Understanding Patient Abandonment Behavior in the Emergency Department

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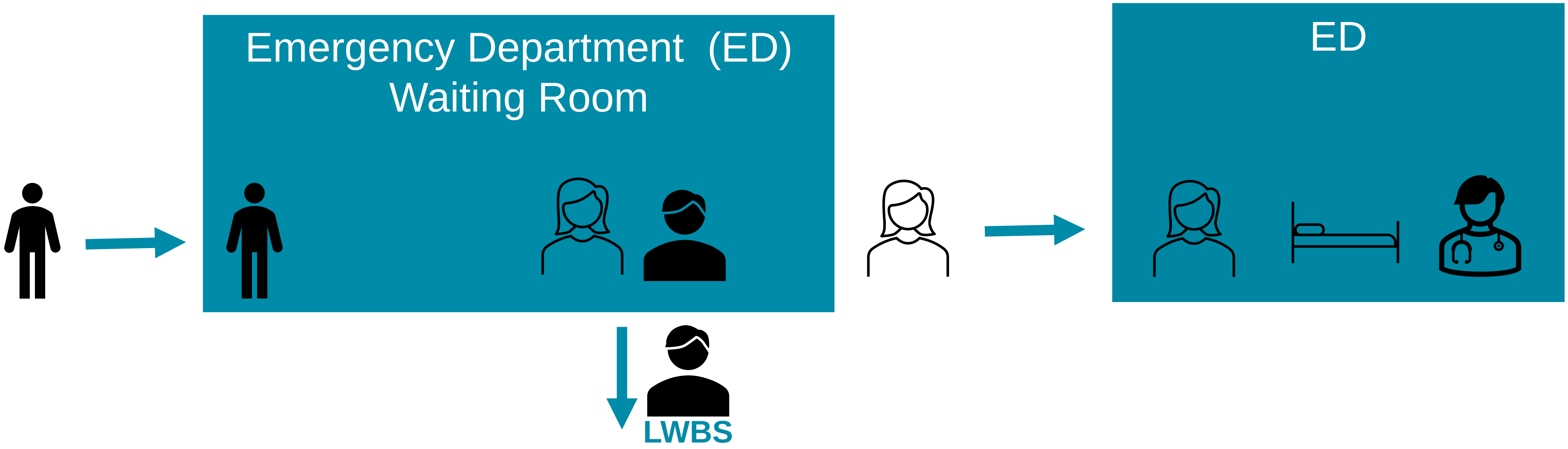
Left Without Being Seen (LWBS)



"It's so common. Management presents us with a metric called LWBS. It's multifactorial, due to problems with nursing flow, ED boarding time, and overall high patient volume. It's a huge operations problem in all EDs…. In many instances, funding for the department is tied to its LWBS rates."

- Emergency Medicine Resident, Yaniv's friend

Why is LWBS a problem?

- "Leaving without being seen by a physician (LWBS), can have serious negative health consequences for patients."[1]

- "Patients who LWBS have different socio-demographic features, methods of accessing the health care system... They are often socially disenfranchised, with limited access to traditional primary care. These patients are generally low acuity, but they are at risk of important and avoidable adverse outcomes."[2]

1 - Bolandifar et al. *Modeling abandonment behavior among patients*. EJOR 2022
2 - Monzon et al. *Patients who leave the emergency department CJEM 2005*

How can we address LWBS from an operational perspective?

- Broad measures
    - Reduce wait times

- Targeted measures
    - Reduce a patient's propensity to leave by changing what *information* they are given.

- Understanding LWBS can be an input for both types.

Research agenda

- **What factors are associated with LWBS?** **Today**
  - Patient characteristics
  - Time of day/Day of week
  - Congestion
    - ***How does observing different <u>event histories</u> affect LWBS?***

] **Static**

] **Dynamic – changes with *<u>events</u>* (arrivals, departure, etc.)**

- **How do patients decide between LWBS and waiting?** **WIP**
  - Assume a behavioral model to describe LWBS decisions.
    - ***Estimate cost and reward parameters. Predict response to various settings.***

- **Improving the ED**
  - Answer counterfactual questions.
    - ***Could LWBS be reduced by changing <u>information / priority / staffing schemes</u>?***

