Associations of Surgical Team Communication with the Layout of Physical Space: A Network Analysis of the Operating Room in a Military Medical Center

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Introduction

- Effective surgical team communication is critical for patient safety as it can prevent adverse events and medical errors.[1]
- Adverse events contribute to negative and sometimes fatal outcomes for patients and impose high economic costs on healthcare systems and consumers.[2]
- Preventable clinician communication errors are the most frequent root cause of surgical adverse events.[3]
- Surgical team communication and, by extension, adverse events can be understood as social processes and outcomes that are bounded by factors such as authority gradients, culture, and organizational hierarchy.[4,5]
- Rank, status, and professional roles intersect in unique ways in military medicine, creating potential barriers to effective communication.[1,5]
- Surgical team communication is contingent on encounters and interactions among individuals and teams, in **physical space**.[6,7]
- The primary mechanism for spatial proximity effects is the configuration or layout of the spatial environment, which shapes how individuals move and navigate their environments.[7,8]
- Spatial network analysis, where spaces in a system are treated as nodes in a network, is a powerful way of analyzing the complex effects of physical space and can help us better understand the links between physical space, communication, and collaboration.
- Spatial network analysis enables us to understand complex workplace layouts in terms of relationships among the rooms and other spaces. [9]
- There is a dearth of studies that use network analysis to examine the spatial context of surgical team communication.

Study Purpose

- In this study, we focus on local, intermediate, and global measures of spatial network centrality that reveal latent or hidden insights about physical space.
- **Purpose:** The purpose of this study was to examine the impacts of spatial layout on communication effectiveness in a Military Medical Center.

Methods

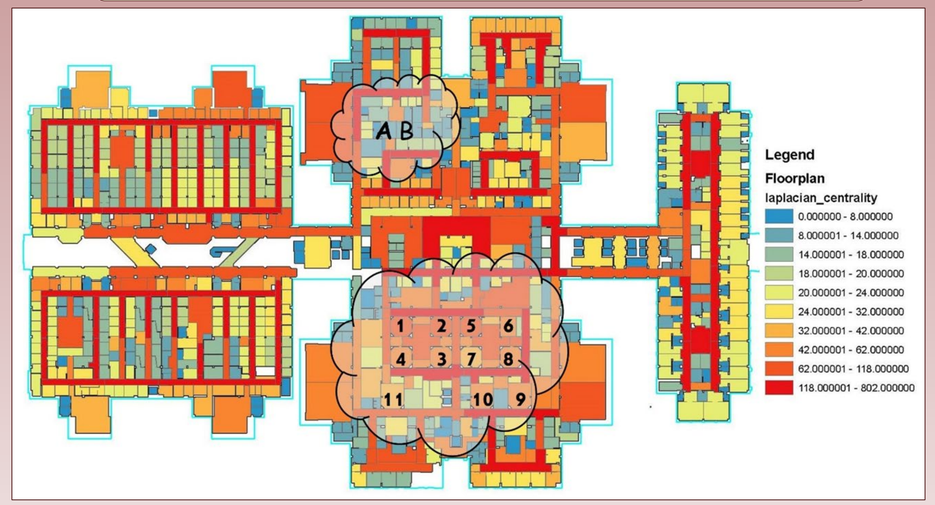
- **Design:** Cross-sectional, prospective, quantitative, and network-centric.
- **Sample**: Total population sampling of 204 clinicians in a large military medical center (36 perioperative nurses, 34 surgical technicians, 62 anesthesia providers, and 72 surgeons), focusing on surgical teams with cases completed within duty hours.
- **Sample Size:** 80% response rate targeted.
- **Setting:** 138-bed military medical center in the southeastern United States with 11 surgical suites and more than 160,000 eligible healthcare beneficiaries. Surgeons from 13 surgical specialties perform more than 11,000 annual surgeries.
- **Data collection:** Targeted five surgical teams for data collection daily via electronic sociometric survey.
- **Inclusion criteria individual:** Active duty, reserve, or National Guard military members and federal employees or government contractors, including students and residents.
- **Exclusion criteria individual:** Supervisory team members who do not provide direct patient care.
- **Team level inclusion criteria:** Priority was given to surgical teams with clinicians who had not been surveyed.

Variables

MEASURES	
Dependent Variables: For both communication types, we created team-level dependent variables by aggregating the individual-level scores for all team members.	
General Communication	Survey item: Team members rated each other on a five-point ordinal scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent) in response to the prompt "Consider today's surgical cases. How well did the person below communicate in general?"
Task-Specific Communication	Survey item: Team members rated each other on a five-point ordinal scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent) in response to the prompt During today's surgical cases, how well did the person below communicate tasks?"
Independent Variables	
Degree	Local measure capturing the number of nodes connected to the focal node in the network. High degree could be both central in part of the building (e.g., the break room in a suite of workspaces) and isolated from other parts of the building.
Laplacian	Intermediate measure: is a function of the focal node's degree plus the degree of its first order (or immediate) neighbors. A space with high Laplacian centrality is important in a larger part of the building beyond the first order e.g., a restroom shared by two or more suites of workspaces.
Betweenness	Global measure capturing how often the focal node is on the shortest paths between other pairs of nodes in the network. A high betweenness space is central across the entire building, like main corridors and circulation spaces.
Control Variables	
Team Size	The count of team members.
Average Complexity	As denoted by the relative value unit (RVU) for each surgical procedure.

