# Challenges and Strategies in Analysis of Administrative Health Data

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# Outline

1. Introduction

2. Large Administrative Health Data Analysis

3. Final Remarks

# 1.1 Introduction: Large Administrative Health Data

- **Readily Available**
  - Canadian Provincial Medical Insurance Databases (*Canadian Health Care System: Universally Accessible, Government-Sponsored*)
  - Disease/Patient Registries: e.g. BC Cancer Registry
  - Vital Statistics: e.g. BC Vital Statistics
  - Various EHRs (electronic health records): e.g. Lab Test Results
  - Recent Administrative Records of Covid-19 Infection

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  - Various EHRs (electronic health records): e.g. Lab Test Results
  - Recent Administrative Records of Covid-19 Infection
- **Lots of Information**
  - Affordable to be looked at (analyzed) from *different* perspectives, and answer *various* questions

$\Longrightarrow$ **Many attempts to use such data to achieve particular aims**

# 1.1 Introduction: Large Administrative Health Data

**Challenges?**

- *Large!* BigData issues
  e.g. large in size and/or many variables

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**Challenges?**

- *Large!* BigData issues
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- *Administrative*
  - **not collected/recorded to serve a particular research purpose**: Required to plan carefully for data extraction and analysis formulation
    e.g. what time origin to use?
  - **incomplete/imperfect data**: Available data are not in the ideal format
    e.g. information only available on a target population within a time window: *left- and/or right-censoring; truncation; measurement error/misclassification*

# 1.2. Examples of Large Administrative Health Data Based Research Programs

**Example 1.** Cancer Survivorship Research Program, BC Cancer Agency (BCCA), Canada (Phase I: 2004 - 2018, PI: *Mary McBride*; Phase II: 2019 - present, PI: *Stuart Peacock*)

- Started from the Childhood, Adolescent, Young Adult Cancer (CAYACS) Survivorship Program: risk classification, assessment, and prediction
- A longitudinal cohort study to examine long-term effect resulted from cancer, using linked data from the *BC Health Insurance* (MSP) and the *BC Cancer Registry*: e.g. hospitalization records, physician claims, diagnoses of other diseases

# 1.2. Examples of Large Administrative Health Data Based Research Programs

**Example 2.** Health Service Provided by Emergency Department (ED), University of Alberta, Canada (2009 - present; PI: *Rhonda Rosychuk*)

- Started with records of mental health (MH) related ED presentations by Alberta residents younger than 18 year-old, from the *Ambulatory Care Classification System* (ACCS, Alberta Health and Wellness)
- Having been expanded to include data from the *Dynamic Cohort of Complex, High System Users* developed by the *Canadian Institute for Health Information* (CIHI)

# 1.2. Examples of Large Administrative Health Data Based Research Programs

**Example 3.** Clinical Management of Opioid Use Disorder (OUD), BC Centre for Excellence in HIV/AIDS, Canada (2018 - present; PI: *Bohdan Nosyk*)

- Using seven linked population-level administrative databases: *BC Health Insurance*, *Discharge Abstract Database*, *PharmaNet*, *BC Corrections*, *Vital Statistics*, *National Ambulatory Care Reporting System* (NACRS), and *Perinatal Database*

- Aiming to emulate target trials to strengthen the evidence base for clinical management

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*Ying (MSc 2006); Ma (MSc 2009); Wang (MSc 2012, PhD 2015); Zhao (PhD 2009); Li (PhD 2019)*

**Example 2.** Health Service Provided by Emergency Department (ED), University of Alberta, Canada (2009 - present; PI: Rhonda Rosychuk)

*Wang (MSc 2014); Thiessen (MSc 2020); Cui (Postdoc 2020); Xiong (Postdoc 2021); Chen (PhD 202x)*

**Example 3.** Clinical Management of Opioid Use Disorder (OUD), BC Centre for Excellence in HIV/AIDS, Canada (2018 - present; PI: Bohdan Nosyk)

*Kurz (MSc 2020); Thomson (PhD 202x)*

$\Longrightarrow$ **The administrative health data have generated many interesting statistical problems.**

# 1.2. Examples of Large Administrative Health Data Based Research Programs

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$\Longrightarrow$ **To motivate and illustrate the following presentation**

# 2. An Example for Analyses of Pediatric Mental Health Emergency Department (MHED) Visit Records

**2.1 Formulation: Recurrent Events Data**

**2.2 Regression Analysis with Doubly-censored Data**

**2.3 Regression Analysis with Truncated Data**

**2.4 Analysis Outcomes**

*PMHC Program Based on Emergency Department Visits (2009 - present; PI: Rhonda Rosychuk)*

**Goal**. To assess the need for pediatric mental health care and to improve the care system.

**Data**. Extracted from the Ambulatory Care Classification System (ACCS), a large, population-based database in Alberta, Canada, initiated in 1999 by the provincial health ministry.

