near-time
  - Processes
  - Streams

- **High Variety**
  - Structured
  - Unstructured
  - Semi-Structured

Variability !!!
My Current Favorite Definition of Complex Big Data

7V'S FOR BIG DATA SUCCESS

- Value
- Visualisation
- Volume
- Variety
- Velocity
- Veracity

Organizational: Focused on informating
Technical: Focus on automating

Variability (constant change) replaced by Vision (transformational change)!

See article by Vit Soupal at https://www.linkedin.com/pulse/7vs-successful-big-data-project-vit-soupal

**Variability (constant change) replaced by Vision (transformational change)! 😊**
Transforming Care Processes in a Complex Data World
(Intromat Project – Bergen, Norway)

- Devices
- Apps
- Processes
  - Data
  - Architecture
- Patients
- Providers
- Dashboard
  - Organization
  - Region
  - Norway
  - Goals
  - Indicators

Online Community – Knowledge Transfer - Innovation
Policy Regulation – Advocate – Accommodate - Change
Some Projects

- Cloud Hosted Performance Management for Community Care
  - Architecture, Indicators, Dashboard

- Toronto: Cardiac Care Performance Monitoring Dashboard
  - Process, Architecture, Goals, Indicators, Dashboard

- Application Meta-Model of Care Process Monitoring
  - Data Architecture (sort of)

- Norway Intromat Project: Schizofreni Process Mining
  - Reverse Engineering a data model of care process
A Cloud-based Surveillance and Performance Management Architecture for Community Healthcare

Benjamin Eze, PhD Thesis, 2019
Champlain region has a population of about 1.2 million.

Champlain LHIN takes care of about 60,000 patients annually.

Patients receive over 2 dozen community healthcare services through the LHIN and 54 Community Support Services (CSS) Agencies.

CSS Agencies are small community healthcare organizations with an active patient population ranging from a few hundred up to 10,000, with limited budgets and small self-managed ad-hoc IT systems.

Each agency has its own data silo

Results in service duplication, limited coordination of care delivery
Community Care Services

Community Care Programs/Services

- Personal Support Services
- Nursing Services
- Hospitalization
- Occupational Therapy
- Adult Day Program
- Assisted Living Services
- Attendant Care
- Community Hospice
- Bereavement
- Crisis Intervention
- Friendly Visits
- Meals on Wheels Transportation
- Support for Caregivers
- Service Arrangement
Current State of Performance Management
Ad Hoc, Incomplete, Manually-Intensive Reports

Agency Financial Officers

Agency-1
Agency-2
Agency-n

Agency Specific Adhoc Billing Invoices

CHCD
Business Intelligence Officers
Financial Officers
Billing summary Database

Agency Management

Limited Ad Hoc Report Requests (Excel)

Agency-1
Agency-2
Agency-n

Cloud-based Performance Management of Community Services
Options Evaluated

- **Option 1**
  - Have each agency implement a data push protocol standard like HL7 CDA or openEHR.

- **Option 2**
  - Implement the same Community Care Information System (CCIS) for all agencies using a Software-as-a-Service (SaaS) application.

- **Option 3**
  - Cloud-based Systematic Hosting Service that supports both organizational autonomy by providing data separation but with zero maintenance or support skills by agency staffs.
- Organization consent has local significance for each incoming data stream.
- Patient consent can be global, local (specific to organization), or partial (apply to select data entities and attributes).
- DI = Deterministic Identifier, QI = Quasi-identifier, SA = Sensitive Attribute
Privacy Compliance Definition Document

- Privacy Compliance Definition Document is the anonymization configuration for Performance Management Services.
- Anonymization is applied to data based on the report recipient.
- Ensures external stakeholders receive only anonymized data while participating stakeholders received data sets with partial anonymization (based on patient consent).

