

# Surgical Case Sequencing's Impact on Patient Flow: A Simulation-Based Study Considering Downstream Resources

## Abstract

**OBJECTIVE:** To evaluate the effect of surgical case sequencing on patient flow delays considering downstream hospital resources.

**BACKGROUND:** Operating Rooms (OR) are often constrained by downstream resources, which affect patient flow and surgeon productivity. As ORs are expensive and resource intensive, it is imperative to prevent delays such as OR and Post Anesthesia Care Unit (PACU) holds. Discrete event simulation (DES) has been used to model operating room flow; however, these models often conflate system and physiological factors affecting patient flow delays. We propose the use of alternative inputs into DES to inform how case sequencing affects PACU and OR holds and attribute these holds to patient or system factors.

**METHODS:** Using DES, we analyzed the effect of case sequencing practices on the occurrence and severity of OR and PACU holds. We constructed a DES of DUH using EHR case data from 2021-2024, considering downstream flow constraints (ICU, PACU, Inpatient Beds).

**RESULTS:** By changing daily case sequencing practices to an "outpatient first" policy, OR holds can be reduced by 72% and PACU holds can be reduced by 21%.

**CONCLUSIONS:** A DES model can reliably provide insight into the effect that downstream resource considerations can have on OR and PACU holds. It is particularly useful in systems operating under constrained resources. We are investigating a pilot of these sequencing practices within our hospital system.

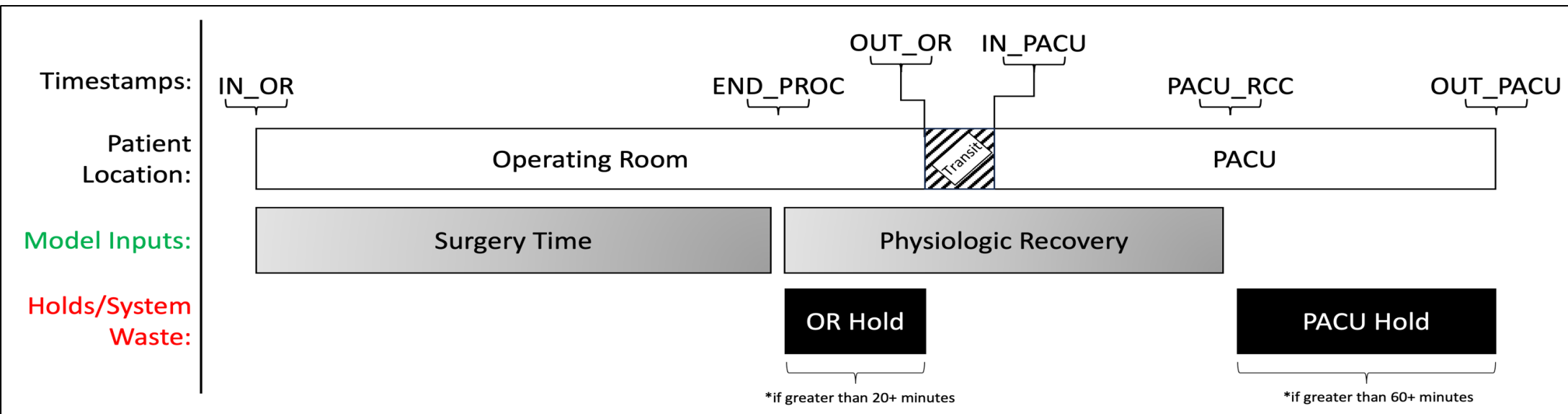


Figure 1: Variables collected and modeled within simulation

## The Problem

Platform	OR	PACU	
	OR Hold (20+ min)	PACU Recovery (180+ min)	PACU Hold (60+min)
DMP OR	32.10%	5.60%	36.10%
Duke North OR	25.30%	4.40%	28.30%
DRH OR	2.90%	1.80%	4.70%
DRAH OR	2.60%	4.30%	14.10%
Eye Center OR	1.70%	0.10%	0.20%
ASC OR	1.20%	1.90%	0.10%
DASC OR	1.00%	0.90%	0.00%
Arrington ASC	0.20%	1.10%	0.00%

DUH cases experiences OR and PACU Hold approximately 30% of the time

Figure 2: OR Hold and PACU Hold experienced across DUHS system.

## Methods

**Dataset:** The dataset contained operating room (OR) and Post-Anesthesia Care Unit (PACU) timestamp data for all procedures at DUH from January 1, 2021, to March 31, 2024 (n=227,622).

**Modeling:** ORs were modeled using discrete event simulation. Multiple scheduling heuristics were tested, including scheduling all outpatient cases first, shortest cases first, and longest cases first.