Literature review

- **"Standard" theoretical abandonment models**
  - Palm (1953), Mandelbaum and Shimkin (1999), Whitt (2006), Baron and Milner (2009)
    - ***Assumes every patient has a randomly drawn deadline***
- **Empirical abandonment studies**
  - Batt and Terwiesch (2015), Bolandifar et al. (2022)
    - ***Initial congestion and <u>average</u> rate of events as covariates***
- **Abandonment as the result of utility maximization**
  - Theoretical (e.g, Afèche and Sarhangian (2015)), empirical (structural estimation), Aksin et al. (2016)
    - ***Call-center settings, where events cannot be observed***

Section Summary: Introduction

- LWBS is a major pain-point for EDs
  - Patients' conditions worsen outside of the hospital.
  - ED funding depends on LWBS rates.
- Our understanding of what factors drive LWBS is limited.
  - ***Can we identify these forces and better guide how operational decisions are made?***

Outline

- The Role of Data
- Exploratory Analysis of LWBS
- How Does LWBS Change Over Patients' Wait
- Next Steps

Outline

- **The Role of Data**
    - **What data do we have?**
    - How does RFID help?
- Exploratory Analysis of LWBS
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Important ED setting specifics

- All patients wait in the same waiting room.
- Pediatrics have their own service area.
- There is no fast track.

- Patients observe:
  - Congestion: the number of people in the waiting room.
  - Arrivals and departures.

- Patients do not observe
  - Their own and others condition severities.

Dataset: 150,960 observations

- An observation describes a patient visit.
- Collected over a span of two years.

Temporal characteristics (RFID)

Age	Sex	ESI Level	Arrival Time	Departure Time	Day of Week	Hour of Day	LWBS
45	Male	5	13:30	14:06	Thurs.	13	0 (served)
46	Female	1	14:30	14:40	Thurs.	14	1 (aband.)

Patient data

- Derived variables:

Congestion related

  - In-flow events: arrivals → Higher vs Lower ESI
  - Out-flow events: service, abandonments, *overtakes*

(arrived after me & served before)

Higher vs. Lower ESI

Arrived before vs. after me

Outline

- **The Role of Data**
  - What data do we have?
  - **How does RFID help?**
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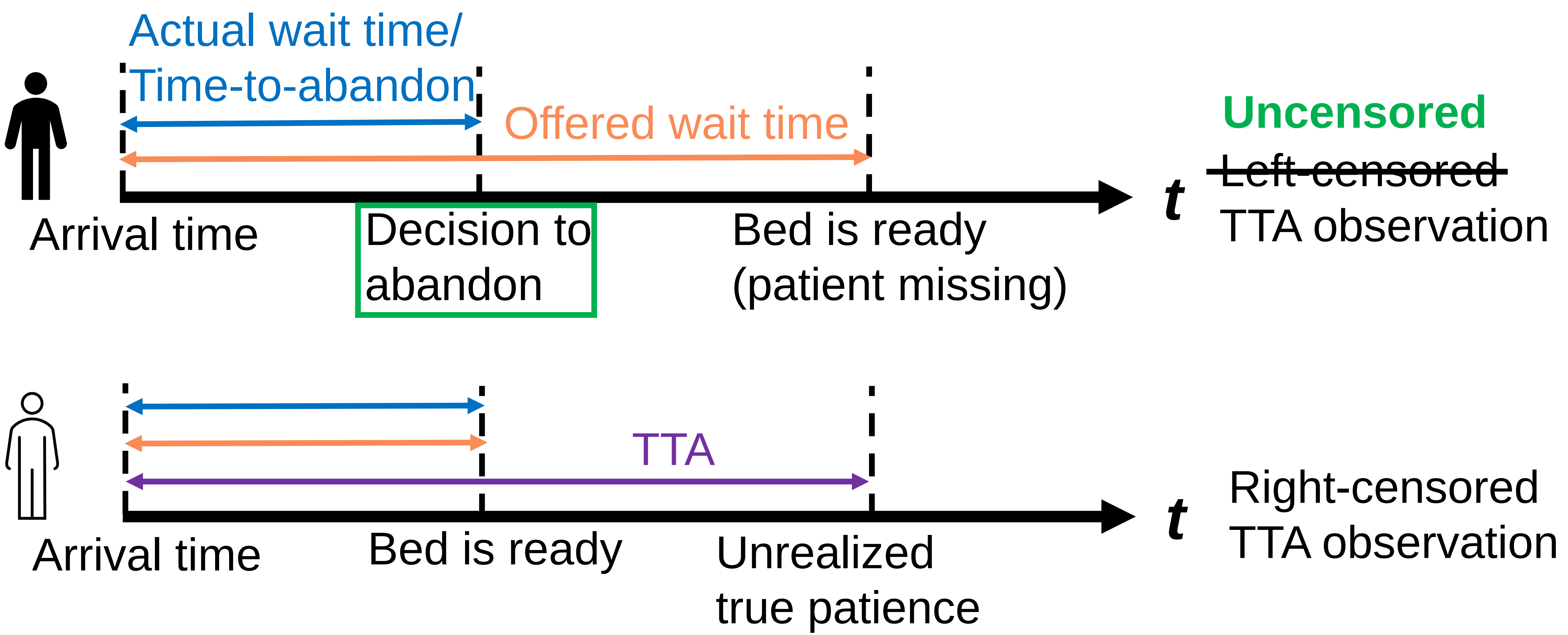
Censoring: endogenous to and random in the ED setting



