HHS Public Access
Author manuscript
Am J Surg. Author manuscript; available in PMC 2024 July 10.

Published in final edited form as:
Am J Surg. 2023 September ; 226(3): 365–370. doi:10.1016/j.amjsurg.2023.06.010.

Demands of surgical teams in robotic-assisted surgery: An assessment of intraoperative workload within different surgical specialties

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Abstract

Background: Current approaches to assessing workload in robotic-assisted surgery (RAS) focus on surgeons and lack real-world data. Understanding how workload varies by role and specialty aids in identifying effective ways to optimize workload.

Methods: SURG-TLX surveys with six domains of workload were administered to surgical staff at three sites. Staff reported workload perceptions for each domain on a 20-point Likert scale, and aggregate scores were determined per participant.

Results: 188 questionnaires were obtained across 90 RAS procedures. Significantly higher aggregate scores were reported for gynecology (Mdn = 30.00) ($p = 0.034$) and urology (Mdn = 36.50) ($p = 0.006$) than for general (Mdn = 25.00). Surgeons reported significantly higher scores for task complexity (Mdn = 8.00) than both technicians (Mdn = 5.00) (p = 0.007), and nurses (Mdn = 5.00).

Conclusions: Staff reported significantly higher workload during urology and gynecology procedures, and experienced significant differences in domain workload by role and specialty, elucidating the need for tailored workload interventions.

Keywords

Workload; Robotic-assisted surgery; NASA-TLX; Cognitive ergonomics

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Declaration of competing interest
Dr. Cohen is the Secretary for the Society of Surgical Ergonomics and Dr. Catchpole has received honorarium from mBeta Healthcare, participates in a DSMB and has a leadership role in HFTH. Remaining authors report no conflicts of interest.

1. Introduction

Robotic-assisted surgery (RAS) is a minimally invasive surgical approach that involves a collaborative interaction between the surgeon and the robotic surgical system. Patients experience less blood loss, smaller incisions, decreased post-operative pain, and a reduced hospital stay compared to traditional surgical approaches.[1,2] For the surgeon, RAS provides benefits such as increased wrist dexterity and decreased tremors.[2] Despite these benefits, RAS introduces a myriad of new challenges for surgical teams in the operating room (OR) and for the wider hospital system. These challenges include increases in costs,[3] fluctuations to the OR environment,[4,5] changes to surgical team dynamics,[1,6] and impacts to physical and cognitive ergonomics, resulting from the surgeon being sequestered to the robotic console away from their surgical team.[7] Despite the availability of training, some OR staff with little or no prior experience may inevitably be staffed on robotic cases. Due to these complexities, cognitive skills that surgical teams develop to compensate for these challenges may degrade during the more complex phases of surgery, such as robot docking or console time.[8]

Workload refers to the interactions between task demands, their corresponding circumstances, and individual skills, behaviors, and perceptions.[9] It is crucial to investigate how cutting-edge technology impacts workload in surgical teams, as increases in demand diminish cognitive resources available to handle unanticipated occurrences, and may even result in burnout, career-ending injuries, or musculoskeletal disorders.[10] The measurement of workload in complex environments spans across a range of industries (e.g., aviation, manufacturing, clinical) and include: (1) objective physiological measures such as eye-tracking[11] and heart rate variability;[12] and (2) subjective measures such as the NASA Task Load Index (NASA-TLX).[9] Although a number of methods exist to assess intraoperative workload, the use of the NASA-TLX and its adaptations remain the most popular approach to date.[13,14]

To discriminate between sources of stress within surgical settings, a validated adaptation known as the SURG-TLX was developed in a similar six-domain structure as the original: (1) *mental demand*; (2) *physical demand*; (3) *temporal demand*; (4) *task complexity*; (5) *situational stress*; and (6) *distractions*.[15] Participants report their perceived levels of workload for each of the six domains on a 20-point Likert scale (where the anchors for 1 and 20 are *low* and *high* for the first three domains, and *not very* and *very* for the latter three domains), and scores for each are summed to produce an aggregate workload score. Studies have estimated the threshold at which physician performance decreases and the potential for patient harm increases to be workload scores approaching 50 or higher.[16,17] Higher mental and physical demand have been associated with inadvertent tissue injuries,[10] however no thresholds currently exist for individual domains.