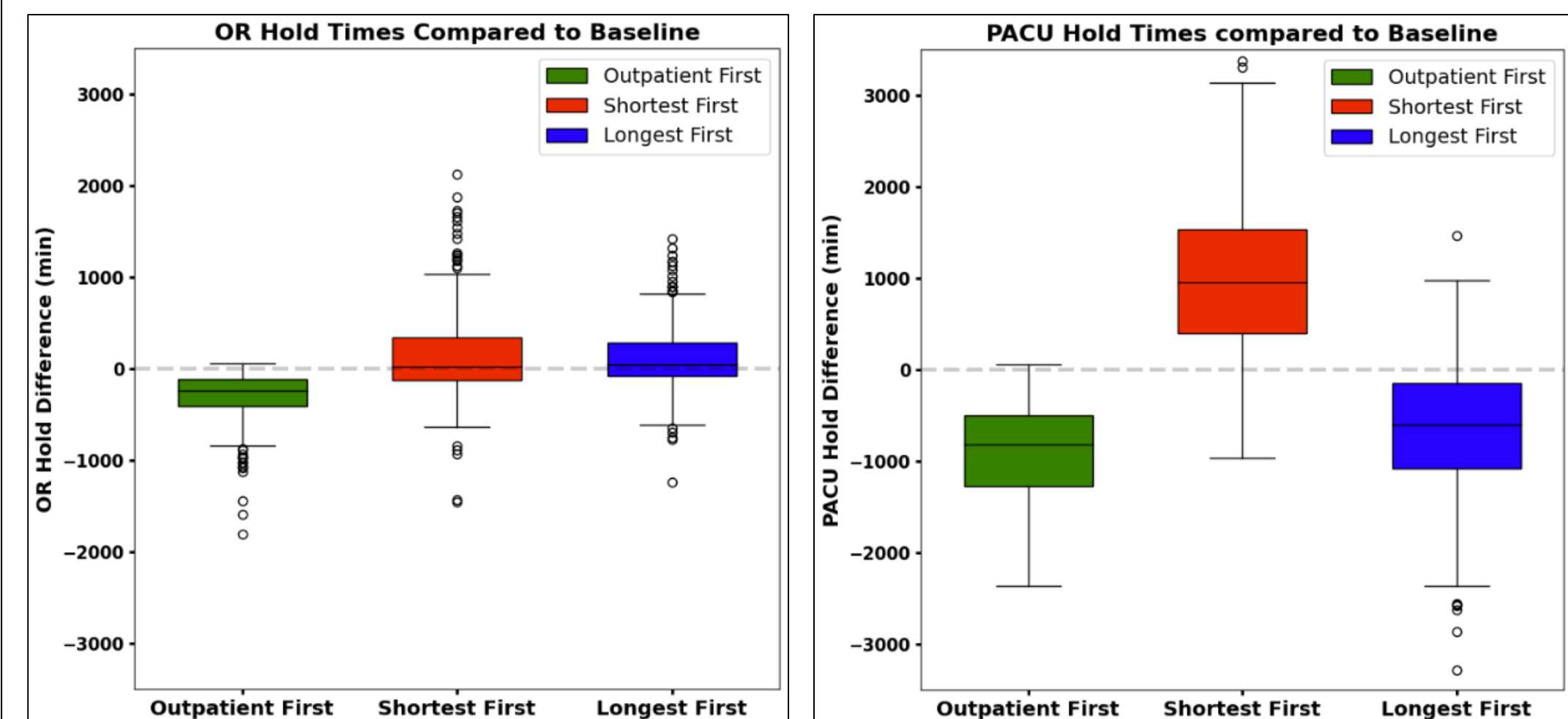
	Case Order for Scheduling Heuristics																		
	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30
Baseline	Case 1 - Inpatient				Case 2 - Outpatient				Case 3 - Outpatient				Case 4 - Inpatient						
Outpatient First	Case 2 - Outpatient		Case 3 - Outpatient		Case 1 - Inpatient				Case 4 - Inpatient										
Shortest Cases First	Case 3 - Outpatient		Case 2 - Outpatient		Case 4 - Inpatient				Case 1 - Inpatient										
Longest Cases First	Case 1 - Inpatient				Case 4 - Inpatient				Case 2 - Outpatient		Case 3 - Outpatient								

Figure 3: Example of scheduling heuristics used in simulation

**Our Question:** How does surgical case sequencing affect the amount of OR and PACU holds experienced by the hospital system?