**Specific Aims**.

- ... ...
- to evaluate frequency of children and youth's MHED visits
- to examine effects of risk factors/exposures, and identify important covariates and temporal changes
- ... ...

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- ... ...
- to evaluate frequency of children and youth's MHED visits
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$\Longrightarrow$ **Quick reaction: to conduct analysis of recurrent events**

# Available information to the PMHC Program?

The MHED data maintained at Rhonda Rosychuk's lab were extracted from *Alberta Health Care Insurance Plan*, including

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- Each record includes
  - starting/ending date, time; age (in year) at service
  - triage level; discharge disposition
  - sex; pSES; residence region
  - birthdate if from April 1 2010 - March 31 2017

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**How to summarize/process the data to achieve the aims?**

# 2.1 Formulation of Alberta Pediatric MHED Visits

Consider the individuals with MHED records as *study units* … …

Subject $i$:

- $N_i(t)$ – the cumulative count of the MHED visits upto time $t$
- $Z_i(t)$ – potential covariates at $t$

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*Questions* before a meaningful statistical analysis ...

- What is an appropriate time?
- What is $Z_i(\cdot)$ to consider?
- What model to assume: it's appropriate; inference on it is meaningful and feasible to make with the current data?

## 2.1A Formulation of Alberta Pediatric MHED Visits

To *begin* with, **what information is available?**

- Focus on the individuals with MHED records, $i = 1, \ldots, n$
- Assume the individuals are independent
- Consider only external time-independent covariates

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- Focus on the individuals with MHED records, $i = 1, \ldots, n$
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For Subject $i$, consider *age* as the individual time:

- $N_i(a), a > 0$: the cumulative count of Subject $i$'s MHED visits since birth at age $a > 0$
- $Z_i$: all the time-indpt covariates of interest

# 2.1A Formulation of Alberta Pediatric MHED Visits

Further ...

- The data extraction window in the calendar time: $[W_L, W_R]$
- The information available on Subject $i$ is over the window in age: $(C_{Li}, C_{Ri})$
  - $C_{Li} = \max(0, W_L - B_i), C_{Ri} = \min(18, W_R - B_i)$, birthdate $B_i$
- Available is the calendar time of Subject $i$'s $j$th recorded ED visit $(T_{ij})$ but the age $A_{ij} = T_{ij} - B_i$ is recorded in years.

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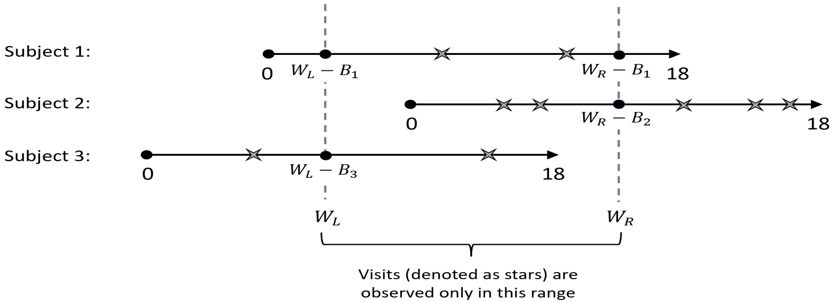

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**Provided all $B_i$ available**, the available data are *doubly-censored*:

$$\bigcup_{i \in \mathcal{O}_1} \left[ \left\{ dN_i(a) : a \in (C_{Li}, C_{Ri}] \right\}; Z_i \right]$$

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**If $B_i$ unavailable?** the available data are *doubly-censored with missing/coarsened censoring time*:

- $C_{Li} = \max(0, W_L - ???), C_{Ri} = \min(18, W_R - ???)$

# 2.1B Formulation of Alberta Pediatric MHED Visits

Note that study subjects associated with the PMHC database form a sample ($\mathcal{O}_1$) from a *biased* sub-population ($\mathcal{P}_1$) of the general population ($\mathcal{P}$), a sample of which the Alberta residents under 18-year-old during 2002-2017 form ($\mathcal{O}$).

- The available MHED visits are *truncated data* when $\mathcal{P}$ is targeted.