Some studies have reported reduced workload for surgeons during RAS compared to procedures performed open or laparoscopically,[18,19] although a recent review identified mixed results among studies comparing this approach to these other modalities.[20] Furthermore, these findings are mainly derived from studies conducted in simulated settings (70%).[19] Investigating workload perceptions through the six domains of the SURG-TLX remains underexplored in RAS and could elucidate underlying challenges that an aggregate score may overlook.[21] Despite playing an instrumental role in the workflow of the OR environment, studies assessing intraoperative workload focus mainly on attending surgeons and/or surgical residents and overlook the experiences of OR staff (e.g., anesthesia providers, circulating nurses, and surgical technicians). Conversely, these varied perceptions among surgical team members have been investigated previously in laparoscopic surgery.[21,22]

Despite these shortcomings, exploring varied workload perceptions among different roles remains critical to improving safety and efficiency, promoting staff well-being, and enhancing team dynamics in the OR. With the knowledge of work system challenges observed in RAS, it is crucial to further understand how demands may differ amongst surgical specialties with varying complexities and how each OR staff member may be impacted. Doing so would generate opportunities for interventions aimed at addressing and optimizing excessive workloads tailored to address role-specific or procedure-specific trends.

The aim of the current study is to quantify the workload experienced by all surgical personnel involved in RAS, across different surgical specialties. By assessing the specific cognitive and physical demands faced by different staff members in their natural setting, these efforts can inform strategies to optimize workload and promote the overall well-being of robotic surgical teams during RAS while improving patient safety.

2. Methods

This prospective study was conducted between July 2019 and April 2022, across three sites (site 1: an academic medical university in Charleston, SC; site 2: a tertiary, academic medical center in Los Angeles, CA; site 3: a community hospital in Marina del Rey, CA). The research protocol was approved by the Institutional Review Board at each site and a waiver of consent was obtained (site 1: Pro00088741; site 2/3: Pro00056245).

2.1. Participants

Data were collected after bariatric, general, gynecologic, and urologic robotic-assisted procedures that were performed using the da Vinci Xi robot. Staff participation in this study was voluntary and participants remained anonymous. Surgeons, anesthesia providers, circulating nurses, and surgical technicians were recruited from each site as a convenience sample, as this study was part of a larger observational study to improve robotic safety, efficiency, and team dynamics.[23] Included within the surgeon and anesthesia groups were any surgeons in training (e.g., residents or fellows), and any anesthesia providers (e.g., anesthesia residents or certified registered nurse anesthetists).

2.2. Measures

Procedure type and length of duration were extracted for each case. The validated SURG-TLX measure was used to assess individual, subjective workload (Fig. 1). This adaptation of the NASA-TLX was deemed more appropriate due to the different surgical specialties included in the study (which may lead to varying procedural complexity). Questionnaires were administered to surgical staff by trained human factors researchers immediately after the completion of the surgical procedure or as the patient was being prepared to be wheeled out to recovery. Researchers used a touchscreen, macro-enabled questionnaire via Microsoft Excel, internally tested for usability, with a dropdown menu selection of 1–20 for each question.

2.3. Data analysis

Analyses were performed using IBM SPSS Statistics (Version 24) and Microsoft Excel. A composite SURG-TLX score was calculated for each participant by summing their scores for the six domains. Means and standard deviations were reported for quantitative variables (e.g., procedure duration; SURG-TLX scores), while count totals and percentages were reported for categorical variables (e.g., surgical specialty, surgical role). A Kruskal-Wallis test was conducted to determine any differences in median SURG-TLX scores by surgical role or surgical specialty overall and for each domain. Post-hoc pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons, and p values < 0.05 were considered significant.

3. Results

188 SURG-TLX questionnaires were obtained from surgical staff across 90 unique robotic-assisted procedures. Table 1 includes the breakdown of participant role and distribution of cases by specialty type by site, as well as their average duration. The following procedures were included within each specialty: *bariatric* = sleeve gastrectomy with hiatal hernia repair (n = 3), sleeve gastrectomy (n = 1), conversion to sleeve (n = 1); *general*: inguinal hernia repair (n = 27), ventral hernia repair (n = 6), hiatal hernia repair (n = 5), cholecystectomy (n = 2), incisional hernia repair (n = 1), umbilical hernia repair (n = 1); *gynecology*: hysterectomy without sacrocolpopexy (n = 14), hysterectomy (n = 3), hysterectomy without urethral sling (n = 1); *urology*: radical prostatectomy (n = 12), partial nephrectomy (n = 9), simple prostatectomy (n = 3), total nephrectomy (n = 1). The average duration across all cases was 223.70 min (SD = 74.92), with the lengthiest operative times belonging to urology (M = 278.39 min, SD = 52.84) and gynecology (M = 264.54 min, SD = 67.35) cases. Circulating nurses (n = 64, 34.04%) and surgeons (n = 52, 27.66%) made up the greatest number of participants.