## Results

### Effect of Scheduling Heuristics



### SCS Heuristics Compared to Baseline

Compared to Baseline Sim	OR HOLD		PACU HOLD	
	% Difference	Minutes Different	% Difference	Minutes Different
Outpatient First	-72% [32%]	-309 [277]	-21% [13%]	-902 [516]
Shortest First	1% [60%]	151 [480]	16% [13%]	980 [813]
Longest First	4% [56%]	120 [373]	-15% [17%]	-649 [742]

Figure 4: Average [SD] percent and min different of heuristics from current baseline scheduling

- An 'Outpatient First' heuristic consistently **decreases OR Hold (-72%) and PACU hold (-21%)** experienced by the hospital.
- Both the 'Shortest First' and 'Longest First' heuristics have more **mixed results** and often increase OR or PACU hold on average.

### Final OR Case Completion Time

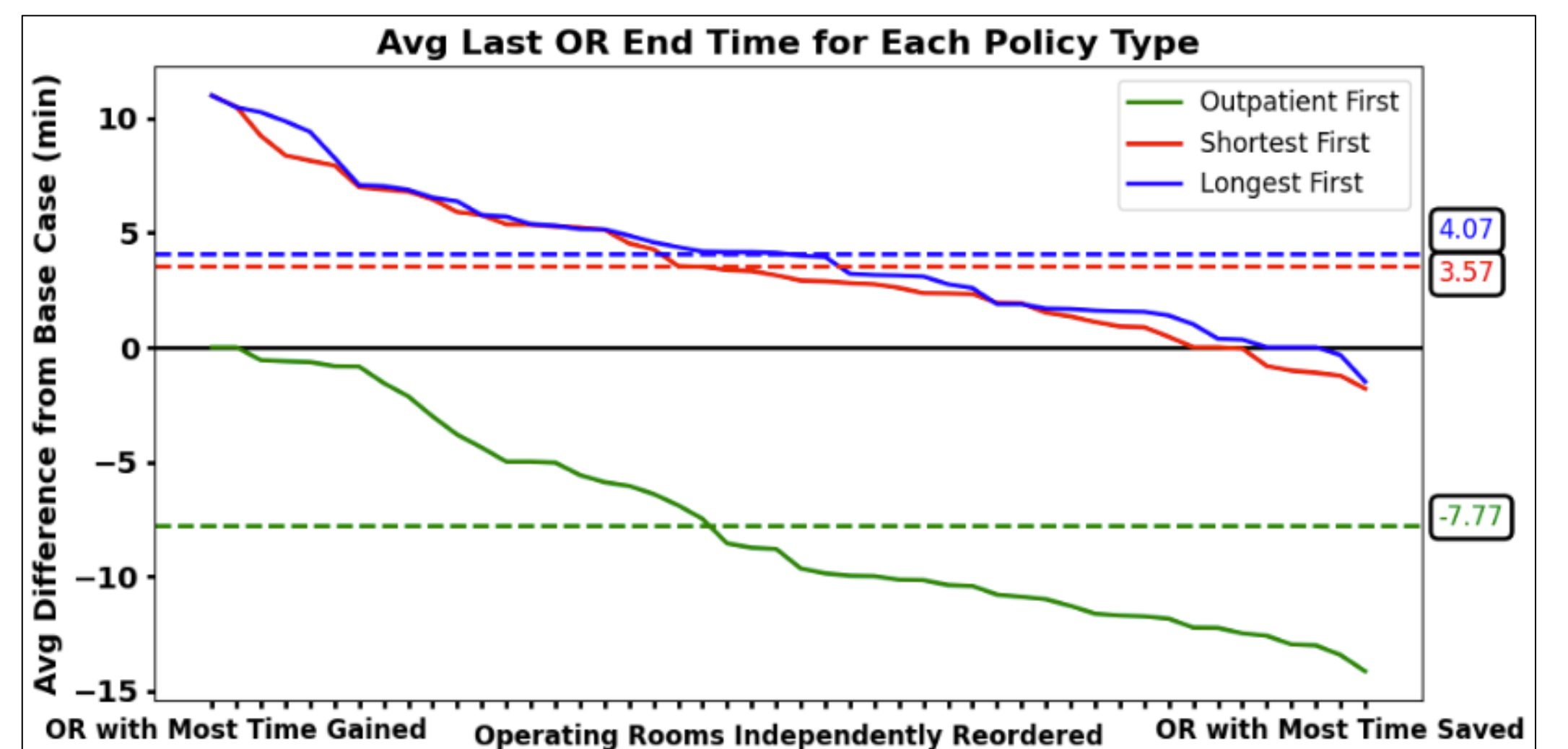


Figure 5: Average difference in last case finish time for each OR. ORs are independently ordered from the most time gained to most time saved (i.e. the leftmost OR is not physically the same OR in all 3 policies).

- The 'Outpatient First' heuristic extended the final case completion time (n=11,078 final cases) in **only 0.88% of cases and improved it in 28.4% of cases**.
- The 'shortest cases first' heuristic **extended the final case completion time in 23.7% of cases** and improved it 17.1% of cases.
- The 'longest cases first' heuristic **extended final case completion time in 22.7% of cases** and improved it in 15.3% of cases.

