Workflow Disruption Cascades in the OR: An Empirical Framework for Modeling High-Risk, High-Disruption Surgical States

MUSC Medical University of South Carolina

Catchpole, Kenneth, PhD; Del Gaizo, John, PhD

Medical University of South Carolina

ABSTRACT

Operating room (OR) workflow disruptions (FDs) are associated with increased team stress, prolonged procedures, and elevated error rates. We introduce the concept of disruption cascades—sequences of escalating events—classified into three mechanisms: random occurrences (which do not constitute a cascade), common-cause triggers, and concatenating "domino effects." This study investigates the presence of these mechanisms and evaluates the ability of artificial intelligence (AI) to detect disruption cascades compared to human experts.

METHOD

Flow disruptions from sixteen surgical cases were manually reviewed by a human expert using custom labeling software to identify disruption cascades. ChatGPT-4 was used to assess AI's ability to detect cascades and measure interrater reliability.

Common-Cause Cascade Example 1 (case time in minutes):

- **0.67** – *Environment:* Doors remained open due to malfunction with the automatic closing process
- **8.28** – *Environment:* Before leaving, CN1 manually closed the doors using a button located at the top of the door
- **205.83** – *Environment:* Doors had to be held open by the PA and Res since they weren't working so CN3 could wheel in bed

Common-Cause Cascade Example 2:

- **0.93** – *Environment:* OR doors won't auto close
- **506.67** – *Environment:* OR doors got stuck open

Common-Cause Cascade Example 3:

- **38.27** – *Environment*: ST2 was moving vision cart but a wire was stuck.
- **38.95** – *Environment:* ST2 adjusting wires on vision cart.
- **40.42** – *Environment:* ST2 taping wires to floor.
- **240.75** – *Environment:* CN1 had some trouble moving the vision cart back because of wires.

Domino-effect Cascade Example:

- **101.42** – *Equipment Failure:* clip that they loaded was broken
- **101.42** – *Coordination:* CN was going to OR4 to get a new clip because they didn't have them ready on this floor
- **103.62** – *Surgical Task Considerations:* surg decided not to use clip after all
- **107.65** – *Coordination:* external person came in with new clips to replace broken one

RESULTS

Interrater reliability between the human expert and ChatGPT-4 was moderate (Cohen's Kappa = 0.63, $p < 10^{-5}$). Among 1,631 FDs, 152 cascades were identified. Approximately two-thirds of disruptions were random (non-cascading). The overall FD rate was 0.43/min, varying by the cascade type in-progress: 0.33/min outside cascades, 0.77/min during domino cascades (0.46/min from domino cascade members), and 0.46/min during common-cause cascades (0.04/min from common-cause cascade members). Random disruptions continued during cascades, compounding their effects.

Table. Cascade rates by condition.

Condition (n cascades)	Duration in minutes	Overall Disruption Rate (n disruptions)	Stand-alone or Random Rate (n disruptions)	Cascade-member Rate (n disruptions)
1. Entire dataset (152)	3,754.92	.43 FD/min (1,631)	.31 FD/min (1,156)	.13 FD/min (475)
2. No cascade in progress	1,818.60	.33 FD/min (592)	.33 FD/min (592)	*Not applicable*
3. Any cascade in progress (152)	1,936.32	.54 FD/min (1,039)	.29 FD/min (564)	.25 FD/min (475)
4. Domino-effect cascades only (130)	881.55	.77 FD/min (679)	.30 FD/min (261)	.46 FD/min (409 Domino-effect disruptions)
5. Common-cause cascades only (22)	1,543.33	.46 FD/min (704)	.29 FD/min (451)	.04 FD/min (66 Common-cause disruptions)
5.1 Long Dormant (6)	*1,481.27*	*.44 FD/min (657)*	*.29 FD/min (436)*	*.02 FD/min (29)*
5.2 Short Duration (16)	*154.48*	*.74 FD/min (114)*	*.35 FD/min (54)*	*.24 FD/min (37)*

Figure 1. Distribution of Cascade Coverage and Disruption Frequency Across Surgical Cases