*How to make inference with the data?*

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*How to make inference with the data?*

Instead of modeling the truncation, following Hu and Lawless (1996),

- to use the available information on $\mathcal{O}_0 = \mathcal{O} \setminus \mathcal{O}_1$: subjects in $\mathcal{O}_0$ did not experience any MHED during 2002-2017

$$\left[ \bigcup_{i \in \mathcal{O}_1} \left[ \{ dN_i(a) : a \in (C_{Li}, C_{Ri}] \}; Z_i \right] \right] \bigcup \left[ \bigcup_{i \in \mathcal{O}_0} \{ dN_i(a) = 0 : a \in (C_{Li}, C_{Ri}] \} \right]$$

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- to integrate with the available demograhic information (on $Z$) of $\mathcal{O}$.

## 2.1C Formulation: A Two-sample Problem

*To explore temporal changes in frequency of children and youth's MHED visits and the associated effects of risk factors/exposures,* $\Longrightarrow$

**Focus on comparisons of MHED visits 2002-2010 (early decade)) vs MHED visits 2010-2017 (late decade)** via

- (i) the *doubly-censored* recurrent events data in §2.2, targeting on $\mathcal{P}_1$;
- (ii) the *truncated* recurrent events data integrated with population based demographic information in §2.3, targeting on $\mathcal{P}$;

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- (ii) the *truncated* recurrent events data integrated with population based demographic information in §2.3, targeting on $\mathcal{P}$;

For Subject $i \in \mathcal{P}^*$ (the target population), assume a marginal model (cf: Hu and Rosychuk, 2016):

$$E[dN_i(a)|Z_i, X_i] = exp\{\alpha(a)X_i + \beta'(a)Z_i + \gamma'(a)Z_iX_i\}d\Lambda_0(a),$$

$X_i$ is the indicator of Subject $i$ from late decade.

For Subject $i \in \mathcal{P}^*$ (the target population),

$$E[dN_i(a)|Z_i, X_i] = exp\{\alpha(a)X_i + \beta'(a)Z_i + \gamma'(a)Z_iX_i\}d\Lambda_0(a), \quad (1)$$

$X_i$ is the indicator of Subject $i$ from late decade.

**Remarks:**

- Model (1) is equivalent to

$$E[dN_i(a)|Z_i, X_i] = \begin{cases} \exp\{\beta_E'(a)Z_i\}d\Lambda_{0E}(a), & i \text{ with early decade} \\ \exp\{\beta_L'(a)Z_i\}d\Lambda_{0L}(a), & i \text{ with late decade} \end{cases}$$

  $\beta_E(a) = \beta(a)$, $\Lambda_{0E}(a) = \Lambda_0(a)$, $\beta_L(a) = \beta(a) + \gamma(a)$, and $d\Lambda_{0L}(a) = exp(\alpha(a))d\Lambda_0(a)$.

For Subject $i \in \mathcal{P}^*$ (the target population),

$$E[dN_i(a)|Z_i, X_i] = exp\{\alpha(a)X_i + \beta'(a)Z_i + \gamma'(a)Z_iX_i\}d\Lambda_0(a), \quad (1)$$

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- We may choose to consider different specifications of Model (1): e.g. Model CCC is $\alpha(a) \equiv \alpha$, $\beta(a) \equiv \beta$, $\gamma(a) \equiv \gamma \Longrightarrow$ the proportional mean/rate (Andersen and Gill) model.

## 2.2 Analysis of Doubly-censored Recurrent Events Data with $\mathcal{P}^* = \mathcal{P}_1$

Provided available birthdates and independent subjects, consider the estimating functions under Model (1): for $a \in [\tau_L, \tau_R]$,

$$U(\phi(a); a|\mathbf{B}) = \int_0^{18} K_h(u-a) \sum_{i \in \mathcal{O}_1} Y_i(u|B_i) \left\{ V_i^*(u,a) - \bar{V}^*(\phi(a); u, a) \right\} dN_i(u)$$

$\phi(a) = \left(\theta(a)', \dot{\theta}(a)'\right)'$ with $\theta(\cdot) = \left(\alpha(\cdot), \beta(\cdot)', \gamma(\cdot)'\right)'$; a kernel function $K(\cdot)$;
$V_i^*(u,a) = \left(V_i', (u-a)V_i'\right)'$ with $V_i = (X_i, Z_i', X_i Z_i')'$;
$\bar{V}^*(\phi(a); u, a) = S^{(1)}(\phi(a); u, a)/S^{(0)}(\phi(a); u, a)$ with
$S^{(q)}(\phi(a); u, a) = \sum_{i \in \mathcal{O}_1} Y_i(u) \left[V_i^*(u,a)\right]^q \exp\{\phi(a) V_i^*(u,a)\}$

**Remarks:**

- following Hu and Rosychuk (2016) to accommodate the situations without birthdates by assuming birthdates uniformly distributed over a year.
- checking for the required independence assumption for the two groups.