## Summary and Conclusions

- It is important to **consider downstream resource constraints** when evaluating optimal scheduling of operating rooms
- 'Outpatient First' heuristic shows strong simulated evidence that it **drastically reduces OR and PACU hold**
- 'Shortest Cases First' and 'Longest Cases First' heuristics have **mixed results** on OR/PACU hold

## Future Work

- Pilot** these findings in real world to understand factors not able to be modeled
  - Including surgeon fatigue, impact of leveled cases, impact on workflow.
- Compare to Pediatric Hospital**, which largely already follows Outpatient First Heuristic
- Allow model to **predict future state: can we predict when a bad day in advance?**

## Acknowledgements

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### Policy Adherence Effect

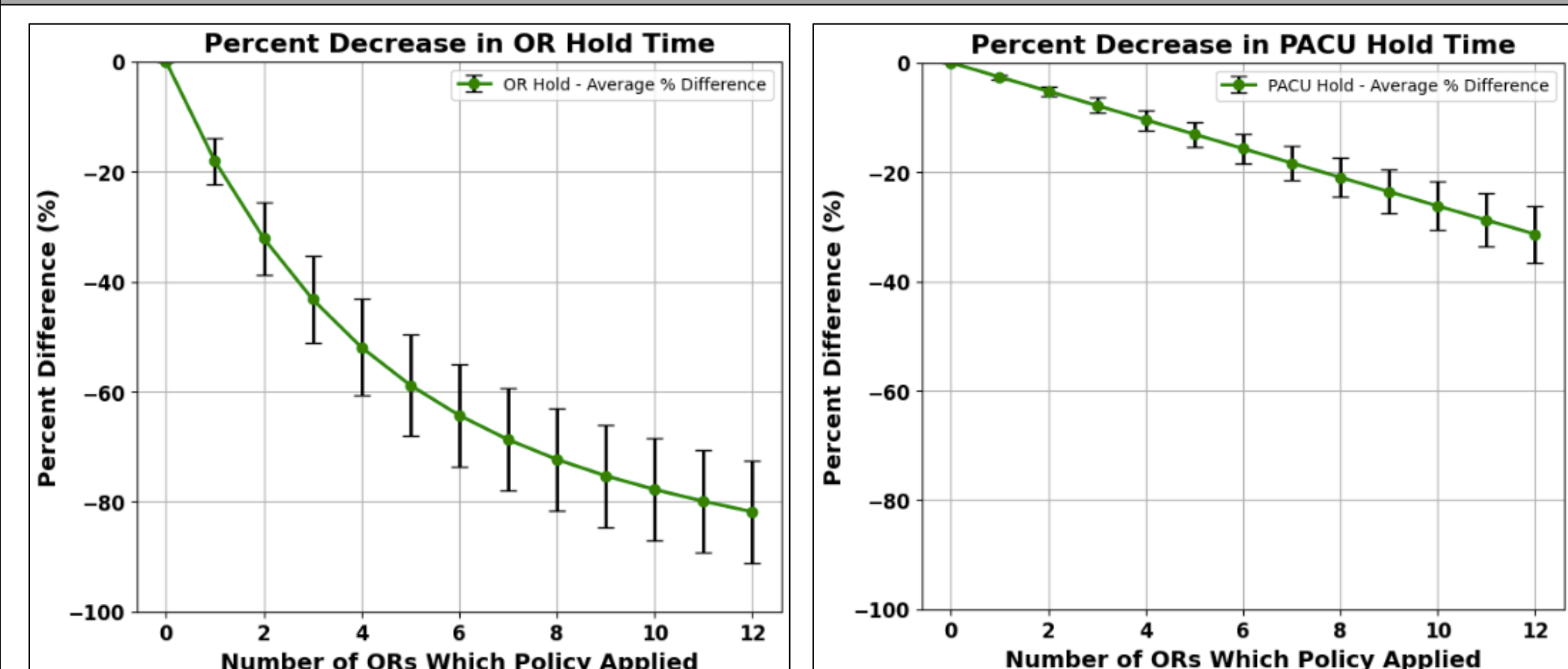


Figure 6: Percent decrease in OR and PACU hold for each additional OR following 'Outpatient First' heuristic. Error bars are standard error.

- A **significant improvement in OR hold** exist with even a single OR being included in the outpatient first heuristic, with an ~20% average improvement for the first OR.
- For each additional OR following the heuristic, there is a **law of decreasing returns** in OR hold reduction, but more variability exist as ORs can have outsized impact.
- PACU Hold decreases linearly** with additional ORs adhering to the heuristic