Accurate event histories

Section Summary: The Role of Data

- 150,960 arrivals into the ED over a two-year span.
  - Age, sex, condition severity, abandonment.
- Precise measurements of when patients enter and leave the waiting room.
  - Real-time congestion can be computed.

Outline

- The Role of Data
- **Exploratory Analysis of LWBS**
  - **Univariate and bivariate descriptive statistics**
- How Does LWBS Change Over Patients' Wait
- Next Steps

Descriptive statistics of abandonment rates

	Min TTA	Mean TTA	Mean Offered Wait	Max TTA
Abandoning Patients	56 seconds	1.6 hours	2.5 hours	6.8 hours

↳ 40 minutes average wait time for served patients

Most severe conditions → (ESI 1)

Least severe conditions → (ESI 5)

ESI	Fraction of data	Abandonment rate
1	2,126 (1.4%)	0%
2	32,098 (21%)	0.7%
3	87,657 (58%)	2.1%
4	27,857 (18%)	4.0%
5	1,129 (0.1%)	6.3%

- **Entire dataset: Only 2.2% of patients abandon!**
- **ESI Levels 4 & 5 adults between 3pm and 9pm: 10.3%!**

Descriptive statistics of abandonment rates

Weekday	Fraction of data	Abandonment rate
Mon	20,874 (13.8%)	2.2%
Tues	21,083 (14.0%)	2.2%
Wed	21,010 (13.9%)	1.4%
Thurs	21,956 (14.5%)	1.7%
Fri	23,125 (15.3%)	3.0%
Sat	21,615 (14.3%)	2.6%
Sun	21,296 (14.1%)	2.1%

Hour of Arrival	Fraction of data	Abandonment rate
0-4	10,065 (6.7%)	1.2%
4-8	12,926 (8.6%)	0.2%
8-12	33,499 (22.2%)	1.0%
12-16	35,706 (23.7%)	2.3%
16-20	36,483 (24.2%)	3.8%
20-0	22,280 (14.8%)	2.6%

Descriptive statistics of abandonment rates

Age	Fraction of data	Abandonment rate
0-17	26,320 (17.4%)	0.3%
18-35	30,187 (20.0%)	4.0%
36-53	29,526 (19.6%)	3.3%
54-71	34,858 (23.1%)	2.0%
72+	30,066 (19.9%)	1.1%

Congestion upon arrival	Fraction of data	Abandonment rate
0-4	79,944 (53.0%)	0.4%
5-9	27,761 (18.4%)	1.8%
10-14	20,778 (13.8%)	4.2%
15+	22,476 (14.9%)	7.3%

Sex	Fraction of data	Abandonment rate
Female	77,035(51.0%)	2.4%
Male	73,922(49.0%)	2.0%

Section Summary: Exploratory Analysis of LWBS

- Groups at higher risk of abandonment:
  - Lower severity patients,
  - Those who arrive in the afternoon and evening,
  - And those who arrive to heavier congestion,
- Patients with age between 18 and 71 abandon at the highest rates.