**Anonymization Settings**

- **Entities/Attributes**
  - ApplyTo {All|Non-Consenting}
  - Risk Level {Low|Medium|High}
  - Approach for DIs {Mask|Suppress}
  - Approach for QIs {Generalize|Suppress}
  - Approach for SA {Date Shifting|Suppress}

- **CDM Entities**

  - **Privacy Settings on Attributes**
    - Name
    - Type {DI, QI, SA}
    - Meta {Anonymization Label}
Preliminary Results

- 48 of 54 CSS with 150k patients are cloud-hosted.
- 17 agencies, with over 30k patients, have signed the DSA
- Nightly data collection and aggregation across the operational databases.
- Follows an all-or-nothing approach to patient consent
- Nightly patient identity matching and progressing clustering of patient profiles
- 25k patients have matches
- 3k patients have possible matches
- 8 active report subscriptions for LHIN and CSS managers
Enterprise Architecture for
Model-Driven Clinical Operations Management in Value-Based Hospitals
Transformation From “Fee for Service” to Value-Based Hospitals

Fee for Service

Vertical
Provider-focused “Silos”

Vs

Quality of Care SLA

Horizontal Patient-focused Service Lines
Information Systems for Clinical Operations Management
Silos vs Service Lines
Quality Based Procedure (Ministry of Health, Ontario, Canada)

Acute Coronary Syndrome

**Figure 6: Pathway for NSTEMI/UA**

ACS (NSTEMI/Unstable Angina) Pathway

1. Cath Only
   - Cardiac ward or CICU
   - Inter-facility transfer
   - EMS, walk-in, or inter-facility transfer
   - Admit to cardiac ward or CICU
   - Admit through hospital ED
   - No: Non-invasive ischemic testing and/or coronary CTA
   - Invasive cardiac testing?
   - Yes: Send to cath lab for procedure
   - No: Positive test?
   - Cardiac ward or CICU
   - Observation

2. SS PCI
   - Inter-facility transfer
   - PCI
   - Invasive cardiac testing?
   - Yes
   - Cardiac ward or CICU
   - Observation

3. Scheduled PCI
   - CABG
   - PCI or CABG?
   - CICU
   - Isolated CABG Pathway
   - Other intervention?
   - Cardiac ward
   - Step-down

Legend
- Process
- Decision
- Location
- Procedure
- Other Pathway
- Standard
- Alternate

1. Cath Only – with or without FFR/IVUS/OCT
2. Same Sitting PCI (SSPCI) – with or without FFR/IVUS/OCT
3. Scheduled PCI (includes staged PCI) – with or without FFR/IVUS/OCT
   a. Patient may be admitted directly to CICU or ward depending on hemodynamic status. A patient who requires immediate further testing is emergent, has unclear diagnosis, or has undetermined severity of disease.
   b. Patient receives non-invasive ischemic testing, medical management, or coronary CTA and cath with or without PCI.
   c. Patient receives non-invasive ischemic testing or coronary CTA Only.
   d. Scheduled PCI are NSTEMI/UA inpatients or transferred from other hospital. Outpatients are reclassified.***
   e. Patient may require CABG after cath or PCI; delayed PCI or medical management after cath.
   f. An event is any cath/PCI with heart failure, cardiac arrest, cardiac tamponade, transfusion for bleeding, etc.; with or without IABP*, ventilator, inotropes, temp poorly, mechanical circulatory support, dialysis, etc.

***IMPORTANT: The NSTEMI/UA patients who are discharged home with arrangements for an outpatient scheduled/staged PCI should be reclassified as stable angina patients.