## 2.3 Analysis of Truncated Recurrent Events Data with $\mathcal{P}^* = \mathcal{P}$

By the available Alberta census information during 2022-2017, consider the estimating functions under Model (1): for $a \in [\tau_L, \tau_R]$,

$$U(\phi(a); a\big|\mathbf{B}) = \int_0^{18} K_h(u-a) \sum_{i \in \mathcal{O}} Y_i(u|B_i) \left\{ V_i^*(u,a) - \tilde{\bar{V}}^*(\phi(a); u, a) \right\} dN_i(u),$$

where $\tilde{\bar{V}}^*(\phi(a); u, a)$ is an approximation to
$\bar{V}^*(\phi(a); u, a) = \frac{\sum_{m \in \mathcal{O}} Y_m(u|B_m) V_m^*(u,a) \exp\{\phi'(a) V_m^*(u,a)\}}{\sum_{m \in \mathcal{O}} Y_m(u|B_m) \exp\{\phi'(a) V_m^*(u,a)\}}$.
$\phi(a) = \left(\theta(a)', \dot{\theta}(a)'\right)'$ with $\theta(\cdot) = \left(\alpha(\cdot), \beta(\cdot)', \gamma(\cdot)'\right)'$, and
$V_i^*(u,a) = \left(V_i', (u-a)V_i'\right)'$ with $V_i = (X_i, Z_i', X_i Z_i')'$.

**Remarks:**

- the approximation by the aggregated population information?
- asymptotic properties of the estimator?

# 2.4 Analysis Outcomes

- Estimates for Time-independent Coefficients

TABLE: Parameter estimates and estimated standard errors of time-independent covariate effects with Model CCC[a] with PMHC data

| | Covariates | wrt $\mathcal{P}_1$ | wrt $\mathcal{P}$ |
|---|---|---|---|
| $\alpha$ | Period | **.282(.020)** | **.605(.020)** |
| | Sex (vs. female) | **-.049(.016)** | **-.414(.016)** |
| $\beta$ | Edmonton (vs. other regions) | **.050(.021)** | **-.225(.019)** |
| | Calgary (vs. other regions) | .003 (.019) | **-.387(.019)** |
| | PeriodSex | **-.058(.023)** | **-.124(.023)** |
| $\gamma$ | PeriodEdmonton | .003(.029) | **-.080(.029)** |
| | PeriodCalgary | .015(.026) | **.196(.026)** |

Model CCC[a]: $E[dN_i(a)|Z_i, X_i] = \exp(\alpha X_i + \beta' Z_i + \gamma' Z_i X_i) d\Lambda_0(a)$.

# 2.4 Analysis Outcomes

- Estimates for Time-independent Coefficients (cont'd)

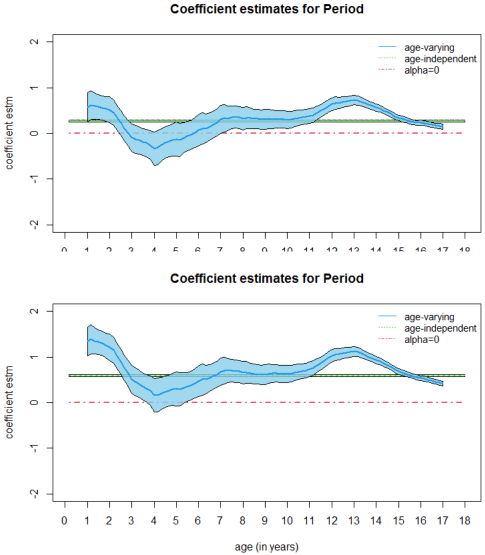
TABLE: Parameter estimates and standard errors for time-independent covariate effects with Model VCC$^b$ with data from the two time periods

| | Covariates | wrt $\mathcal{P}_1$ | wrt $\mathcal{P}$ |
|---|---|---|---|
| $\alpha^*$ | Period | – | – |
| $\beta$ | Sex (vs. female) | **-.049(.016)** | **-.410(.015)** |
| | Edmonton (vs. other regions) | **.051(.021)** | **-.218(.019)** |
| | Calgary (vs. other regions) | .004(.019) | **-.385(.018)** |
| $\gamma$ | PeriodSex | **-.055(.020)** | **-.130(.020)** |
| | PeriodEdmonton | .001(.029) | **-.089(.025)** |
| | PeriodCalgary | .015(.026) | **.198(.022)** |

Model VCC$^b$: $E[dN_i(a)|Z_i, X_i] = \exp(\alpha(a)X_i + \beta' Z_i + \gamma' Z_i X_i) d\Lambda_0(a)$.