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Outline

- The Role of Data
- Exploratory Analysis of LWBS
- **How Does LWBS Change Over Patients' Wait**
- Next steps

Time-dependent factors of LWBS

- Condition severity (ESI), patient characteristics (age, sex), temporal factors (hour of arrival, day of the week).
- What about congestion and observed events? ***What is the right event history?***
  - In-flow (arrivals)
    - ***Stratification: by ESI Level, etc.***
  - Out-flow (departures into service, abandonments)
    - ***Stratification: by ESI Level, time of arrival, etc.***
  - ***Temporal aggregation: events that occur in the same 10-minutes, same hour, etc.***
  - ***Stopping: only consider events in the first 30 minutes, 10 hours, etc.***
  - ***Interaction: congestion at the time of the event***
- **E.g.: Congestion measured at arrival and every 30 minutes thereafter, as well as arrivals, abandonments and overtakes observed every 30-minutes after arriving.**

Time-dependent factors of LWBS

- ***What events are associated with patient abandonment?***
  - ***H: in-flows increase the risk of LWBS, out-flows reduce it.***

  - ***Does the response depend on waiting-room congestion?***
    - ***H: the effect is stronger at higher congestion levels.***

  - ***Is the response stronger earlier or later during the wait?***
    - ***H: the effects is stronger at later times during the wait.***

Measuring the risk of abandonment

- Let $T \sim F(\cdot)$ denote the time until abandonment

- Survival function: $S(t) = 1 - F(t) = P(T > t)$

- Hazard function: $h(t) = -\frac{S'(t)}{S(t)}$

- Proportional hazard model (given features x): $h(t|x) = h_0(t)\exp(\beta^T x)$

The estimated model

- Time-dependent survival model:

$$h(t|x(t)) = h_0(t) \exp\left[\beta_1^T X + \beta_2 c(t) + \sum_{k=1}^{K} \beta_{3k} c_k(t) + \sum_{flow} \sum_{k=1}^{K} \left(\beta_{4k}^{flow} R_k^{flow}(t) + \beta_{5k}^{flow} c_k(t) R_k^{flow}(t)\right)\right]$$

Patient & **Temporal** **features**

- Divide patient's wait into *K* intervals:
  - Measure the level of congestion at the onset of each interval
  - Measure the rate of each event during the interval
  - Account for the interaction of these two factors

Focus on patients of higher severity: ESI Level 3

- Aggregate events across all ESI Level.
- Consider those **who waited at least 30 minutes.**
- Divide each patient's wait into 30-minute intervals.
- Focus on the first 4 intervals (2 hours)

- ***How does observing an additional arrival between the 30th and 60th minutes of waiting affect the risk of LWBS?***

List of covariates:

Congestion

CongestionInitial
Congestion
Congestion1
Congestion2
Congestion3
Congestion4

patients waiting at the onset of the 1st, 2nd, 3rd, 4th 30-minute interval of waiting

Observed Events

AbandsRate1	AbandsRate1xCongestion1
AbandsRate2	AbandsRate2xCongestion2
AbandsRate3	AbandsRate3xCongestion3
AbandsRate4	AbandsRate4xCongestion4
ArrivalsRate1	ArrivalsRate1xCongestion1
ArrivalsRate2	ArrivalsRate2xCongestion2
ArrivalsRate3	ArrivalsRate3xCongestion3
ArrivalsRate4	ArrivalsRate4xCongestion4
DepartureRate1	DepartureRate1xCongestion1
DepartureRate2	DepartureRate2xCongestion2
DepartureRate3	DepartureRate3xCongestion3
DepartureRate4	DepartureRate4xCongestion4
OvertakeRate1	OvertakeRate1xCongestion1
OvertakeRate2	OvertakeRate2xCongestion2
OvertakeRate3	OvertakeRate3xCongestion3
OvertakeRate4	OvertakeRate4xCongestion4

Patient and Temporal Features

Age
Sex
Time0-4
Time12-16
Time20-24
Time4-8
Time8-12
Weekend
WeekendxTime0-4
WeekendxTime12-16
WeekendxTime20-24
WeekendxTime4-8
WeekendxTime8-12

Time-dependent factors of LWBS: Arrivals

- ***H: arrivals increase the risk.***
  - At congestion = 0, an additional arrival in the 2nd interval increases the risk of LWBS by 16%.
- X ***H: later events have more impact.***
  - Events in the 1st interval have no impact.
- X ***H: effect is stronger at high congestion.***