* CICU = Cardiac Intensive Care Unit; IABP = Intra-Aortic Balloon Pump
Cardiac Care Process
Business Process Model Notation (BPMN) – IBM BPM

GOAL: Ensure PCI Operation Performed within 90 minutes of heart attack
BPM, RTLSS, Dashboarding

- BPM
- RTLS
- Other Systems
- Test Console

Message Broker

CEP

State Monitor Engine

Real-Time Dashboard

Historical Performance Reporting

DataWare House

Event Log, Current State, Alerts, Metrics
Model into 3 Layers: Organizational, Processes, Systems

Organizational Layer

- Bottlenecks, quality issues happen at handoffs across organizational boundaries
Integrate Monitoring into Processes Layer

- Horizontal “Swim lanes” for different roles
- Vertical swim lanes to identify states
### Monitoring Patient Progress (with targets)

<table>
<thead>
<tr>
<th>State</th>
<th>Start Time</th>
<th>End Time</th>
<th>Duration (mins)</th>
<th>Target (mins)</th>
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<td>15</td>
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<td>N/A</td>
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<td>IN_PHYS_RE_ASSESS</td>
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<td>2013-03-02 10:12:00.0</td>
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<td>2013-03-02 10:00:00.0</td>
<td>20</td>
<td>30</td>
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<td>WAIT_FOR_ORDERS_EXECUTION</td>
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<td>2013-03-02 09:40:00.0</td>
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<td>30</td>
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<td>IN_BED_ED</td>
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<td>2013-03-02 08:19:00.0</td>
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<tr>
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<td>2013-03-02 08:15:00.0</td>
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<td>N/A</td>
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<tr>
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<td>2</td>
<td>30</td>
</tr>
<tr>
<td>TRIAGED</td>
<td>2013-03-02 08:08:00.0</td>
<td>2013-03-02 08:10:00.0</td>
<td>2</td>
<td>30</td>
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</table>

Showing 1 to 12 of 12 entries

**Overall Duration:** 3 hours 1 mins
Care Process
Near Real-Time Dashboard

<table>
<thead>
<tr>
<th>State Name</th>
<th>Average State Duration</th>
<th>Target Duration</th>
</tr>
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<tbody>
<tr>
<td>Trigged</td>
<td>9 minutes</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Wait For Physician Initial Assessment</td>
<td>20 minutes</td>
<td>30 minutes</td>
</tr>
<tr>
<td>In Patient Initial Assessment</td>
<td>14 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>In Bed ED</td>
<td>6 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Orders Execution</td>
<td>57 minutes</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Wait For Physician Re-Assessment</td>
<td>22 minutes</td>
<td>30 minutes</td>
</tr>
<tr>
<td>In Patient Re-Assessment</td>
<td>21 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Bed CW</td>
<td>10 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Transport CW</td>
<td>14 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>In Transport CW</td>
<td>12 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>In Bed CW</td>
<td>32 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Procedures</td>
<td>54 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Transport CCL</td>
<td>16 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>In Transport CCL</td>
<td>11 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>In Bed CCL</td>
<td>21 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>In Procedure Angiogram</td>
<td>46 minutes</td>
<td>45 minutes</td>
</tr>
<tr>
<td>In Procedure PCI</td>
<td>48 minutes</td>
<td>1 hour 30 minutes</td>
</tr>
<tr>
<td>In Consultation 3</td>
<td>21 minutes</td>
<td>0 minutes</td>
</tr>
<tr>
<td>Wait For Discharge</td>
<td>2 hours 3 minutes</td>
<td>0 minutes</td>
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</tbody>
</table>
Nurse Prioritized Task Based Report

Open Tasks

- Overdue (1)
  - Task: Patient arrival at ED
    - Due: January 17, 2015 3:29 AM
    - Assigned to ED Nurse
  - Task: Patient triage
    - Due: January 17, 2015 7:54 PM
    - Welcome the Patient: tom, null

- At Risk (1)

- Due Today (2)
  - Task: Patient arrival at ED
    - Due: January 17, 2015 7:50 PM
    - Assigned to ED Nurse
  - Task: Patient arrival at ED
    - Due: January 17, 2015 7:50 PM
    - New Patient Visit: 1877

Showing 4 of approximately 4 results
Process Status Based Report (Bottle Necks)
Intromat Project
https://intromat.no/

INTROMAT (INtroducing personalized TReatment Of Mental health problems using AdaptiveTechnology)

Appointed by The Norwegian Research Council as one of three projects chosen in their IKTPLUSS Lighthouse call.