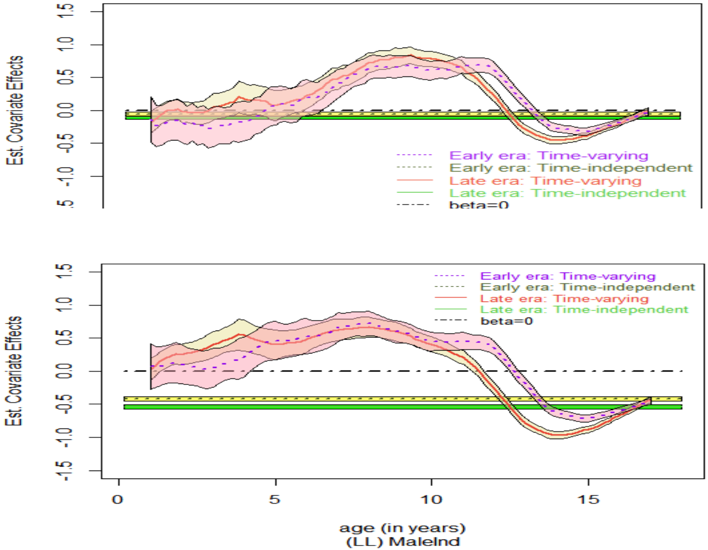
$*$: time-varying model components.

## 2.4 Analysis Outcomes: $\alpha(\cdot)$ Estimates with Models CCC, VVV




**(a) the MHED cohort ($\mathcal{P}^* = \mathcal{P}_1$); (b) the Alberta residents ($\mathcal{P}^* = \mathcal{P}$)**

## 2.4 Analysis Outcomes: Estimates of $\beta_E(\cdot)$ and $\beta_L(\cdot)$ ($Sex$) with Models CCC, VVV – (a) MHED cohort ($\mathcal{P}^* = \mathcal{P}_1$); (b) Alberta residents ($\mathcal{P}^* = \mathcal{P}$)



# 3. Final Remarks: What have we done for the PMHC program?

This project has conducted

- useful summary of the MHED data (from $\mathcal{O}_1$), and then $\mathcal{O}$.
- statistical inference on $\mathcal{P}_1$, and then $\mathcal{P}$ if $\mathcal{O}_1/\mathcal{O}$ forms a random sample.
- What if $\mathcal{O}_1$ or $\mathcal{O}$ is not a random sample of the target population?

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With $\mathcal{D} = \{X_1, \ldots, X_n\}$,

- to calculate the sample mean $\bar{X} = \sum_{i=1}^n X_i \big/ n$ to summarize $\mathcal{D}$.
- If $\mathcal{D}$ is a random sample of the target population $\mathcal{P}$ with mean $\mu$, one may use $\bar{X}$ to estimate $\mu$ and form $\mu$'s (approximate) confidence interval.
- What if not?

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- What if not? e.g. *inverse probability weighted estimator*

# 3. Final Remarks: Whatelse to do for the PMHC program?

*Many interesting issues to further explore:*

- What if $B_i \not\sim$ the uniform distn?
- Use alternative models to the proportional type regression models? e.g. to consider intensity-based modeling
- How to explore and account for spatio-temopral correlation underlying the MHED visits?
- Consider different study units, such as health regions/sub-regions, and calendar time, to explore the visits spatio-temporally?
- … …

# 3. Final Remarks: Large Administrative Health Data

- **Readily Available**
- **Lots of Information**
  - Affordable to be looked at/analyzed from *different* perspectives, to answer *many* interesting questions
- **Challenges = Interesting/Not Boring**
  - *Large!* BigData issues
  - *Administrative!* **not collected/recorded to serve a particular research purpose**
- **To Use Administrative Data**
  - Careful design/plan is required for extraction.
  - When analyzing administrative data,
    - account for their special features appropriately, and
    - **consider to use available additional information**

      $\Rightarrow$ efficient, robust, easy-to-implement procedures

# Acknowledgements


- The key part of the presentation is based on a recent joint work with *R. Rosychuk* (Univ of Alberta) and *Y. Xiong* (Fred Hutchinson Cancer Research Center), sponsored by NSERC and CIHR: Xiong, Hu, and Rosychuk (2022).

- A comment from *Jerry Lawless* on a previous verision of the presentation has led to a big modification of the work.

# Thank-you for the attention!