Covariate	Coefficient
ArrivalRate1	0.04
ArrivalRate2	0.08***
ArrivalRate3	0.05**
ArrivalRate4	0.04
ArrivalRate1xCongestion1	0.00
ArrivalRate2xCongestion2	-0.01***
ArrivalRate3xCongestion3	-0.01***
ArrivalRate4xCongestion4	0.00

*: *p*-val < 0.1, **: *p*-val < 0.05, ***: *p*-val < 0.01

Time-dependent factors of LWBS: Arrivals

- If congestion < 8 after 30 minutes, observing arrivals *increases* the risk.
  - Otherwise, they *reduce* the risk.
- If congestion < 5 after 60 minutes, observing arrivals *increases* the risk.
  - Otherwise, they *reduce* the risk.
- Average congestion upon arrival is 6.4.
  - For arrivals between 6pm and 7pm, this grows to 11.0.
- At low congestion, observing others enter signals a lower likelihood of being served shortly.
- At high congestion, others entering makes me more protective of my spot in line.

Time-dependent factors of LWBS: Abandonments

- ***H: abandonments reduce the risk.***
  - After a sufficiently long time, the risk increases.
- X ***H: later events have more impact.***
  - Events in the 1st interval have no impact.
- X ***H: effect is stronger at high congestion.***

Covariate	Coefficient
AbandRate1	0.46
AbandRate2	-0.37***
AbandRate3	0.16
AbandRate4	0.24***
AbandRate1xCongestion1	-0.01
AbandRate2xCongestion2	0.02***
AbandRate3xCongestion3	-0.01**
AbandRate4xCongestion4	-0.01***

*: p-val < 0.1, **: p-val < 0.05, ***: p-val < 0.01

Time-dependent factors of LWBS: Abandonments

- If congestion < 19 after 30 minutes, observing others LWBS *reduces* the risk.
    - Otherwise, they *increase* the risk.
- If congestion < 23 after 90 minutes, observing others LWBS *increases* the risk.
    - Otherwise, they *reduce* the risk.
- Early on…
    - At low congestion, observing others LWBS signals a higher likelihood of being served shortly.
    - At high congestion, observing others abandoning makes me more likely to follow their lead.
- Eventually, the effect of observing others LWBS has the same direction as observing arrivals.

Time-dependent factors of LWBS: Overtakes

- ***H: overtakes reduce the risk.***
- X ***H: later events have more impact.***
  - Events in the 1st interval have no impact.
- X ***H: effect is stronger at high congestion.***

Covariate	Coefficient
OvertakeRate1	-0.76
OvertakeRate2	-0.17***
OvertakeRate3	0.02
OvertakeRate4	-0.17**
OvertakeRate1xCongestion1	0.03
OvertakeRate2xCongestion2	0.01***
OvertakeRate3xCongestion3	0.00
OvertakeRate4xCongestion4	0.01**

*: p-val < 0.1, **: p-val < 0.05, ***: p-val < 0.01

Time-dependent factors of LWBS: Overtakes

- If congestion < 17 after 30 minutes, observing overtakes *reduces* the risk.
  - Otherwise, they *increase* the risk.
- If congestion < 17 after 90 minutes, observing overtakes *increases* the risk.
  - Otherwise, they *reduce* the risk.
- At low congestion, getting overtaken signals a higher likelihood of being served shortly.
- At high congestion, getting overtaken makes me more likely to abandon.

Time-dependent factors of LWBS: ESI 3

- Events occurring during the first 30-minutes of waiting have no impact on patients' survival.
- Events during the second 30-minutes of waiting *do* have an impact.
- If congestion < 8 after 30 minutes:
  - Observing more arrivals will increase the risk of LWBS.
  - Observing more overtakes and abandonments will decrease the risk.
- If congestion > 19, these effects will change sign.

Time-dependent factors of LWBS

- Repeat the analysis for ESI Level 4 and 5 patients combined.
- Do similar patterns emerge?
- If not, how do low severity patients differ from those with higher medical priority?

Time-dependent factors of LWBS: Arrivals

- ***H: arrivals increase the risk.***

X
- ***H: later events have more impact.***
    - Events in the 1st interval have no impact.
- ***H: effect is stronger at high congestion.***
- If congestion < 11 after 60 minutes, observing arrivals *increases* the risk.
    - Otherwise, they *reduce* the risk.