3.1. Aggregate workload by surgical role and specialty

Results showed that participants had an average subjective workload of 32.65 (SD = ± 18.77). Although surgeons and surgical technicians had an aggregate subjective workload score that was higher (M = 34.85, SD = ± 16.24; M = 33.83, SD = ± 19.99) than circulators and anesthesia providers (M = 32.20, SD = ± 20.07; M = 28.13, SD = ± 17.20), there was no significant difference in perceived scores across surgical roles, $\chi 2(3) = 3.494$, $p = 0.322$. A positive linear trend was observed between operative duration and aggregate subjective workload scores (Fig. 2). Overall, 39 participants (20.7%) from 29 cases reported workload scores above 50, of which were reported primarily during urology procedures (n = 13, 44.83%) and were mainly surgeons (n = 14, 35.90%) and circulating nurses (n = 11, 28.20%).

A significant difference was found in median workload scores between surgical specialties, $\chi 2(3) = 14.297$, $p = 0.003$. A post-hoc analysis revealed significantly higher aggregate scores for gynecology (Mdn = 30.00) ($p = 0.034$) and urology (Mdn = 36.50) ($p = 0.006$) than for general (Mdn = 25.00). Interactions between role and specialty were not assessed, however, surgeons and circulators reported higher scores on average during urology procedures (M = 45.13, SD = ± 15.66; M = 38.94, SD = ± 25.12), while higher scores were reported during bariatric procedures for anesthesia providers (M = 33.00, SD = ± 28.61) and during gynecology procedures for surgical techs (M = 41.71, SD = ± 20.76) (Table 2).

3.2. Domain workload by surgical role and specialty

Results indicated significant median score differences between surgical roles solely for task complexity, $\chi 2(3) = 14.678$, $p = 0.002$ (Fig. 3). A post-hoc analysis revealed significantly higher scores for surgeons (Mdn = 8.00) than surgical technicians (Mdn = 5.00) ($p = 0.007$) and circulating nurses (Mdn = 5.00) ($p = 0.007$). No significant differences were observed by role in other domains. Between surgical specialties, median scores significantly differed for mental demand, $\chi 2(3) = 10.493$, $p = 0.015$, physical demand, $\chi 2(3) = 11.542$, $p = 0.009$, task complexity, $\chi 2(3) = 18.111$, $p = 0.000$, and situational stress, $\chi 2(3) = 10.489$, $p = 0.015$ (Fig. 3). Post-hoc analyses revealed significantly higher median scores in gynecology compared to general for mental demand (Mdn = 5.00 – gynecology, Mdn = 4.00 – general, $p = 0.046$), physical demand (Mdn = 5.00 – gynecology, Mdn = 4.00 – general, $p = 0.012$), and situational stress (Mdn = 5.00 – gynecology, Mdn = 3.00 – general, $p = 0.017$). Moreover, scores in urology (Mdn = 10.00) were significantly higher than in general (Mdn = 5.00) for task complexity ($p = 0.000$).

4. Discussion

This study assessed the subjective workload perceptions of 188 surgical team members using the SURG-TLX, across 4 different RAS specialties. Current studies suggest that a robotic approach reduces or eliminates workload associated with traditional surgical approaches, but roughly one-fifth of the participants reported scores that exceeded the threshold of 50, attributed mostly to surgeons. It also appears that workload perceptions remain higher for some specialties more than others, which emphasizes the need for workload in RAS to be optimized further. We demonstrated that overall workload significantly differs by surgical specialty, suggesting that the individual pain points of staff may derive from unique demands within certain surgery types. Moreover, when discriminating between sources of workload considerable differences were observed related to surgical role and specialty within each of the six domains of the SURG-TLX.