- **Spatial network analyses:** We used ArcGIS 10.6 and facility provided electronic floor plans to generate the spatial network and for network maps/graphs and Pajek to compute spatial network centrality (degree, Laplacian, and betweenness).
- **Statistical analysis:** We used Stata MP 16.1 for descriptive statistics and linear regression to examine the associations between the two types of surgical team communication and the three dimensions of spatial network centrality.

Findings



- Figure 1. Laplacian centrality for the OR's spatial network. Surgical suites such as 1, 2, and 5 have higher centrality compared to others like 11, A, and B. Higher centrality spaces are rendered in warmer colors (oranges and reds) while lower centrality spaces are shown in cooler colors (blues and greens).
- Response rate: 77% (157/204 participants). Data were collected from 137 surgical teams.
- General and task-specific communication ranged from 3.4-5.0 and 3.5-5.0, respectively (for both, median = 4.7).
- Team size ranged from 4 to 6 individuals (median = 4).

Findings

Table 1. Regressions for team-level general surgical communication (GCOM)

	(1)	(2)	(3)	(4)
VARIABLES	GCOM	GCOM	GCOM	GCOM
Degree		-0.0809*		
		(-0.210)		
Laplacian			-0.00604***	
			(-0.294)	
Betweenness				-95.83*
				(-0.204)
Team size	-0.0614	-0.0451	-0.0486	-0.0568
	(-0.142)	(-0.104)	(-0.112)	(-0.131)
Average complexity	0.00230	0.00188	0.000634	0.00143
	(0.0530)	(0.0434)	(0.0146)	(0.0329)
Constant	4.865***	5.085***	5.143***	4.934***
Observations	137	137	137	137
R-squared	0.020	0.063	0.105	0.061

Normalized beta coefficients in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Table 2. Regressions for team-level task-specific surgical communication (TCOM)

	(5)	(6)	(7)	(8)
VARIABLES	TCOM	TCOM	TCOM	TCOM
Degree		-0.0845*		
		(-0.214)		
Laplacian			-0.00670***	
			(-0.318)	
Betweenness				-106.6**
				(-0.220)
Team size	-0.0909*	-0.0738	-0.0766*	-0.0857*
	(-0.204)	(-0.166)	(-0.172)	(-0.192)
Average complexity	0.00369	0.00325	0.00184	0.00271
	(0.0827)	(0.0730)	(0.0412)	(0.0609)
Constant	4.969***	5.199***	5.277***	5.046***
Observations	137	137	137	137
R-squared	0.042	0.087	0.141	0.090

Normalized beta coefficients in parentheses
*** p<0.001, ** p<0.01, * p<0.05

- **ORs that are located more centrally in the spatial system are correlated with poorer surgical team communication**.
- Surgical suites with the lowest centrality (i.e., Figure 1, OR 11, A, B) were associated with the highest communication effectiveness.
- Network centrality had a larger effect on task-specific than on general communication.
- Laplacian centrality had the strongest relationship with both general (β = -0.294) and task-specific (β = -0.318) communication.
- We surmise that communication improved as the physical distance from high traffic areas increased due to fewer distractions, noise, and less ease of access by team members not directly involved in direct care.

Implications

- The location of a surgical suite in the network topology of the medical center was significantly associated with surgical team communication.
- Spatial design or redesign of the OR can be used to mitigate communication failures in surgical teams.
- The design and configuration of ORs within medical centers is an important consideration for supporting clinician communication and collegial relationships among surgical team members.
- Hospital architects should design ORs to limit the negative aspects of being located near high-traffic areas.
- Leaders can help mitigate some challenges inherent in the combat environment by modifying the surgical spatial layout to support communication while limiting distractions, noise, and traffic.
- Future researchers should investigate the impact of spatial design on OR communication, safety, and **patient outcomes**.

Limitations

- Data collected from a single military medical center.
- Communication effectiveness potentially was influenced by the unique site setting containing authority gradients and the presence of a clear rank structure.
- Including patient outcomes in the analysis would have provided deeper results.

References available upon request

This Study is "In Press" at Health Environments Research & Design Journal (HERD)

Kabo FW, Stucky CH, De Jong MJ. A Spatial Network Analysis of Surgical Team Communication in a Large Military Medical Center. HERD. 2023; In Press.

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The US Army Regional Health Command Atlantic Institutional Review Board (IRB) determined that the study did not meet the definition of human subjects research and provided an exemptio classification.