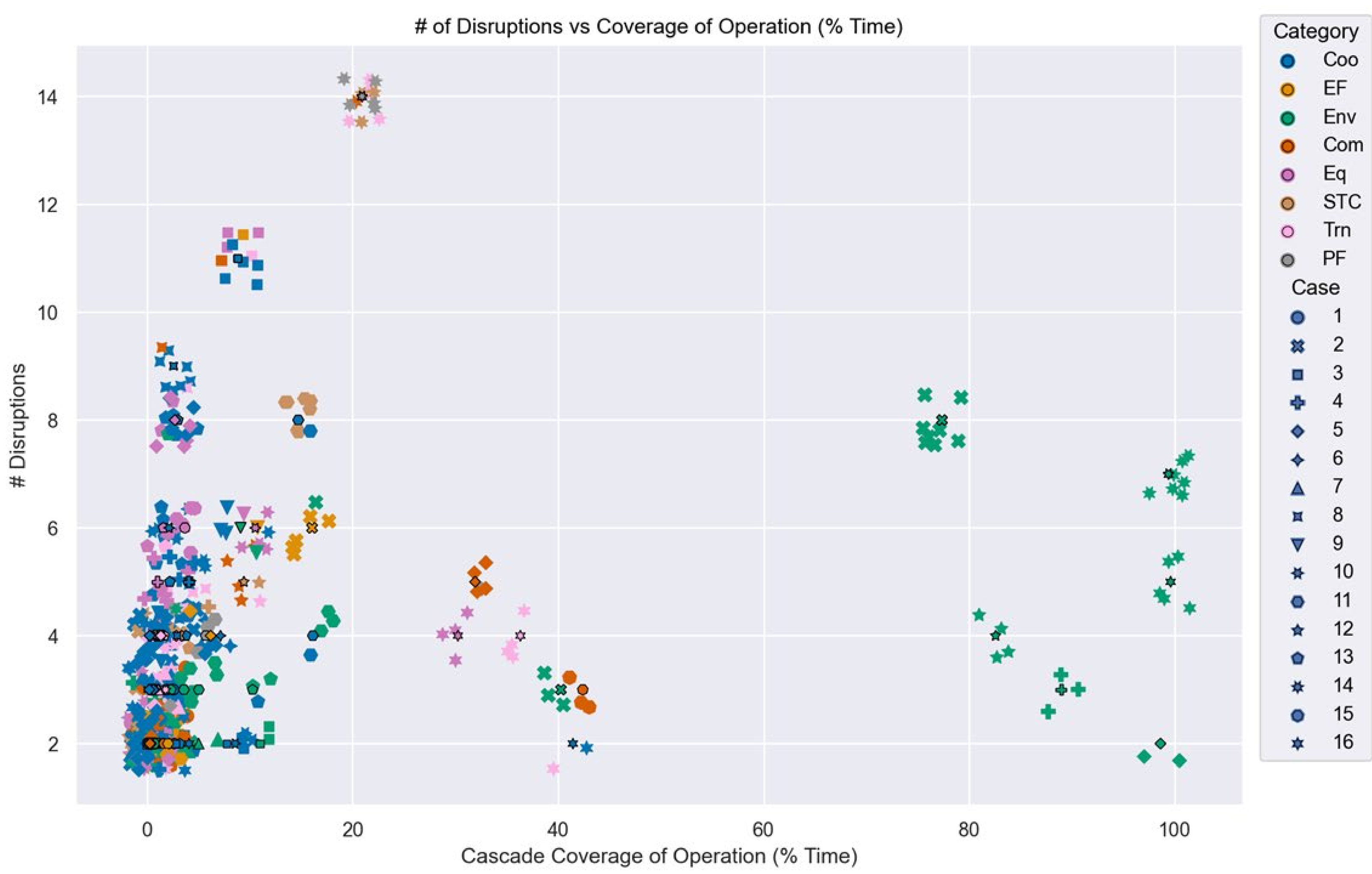

Figure 2. IRR of Human vs AI for Cascade Labeling

Human	Cascade	Not Cascade
AI		
Cascade	67	25
Not Cascade	17	147

Human	0	1	2	3	4	5	6	7	8	9	10	11	13	15	16
AI															
0	147	3	0	0	6	0	1	2	2	3	0	0	0	0	0
1	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0
2	2	0	3	0	0	2	0	0	0	0	0	0	0	0	0
3	4	0	0	5	0	1	0	0	0	0	0	0	0	0	0
4	4	0	0	2	6	0	0	0	0	0	0	0	0	0	0
5	3	0	0	1	0	7	0	1	0	0	0	0	0	0	0
6	2	0	0	0	0	1	8	0	0	0	0	0	0	0	0
7	1	0	1	0	0	0	0	5	1	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0
12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

CONCLUSIONS

All three disruption mechanisms—random, common-cause, and domino—were observed. Common-cause cascades stem from persistent environmental factors and tend to be low-rate but long-duration. Domino cascades are high-rate and short-duration. Random disruptions occur across all states, compounding overall disruption. The moderate agreement between human and AI detection suggests that automated tools may support early identification of error-prone states and enhance proactive surgical safety strategies.

SUMMARY

This study finds that surgical flow disruptions (FDs) often occur in interconnected cascades, not just as isolated events. Of the 1,631 FDs observed, about one-third were part of cascades, especially those involving coordination and patient factors. Short, intense domino cascades and longer, persistent common-cause cascades suggest distinct mechanisms of disruption. While single FDs may not impact outcomes, their accumulation is linked to increased surgical errors. Targeting cascade triggers, rather than eliminating all disruptions, may improve safety. Though limited by sample size and observer subjectivity, future use of OR "black-box" technology and machine learning could enhance precision and support broader applications in safety research.

REFERENCES

1. Reason JT. Human Error. University Press; 1990.
2. Darbra RM, Palacios A, Casal J. Domino effect in chemical accidents: main features and accident sequences. J Hazard Mater. 2010;183(1-3):565-573. doi:10.1016/j.jhazmat.2010.07.061
3. Catchpole KR, Giddings AE, de Leval MR, et al. Identification of systems failures in successful paediatric cardiac surgery. Ergonomics. 2006;49(5-6):567-588.
4. Koch A, Burns J, Catchpole K, Weigl M. Associations of workflow disruptions in the operating room with surgical outcomes: a systematic review and narrative synthesis. BMJ Qual Saf. 2020;29(12):1033-1045. doi:10.1136/bmjqs-2019-010639
5. Wiegmann DA, Elbardissi AW, Dearani JA, Daly RC, Sundt TM. Disruptions in surgical flow and their relationship to surgical errors: an exploratory investigation. Surgery. 2007;142(5):658-665.
6. Eppler MB, Sayegh AS, Maas M, et al. Automated Capture of Intraoperative Adverse Events Using Artificial Intelligence: A Systematic Review and Meta-Analysis. J Clin Med. 2023;12(4). doi:10.3390/jcm12041687