Misalignment of Cognitive Processes within Cardiac Surgery Teams

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INTRODUCTION

In high-risk high-stakes environments, such as the cardiac operating room (OR), the cognitive processes of each surgical team member, as well as alignments or misalignments between team members play a critical role in team performance and consequent patient care quality and safety. In OR settings, a multidisciplinary team approach is essential, with each member, individually and as a team, playing a pivotal role in surgical outcomes. This study's goal was to investigate the cognitive processes of cardiac surgery teams, particularly focusing on the potential misalignment between surgeons, anesthesiologists, and perfusionists during coronary artery bypass grafting (CABG) procedures. We evaluated critical intraoperative cognitive processes, including decision-making, communications, and problem-solving strategies across different phases of CABG procedures, providing quantitative measurements of misalignments within the teams, and reporting the specific phases of surgery that have the highest cognitive process misalignments. By analyzing these cognitive dynamics, our goal is to enhance the understanding of team coordination and cognitive distribution in the operating room. Specifically, by pinpointing where and how cognitive misalignments occur, we can develop targeted interventions. These interventions aim to streamline communication, decision-making, and problem-solving, ultimately contributing to improved patient care and team efficiency in cardiac surgery.

MATERIALS AND METHODS

Study Participants: This study was conducted at a tertiary teaching hospital in the United States. The research protocol was approved by the local Institutional Review Board. Nine subject-matter experts, members of a cardiac surgery department participated in this study: three cardiac surgeons, three perfusionists, and three cardiac anesthesiologists.

Cognitive Task Analysis (CTA): This study is a secondary analysis of data from [1], where CTA was used to elucidate the cognitive processes during the intraoperative phase of CABG. We conducted individual semi-structured interviews with subjectmatter experts to elucidate their cognitive processes. The interviews were based on video vignettes from the procedure, aiding in the comprehensive capture of the following intraoperative cognitive processes: decisionmaking, critical communications, pitfall identification, problem prevention/solving strategies, and perceived cognitive workload. Interviews were standardized, with questions aimed at uncovering specific cognitive processes for each of the 14 surgical steps. A physician with expertise in human factors reviewed all interview recordings, creating a comprehensive list of cognitive elements.

Measurement of Perceived Cognitive Load: The perceived cognitive workload was assessed using a visual analogue scale (VAS). Participants were asked to rate their mental demands for each step on a scale from 1 (minimum demand) to 100 (maximum demand). This self-reported measure reflects the subjective cognitive burden experienced by each OR team member during different phases of the CABG procedure.

Misalignment Analysis: From the CTA dataset, we identified the key cognitive processes mentioned by each role (surgeon, anesthesiologist, and perfusionist). We anticipate that team alignment will take place when the team members share similar cognitive processes. Grounded in this hypothesis, the misalignment score for each cognitive process in each surgical phase was derived from the absolute difference in the number of mentions between each role pair. For instance, if a process was mentioned 10 times by a surgeon and 4 times by a perfusionist, the score would be $|10 - 4| = 6$. These scores quantify the cognitive alignment disparity among the roles. We then visualized these scores using a heatmap, which shows the variation in cognitive processes across different role interactions during CABG surgery, pinpointing areas where inter-role communication may be optimized.

RESULTS

A total of 9 interviews generated 16 hours and 3 minutes of audio data. Demographic characteristics of the subject-matter experts are detailed in Table 1. The CTA identified 137 unique intraoperative cognitive processes.

Table. 1 Subject-Matter Experts' Characteristics

	Surgeons (N = 3)	A nest hesiol ogists (N = 3)	Perfusionists (N = 3)
Age, y	56.3	43.0	45.7
Sex (male/female)	2/1	2/1	3/0
Experience, y*	23.7	9.3	19.0
Number of CABGs*	1967	700	1200

*Since cardiac surgery training was completed.

Perceived Cognitive Workload: The analysis of perceived cognitive workload revealed significant variations across different surgical steps and roles. For instance, the highest cognitive demands were reported during steps such as "separate from bypass," "anastomoses," and "cannulation," while the lowest demands were noted in "sterile prepping" and "sternotomy." This variation in perceived workload underscores the differing cognitive challenges encountered by surgical team members at various stages of the procedure.