Improve public mental health with innovative ICT.
INTROMAT Investigation: Reverse engineering a care process
Mental Health: Schizophreni

- **Existing data**
  - Hospital wide database of patient encounters used for billing events 2005-2015
  - Psychiatry specific database of more detailed care data 2005-2015 including blood samples, medications, demographics etc.

- **New Technology – Process Mining**
  - Analyzes sequences of events to identify process patterns
  - Used to identify bottlenecks, quality control issues
  - Could it be used to understand and characterize schizophrenia care?
  - Could the insights be used to reduce relapse episodes requiring acute care intervention
  - Could it be used to meet government mandated SLA agreements?

- **Approach**
  - Extract hospital Consult Events: Enter Unit, Diagnosis Procedure, Exit Unit
  - If analysis shows promise, extend to include Psychiatry database
High level view of Hospital Process
Filter on Schizophreni Diagnosis code F203 (34 encounters) Shows a Cluster of Companion Alcohol Diagnosis F1026 (12)
**Frequency of Activities (Unit, Diagnosis, Procedure) for the 6 Schizofreni Diagnosis Codes**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
<th>Relative Frequency</th>
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<tbody>
<tr>
<td>F10:F1026</td>
<td>12</td>
<td>8.70%</td>
</tr>
<tr>
<td>M:OAAB00</td>
<td>9</td>
<td>1.31%</td>
</tr>
<tr>
<td>M:IBE00</td>
<td>11</td>
<td>13.92%</td>
</tr>
<tr>
<td>M:IBDC00</td>
<td>23</td>
<td>17.39%</td>
</tr>
<tr>
<td>M:OBAA00</td>
<td>76</td>
<td>11.03%</td>
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<td>M:OBAB00</td>
<td>62</td>
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<td>1</td>
<td>0.17%</td>
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<tr>
<td>M:IBDC00</td>
<td>62</td>
<td>9.0%</td>
</tr>
<tr>
<td>M:OBAA00</td>
<td>10</td>
<td>1.45%</td>
</tr>
<tr>
<td>M:IBDC00</td>
<td>52</td>
<td>7.55%</td>
</tr>
<tr>
<td>M:OBAA00</td>
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<td>0.29%</td>
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<tr>
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<td>M:OBAA00</td>
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<td>M:IBDC00</td>
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<tr>
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</tr>
<tr>
<td>M:OBAA00</td>
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<td>0.29%</td>
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</table>

Alcohol Addiction: M:OBAA00, M:IBDC00
Opioid Addiction: F10:F1122
Depression Episode: M:OBAA00
Cannabis: F12:F1121
Most Common Schizofreni Diagnosis Code (161) with Opiod Cluster (10)
Resource Usage: Pyscheducative Training for Alcohol and Cannabis only?

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<th>Resource</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>Entry</td>
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<tr>
<td>Schizofreni</td>
<td></td>
<td></td>
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<tr>
<td>Exit</td>
<td></td>
<td></td>
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<tr>
<td>Psykiske lidelser og atferdssfi</td>
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<tr>
<td>Mestringsorientert samtale</td>
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- **Psykoedukativ behandling**: 6 (4.33%)
- **Psykoedukativ behandling**: 11 (13.92%)
- **Psykoedukativ behandling**: 1 (0.15%)

### Additional Resources

- Resource F203.csv
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<td>24.64%</td>
</tr>
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<td>Psykiske lidelser og atferdssfi</td>
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<td>8.70%</td>
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<tr>
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<td>6.52%</td>
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  | **Psykoedukativ behandling**: 6 (4.33%)
  | **Psykoedukativ behandling**: 11 (13.92%)

