Consecutive Surgeries with Complications: The Impact of Scheduling Decisions

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General Surgeons and Patient Scheduling

Surgeons select which patients to assign to a day of surgery and in what order the surgeries will be performed:

- They are given several days in the operating room per month and can perform multiple surgeries on each day.
- They must forecast and anticipate uncertainty in the operating room (OR):
    - Disease/Patient characteristics
    - Operating team (e.g., nurses)
    - Over/under utilization of OR
- Each surgeon employs a scheduling policy that depend on their personal preferences.

Research Questions

- Scheduling decisions have *operational* ramifications (e.g., overtime).
  1. Do scheduling decisions affect clinical quality?
  2. What are the features of an (in)effective schedule?

Research Contributions

We link advanced scheduling decisions, made by a surgeon to support their core organizational function, to quality outcomes.

1. After a complication occurs, a subsequent surgery is more likely to experience a complication (a *complication cascade*).
    - This is related to surgical complexity and variety.

2. Typical operational interventions (scheduling more slack time for rest, recovery, and reflection) does not mitigate the risk.
    - Surgeons may not be addressing issues in-process.

Outline

1. Hypothesis Development
   - Clinical quality and surgical complexity.

2. Empirical Strategy and Results
   - Dataset description and propensity score analysis.
   - Logistic regression model and corresponding results.
   - Robustness checks and alternative hypotheses.

3. Managerial Implications
   - Evidence-based operational decision-making.

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Clinical Quality

- Most surgeries conclude without any major problems. However, during some surgeries, a complication occurs.

Types of Surgical Complications	
Septic Shock	Renal Failure
Deep Vein Thrombosis	Stroke
Death	Surgical Site Infection
Ventilation Intervention	Pulmonary Embolism
Cardiac Arrest	Myocardial Infarction
Intubation	Bleeding Transfusion

- Exclusively focusing on mortality is too crude a measure while no data exists on “near misses” (e.g., aviation, law enforcement).

Surgical Complexity

Laparoscopic (Simpler)	Open (More Complex)
	
Minimally invasive techniques: • experience fewer side effects • shorter length-of-stay in the hospital • decreased rate of complications	Large incisions are made in the tissue: • a better view of internal structures • an option for all surgical procedures • reserved for more complex cases

Hypothesis Development

<u>Hypothesis 1:</u> ***A complication in a surgery increases the odds of a complication in the subsequent surgery (a complication cascade).***

- If a patient is at an increased risk of a complication, surgeons either immediately realize an issue has occurred or believe that it is more likely to eventually occur (Clarke et al., 2013; Sanchez et al., 2017).
- This has negative psychological consequences, i.e., questioning the belief in one's own capacity to perform that task and/or shifting the focus away from the performance of a task (Frese and Keith, 2015).
- The immediate future performance of a similar task may suffer (Moritz et al., 2000; Smith et al., 2006, Stirin-Tzur et al., 2016).

Hypothesis Development

<u>Hypothesis 2:</u> ***The greater the slack time between consecutive surgeries, the lower the odds of a complication cascade.***

- Surgeons are encouraged to reduce slack time because they get paid (fee-for-service) to perform surgery (Johnston and Diamant., 2019).
- Surgeons also seek to reduce slack time between surgeries as it represents a cost to the institution (Erdogan and Denton, 2010).
- Systems with small amounts of slack time between tasks are tightly-coupled (Cooke and Rohleder, 2006; Tamuz and Harrison, 2006) and more susceptible to repeated errors (Shrivastava et al., 2009).

Hypothesis Development

<u>Hypothesis 3:</u> ***A complication cascade is more likely to occur with consecutive complex surgeries (open/open) versus any other pairing.***

- Open surgeries are more complex as they are typically reserved for more difficult patients/procedures as compared to laparoscopic surgery (Velanovich, 2000; CCL, 2005; Varela et al., 2010, Xiong et al., 2017).
- Task variety has a negative effect on productivity in the performance of complex tasks because it shifts focus and incurs a cognitive setup cost (e.g., Staats and Gino, 2012; KC and Staats, 2012; Avgerinos and Gokpinar, 2018).
- Exposure to task variety is inherently distracting (e.g., Monsell, 2003). Distractions prevent the negative transfer effect associated with recent errors (Reed, 1989; Zollo and Reuer, 2010) associated with the performance of complex tasks/environments (Tamuz and Harrison, 2006).

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Dataset Description

Approximately 29,500 surgeries performed by 111 surgeons from 2005 to 2015 in several hospitals located in Ontario, Canada.

- There were 424 different surgery types; ~15% had a complication.
- Surgeons performed an average of 1.7 surgeries per day (max of 8).
- In 75% of cases, back-to-back surgeries were of a different type.