Misalignment in Cognitive Process: A notable variation was observed in cognitive processes between roles across different surgical steps. For instance, the steps 'clamp aorta and deliver cardioplegia' and 'anastomoses' showed the greatest misalignment between surgeons and anesthesiologists, with values of 12 and 10, respectively. These findings highlight specific stages in surgical procedure where misalignments in cognitive processes are most pronounced. Such discrepancies suggest areas where enhanced communication and coordination may be beneficial. The visualization underscores the steps with the greatest need for attention in terms of cognitive alignment, thereby providing a guide for targeted interventions to improve team performance and patient outcomes in surgical settings.

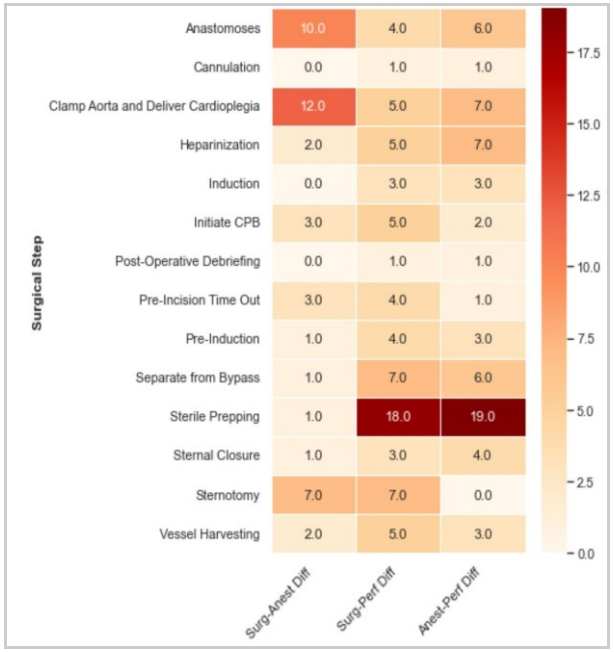

Figure. 1 Heatmap of cognitive process misalignments in CABG surgery

***Association of Misalignment of Cognitive Process and Team Perceived Cognitive Load*:** To evaluate the link between team-level perceived cognitive load and misalignment scores, we averaged both the misalignment scores and perceived cognitive loads across roles. We then analyzed their relationship using a nonparametric Spearman correlation, yielding a coefficient of 0.42 ($p < 0.01$). This indicates a moderate positive correlation, suggesting higher cognitive load is associated with increased misalignment.

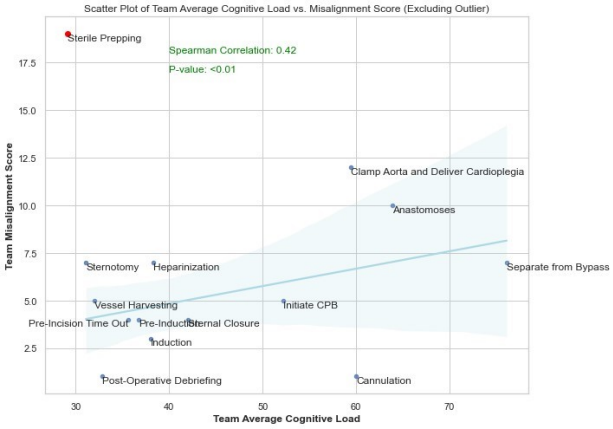

Figure. 2 Heatmap of cognitive process misalignments in CABG surgery

DISCUSSION

The findings of this study highlight significant variations in cognitive processes among surgeons, anesthesiologists, and perfusionists during CABG surgery. The identified misalignments in cognitive processes point to potential areas for improvement in team communication and collaboration. The positive correlation between team average cognitive load and misalignment score underscores the complexity of cognitive dynamics in surgical teams. It suggests that higher cognitive load could be a factor in exacerbating misalignments in understanding and approach among team members.

These findings are preliminary evidence for developing targeted interventions and training programs aimed at enhancing cognitive alignment in surgical teams. By addressing the identified gaps, such initiatives could lead to more synchronized and effective team performance, thereby improving patient safety and outcomes. Furthermore, the study contributes to the broader understanding of team dynamics in high-pressure medical environments, offering a framework that could be applied to other complex surgical settings. Future research could focus on extending this study to other types of surgeries and healthcare settings, to further validate and expand upon these findings.

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