- Resource F208.csv
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<td>Bipolar affektiv lidelse</td>
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<td>Prosedyre rettet mot en gruppe</td>
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<td>Andre symptomer og tegn med</td>
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<td><strong>Structured kartlegging av psyki</strong></td>
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<td><strong>Structured kartlegging av kogni</strong></td>
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<tr>
<td>Exit</td>
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  | **Psykoedukativ behandling**: 5 (3.80%)
  | **Psykoedukativ behandling**: 11 (13.92%)

- Resource F2009.csv
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<tr>
<td>Entry</td>
<td>52</td>
<td>33.33%</td>
</tr>
<tr>
<td>Schizofreni</td>
<td>52</td>
<td>33.33%</td>
</tr>
<tr>
<td>Exit</td>
<td>52</td>
<td>33.33%</td>
</tr>
</tbody>
</table>

- Resource F200.csv
<table>
<thead>
<tr>
<th>Resource</th>
<th>Frequency</th>
<th>Relative frequency</th>
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<td>Entry</td>
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<tr>
<td>Mestringsorientert samtale</td>
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</tr>
<tr>
<td>Psykiske lidelser og atferdssfi</td>
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<td>1.45%</td>
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<tr>
<td>Kognitiv terapi</td>
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<tr>
<td>AnsvarsgropemÅ® te</td>
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<td>0.73%</td>
</tr>
<tr>
<td>Gjennomgripende utviklingsf</td>
<td>4</td>
<td>0.58%</td>
</tr>
<tr>
<td>Intramuskulær injeksjon av</td>
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<td>0.58%</td>
</tr>
<tr>
<td>Behandlingsplan</td>
<td>3</td>
<td>0.44%</td>
</tr>
<tr>
<td>Individuell rÅ¥dighet i fore</td>
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<td>0.44%</td>
</tr>
<tr>
<td>Spiseforstyrrelser</td>
<td>2</td>
<td>0.29%</td>
</tr>
<tr>
<td>Systematisk intervju om psyk</td>
<td>1</td>
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</tr>
<tr>
<td>Strukturerd kartlegging av psyk</td>
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</tr>
<tr>
<td>Vurdering av selvmedssfare</td>
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</tr>
<tr>
<td>Systematisk kartlegging av so</td>
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<tr>
<td>Evaluering av behandlingspl</td>
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<tr>
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<td>IBG00</td>
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<tr>
<td>Motivende intervju/endr.</td>
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<td>0.15%</td>
</tr>
<tr>
<td>Schizotop lidelse</td>
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<td>0.15%</td>
</tr>
</tbody>
</table>
Measures Number of Events per Patient and Duration
Co-Morbidity not high frequency but Cannabis long duration

<table>
<thead>
<tr>
<th>Case ID</th>
<th>Events</th>
<th>Variant</th>
<th>Started</th>
<th>Finished</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>193EB0685CC9</td>
<td>79</td>
<td>Variant 1</td>
<td>11.10.2011 24.04.2017 14:00:00</td>
<td>193 days, 1.67E+10</td>
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<tr>
<td>02021C4F</td>
<td>156</td>
<td>Variant 1</td>
<td>27.04.2017 14:30:00</td>
<td>106 days, 9.17E+09</td>
<td></td>
</tr>
</tbody>
</table>

Cannabis
Next Steps

- **Understand and Pre-Process Data Better**
  - Consults with Epicrisis (not all Patient Activity as one event stream)
  - Define relapse episode
  - Adjust filters to right mix of events, consults

- **Process mining Community**
  - [https://fluxicon.com/disco/](https://fluxicon.com/disco/)
  - [http://www.processmining.org/](http://www.processmining.org/)
  - [http://www.padsweb.rwth-aachen.de/wvdaalst/](http://www.padsweb.rwth-aachen.de/wvdaalst/)

- **Provide additional tool support** for dimensional analysis, clustering, and anomaly detection (demographics, medications, blood work etc.)

- Define consensus on core process steps and SLA and Indicators (**Dashboard**)

- Extend to other mental health (depression, anxiety, ADHD, …)