Data Fields	
Surgeon	Surgery Duration
ASA Class	Surgery Type
Open/Laparoscopic	Patient Age
Patient Sex	Hospital
Trainees	Nurses
Date & Time	Surgery Order
Complication?	Type of Complication

Propensity Score Matching

We attempt to mimic a controlled experimental setting:

- 972 surgeries (*treated*) followed a surgery with a complication.
  - Open surgeries (57%); laparoscopic surgeries (43%).
- We used a nearest neighbor algorithm to find similar (*control*) observations that followed a surgery without a complication.
  - We matched three-to-one (2,916) due to the size of the control set.
- We selected matching variables that affected both *treated* and *control* surgeries (Heckman et al., 1997).
    - **Surgeon:** skill set, knowledge, experience, scheduling approach
    - **Hospital:** institutional culture, equipment, pool of personnel
    - **Nurses and Trainees:** number of residents and assistants present
    - **Day / Month / Year:** idiosyncratic temporal effects

Conditional Logistic Regression Model

The sample contains *treated* and *control* observations with similar propensity scores (mimicking a controlled experimental setting):

$$logit(y_i) = \alpha U_i + \beta V_i + \gamma W_i + \delta U_i V_i + \eta U_i W_i + \boldsymbol{\theta X_i}$$

y_i: Whether or not there was a complication in focal surgery i.

$\boldsymbol{X_i}$: Control variables include patient, surgeon, and surgery characteristics (e.g., ASA class, age, sex, duration, variance, time) for focal surgery i.

U_i: Whether focal surgery i followed a surgery with a complication.

V_i: The slack time between focal surgery i and the previous surgery.

W_i: Whether focal surgery i and the previous surgery were of similar complexity (e.g., open/open, open/laparoscopic).

Hypothesis Confirmation

✓ *Hypothesis 1: A complication in a surgery increases the odds of a complication in the subsequent surgery (a complication cascade).*

- *On average, the probability of a complication increases by over 4% when a surgery follows a previous surgery with a complication.*

× *Hypothesis 2: The greater the time slack between consecutive surgeries, the lower the odds of a complication cascade.*

- *Surgeries separated by larger amounts of slack time are not associated with any reduction in the odds of a complication*

Hypothesis Confirmation

✓ *<u>Hypothesis 3:</u> A complication cascade is more likely to occur with consecutive complex surgeries (open/open) vs. any other pairing.*

Effect Size	Sequence (***indicates that the p-value < 0.001)			
	Open/ Open	Laparoscopic/ Open	Open/ Laparoscopic	Laparoscopic/ Laparoscopic
Average Change in Probability	8.40%***	2.47%	-0.35%	-0.12%

Strength of Findings

We analyzed the robustness of our empirical results:

- Rosenbaum's sensitivity analysis indicates that our results are sufficiently robust to unobserved confounding.
- We analyzed the matched sample and found that no surgeon was represented substantially more often.
- Patient-surgeon or surgeon-patient selection bias is not a factor.
- Discussions with surgeons indicate that physical exhaustion is *not* driving the results. Further, no empirical evidence of longer surgery times between surgeries with/without a complication.

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So what?!?!

We link advanced scheduling decisions, made by a surgeon to support their core organizational function, to quality outcomes.

1. Practitioners should be aware that operational, day-to-day decision-making may have *clinical* consequences.

2. Surgeons should avoid the consecutive *scheduling* of highly complex procedures (i.e., open/open surgeries).
    - Task variety may be a useful strategy to recover from mistakes as they inevitably occur in the performance of complex tasks.
    - Scheduling more slack time does not mitigate the risk.

Thank you! Questions?

Unobserved Confounding

× Maybe we failed to account for a variable that provides an alternative explanation for a complication cascade?

- Performed Rosenbaum's method of sensitivity analysis.
- Introduces a parameter Γ which captures how much the matching deviates from a random assignment ($\Gamma = 1$ is random assignment).
- A surgery must be twice as likely to experience a complication due to a covariate not included in the matching for our inferences to be invalid.
  - This an acceptable threshold for social science research (Keele, 2010).

Alternative Hypothesis

× Are complication cascades actually the result of a systematic deficiency on the part of an individual surgeon?

- This was controlled for in our empirical specification.
- No surgeon is represented substantially more often in the sample.

× Do complication cascades somehow exhibit similar features?

- Only 33% of back-to-back complications were of the same type.
- For back-to-back surgeries, the types of complications were not necessarily associated with performing identical surgical tasks.

Alternative Hypothesis

× Surgeries ending in a complication may be more physically fatiguing. Is it physical exhaustion that is driving the observations?

- Anonymous discussions with some of the surgeons in our study indicated this was not the case. For example, one surgeon remarked that the emotional toll that stems from managing the operating room around these events is an *"unbelievable stressor that has taken years off my life."*
- No evidence of longer surgery times for those that experienced a complication.

× Is there patient-surgeon or surgeon-patient selection bias?

- Physicians and patients are unaware of a particular surgeon's performance.
- Informal swapping of patients is not a regular occurrence and is associated with the pursuit of professional activities – such as research and teaching.