Covariate	Coefficient
ArrivalRate1	-0.83
ArrivalRate2	-0.04
ArrivalRate3	0.11***
ArrivalRate4	-0.07
ArrivalRate1xCongestion1	0.02
ArrivalRate2xCongestion2	0.00
ArrivalRate3xCongestion3	-0.01***
ArrivalRate4xCongestion4	0.00

*: p-val < 0.1, **: p-val < 0.05, ***: p-val < 0.01

Time-dependent factors of LWBS: Abandonments

- ***H: abandonments reduce the risk.***
- X ***H: later events have more impact.***
  - Events in the 1st interval have no impact.
- ***H: effect is stronger at high congestion.***
- If congestion < 28 after 60 minutes, observing others LWBS *reduces* the risk.
  - Otherwise, they *increase* the risk.

Covariate	Coefficient
AbandRate1	-13.31
AbandRate2	0.37**
AbandRate3	-0.28**
AbandRate4	-0.17
AbandRate1xCongestion1	0.15
AbandRate2xCongestion2	-0.01
AbandRate3xCongestion3	0.01^{+}
AbandRate4xCongestion4	0.00

$^{+}$: p-val < 0.11, **: p-val < 0.05, ***: p-val < 0.01

Time-dependent factors of LWBS: Overtakes

- ***H: overtakes reduce the risk.***
- X ***H: later events have more impact.***
  - Events in the 1st interval have no impact.
- ***H: effect is stronger at high congestion.***
- If congestion < 15 after 60 minutes, observing overtakes *reduces* the risk.
  - Otherwise, they *increase* the risk.
- If congestion < 15 after 90 minutes, observing overtakes *increases* the risk.
  - Otherwise, they *reduce* the risk.

Covariate	Coefficient
OvertakeRate1	1.02
OvertakeRate2	0.06
OvertakeRate3	-0.15**
OvertakeRate4	0.15*
OvertakeRate1xCongestion1	-0.22
OvertakeRate2xCongestion2	0.00
OvertakeRate3xCongestion3	0.01**
OvertakeRate4xCongestion4	-0.01**

*: *p*-val < 0.1, **: *p*-val < 0.05, ***: *p*-val < 0.01

Time-dependent factors of LWBS: ESI 4 & 5

- Events occurring during the first 30-minutes of waiting have no impact on patients' survival.
- Events during the third 30-minutes of waiting *do* have an impact.
- If congestion < 11 after 60 minutes:
  - Observing more arrivals will increase the risk of LWBS.
  - Observing more overtakes and abandonments will decrease the risk.
- If congestion > 28, these effects will change sign.

Do these effects depend on congestion?

- At **low congestion**, observing others…
  - **Enter the waiting room** indicates a lower likelihood of being served shortly, which **increases the risk of LWBS.**
  - **Abandon or overtake** indicates a greater likelihood of being served shortly, which **decreases the risk of LWBS.**
- At **high congestion**, observing others…
  - **Enter the waiting room** makes patients more protective of their spot in line, which **decreases the risk of LWBS.**
  - **Abandon or overtake** makes patients less confident that they will be served shortly, which **increases the risk of LWBS.**

Section Summary: Time-Dependent LWBS Analysis

- Account for the events (arrivals, departures, etc.) that patients observe during their wait.
- Event histories affect LWBS. At low congestion:
  - Arrivals *increase* the risk of LWBS,
  - Overtakes and abandonments *reduce* the risk.
- At high congestion, direction of the effect changes.
- This impact of events on LWBS occurs earlier for higher severity patients.

Today’s talk

- What is LWBS?

- What factors are associated with LWBS?

- How do events during patients’ waits affect LWBS?

Future Directions: Improving ED Operations

- The events that patients observe during their wait have a significant affect on their decision to abandon.
  - E.g., at times of low congestion, the number of arrivals observed after waiting for 30 minutes increases the likelihood that an ESI Level 3 patient will decide to abandon.
  - *So what? Implications on operations are unclear.*
- **Event histories:** which one accurately describes patients' decisions of when to *wait* and when to *abandon*?
- Behavioral model to describe abandonment decisions.
  - Estimate patients' *cost* of waiting and *reward* for service.
- **Using out-of-sample validation…**
- Answer counterfactual questions.
  - Do patients abandon less under alternative *information* policies?

Thank You!

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