The average workload across all participants and surgical specialties was 32.65, which is consistent with prior research in RAS.[24] On average, surgeons and surgical technicians reported higher aggregate scores however, there were no significant differences observed between surgical roles. Aggregate workload scores were significantly higher in gynecology and urology procedures which may be related to these specialties encompassing very strenuous or complex surgery types. In fact, most scores that exceeded the threshold of 50 derived primarily from urology cases (44.8%), which included primarily robotic partial nephrectomy and robotic radical prostatectomy procedures. Moreover, surgeons and circulating nurses reported workload scores above 50 more frequently than the other roles, which helps us understand that these roles may be more susceptible to experiencing levels of workload that may pose a risk to surgical performance and patient safety. These findings may be due to extensive human-robot interactions required of surgeons and numerous responsibilities for nurses outside of the sterile field that are necessary for safety and efficiency in RAS.

In the domains of the SURG-TLX, significantly higher workload scores were reported for surgeons than both circulating nurses and surgical technicians for the task complexity domain, reflecting the demand that gets placed on attendings and surgical trainees in this complex environment. Due to physical separation from the surgical team at the patient's bedside, surgeons are confined to the robotic console for a significant portion of the procedure and face the challenge of finding innovative methods to maintain situational awareness and closed-loop communication amongst team members despite these barriers. This suggests that their workload may be critically impacted by the overall complexity of an RAS procedure, which can be attributed to the heightened cognitive demands required, coupled with ergonomic challenges.

Between surgical specialties, domain scores for participants were significantly higher in gynecology than general procedures for mental demand, physical demand, and situational stress. Vaginal surgery teams encounter significant ergonomic challenges in their limited workspaces, resulting in an 87% prevalence of musculoskeletal disorders among vaginal surgeons.[25] Although a robotic approach may aid in reducing these challenges for surgeons, surgical technicians remain responsible for steadily holding the anatomy in place as the bedside assistant or maintaining the surgeon's visualization by working with the bedside assistant to suction all liquids through the assistant port and handling all instruments.[26] Nonetheless, the unique demands imposed by RAS in gynecology remain underexplored and warrant further investigation. Furthermore, participant scores for task complexity were significantly higher for urology than general procedures. Hernia repairs within general surgery tend to be simpler and quicker in contrast to the considerably longer and more intricate urologic procedures, which include partial nephrectomy and radical prostatectomy. Although our study didn't assess interactions between surgical roles and specialty, both surgeons and circulating nurses reported higher aggregate workload scores, on average, for urology cases than any other specialty. For a surgeon, these procedures tend to be higher risk as patient factors[27] and increased risk of intraoperative blood loss related to longer procedure duration may increase the complexity of surgery.[28] In the case of partial nephrectomy, renal loss may occur if not performed expeditiously. Similarly, for a circulating nurse whose duties span across all phases of surgery, it is not surprising that they experienced higher workload during procedures with the longest average duration (nearly 5 h) as they are responsible for coordinating tasks within and outside of the OR (e.g., robot docking, transfers to PACU), ensuring all necessary equipment is readily available in the OR (and retrieving it if not), as well as resolving all robotic equipment malfunctions over a prolonged period of time.[29]

Our findings suggest that modifications to RAS configurations are warranted in order to optimize workload perceptions amongst staff members, especially within surgical specialties with more complicated procedures. Although individual scores for the SURG-TLX domains don't reveal levels at which safety may be at risk, they assist in narrowing in on the pain points of each surgical role during procedures within different surgical specialties. Developing specialized interventions and training methods for novel or current surgical staff that are specific to different RAS procedure types would help support staff in successfully strengthening their range of skillsets, rather than assume a one-size-fits-all approach is best. Raheem et al.[29] and Bissonette et al.[26] have each developed guides for specific surgical roles (e.g., nursing staff, bedside assistants), for specific specialties (e.g., urology, gynecology) that eluciate the complexities of their roles within these procedures. This approach enhances training by diving deeper into each roles' skillsets that are necessary to deliver quality care in these specific environments. Surgeons may benefit from interventions focused mainly on improving ergonomics and burnout in more complex surgical cases, however the entire team may benefit from interventions such as 'micro breaks' developed specifically to enhance mental and physical function.[30] Navigating new technology can be cumbersome, and a focus group of circulating nurses revealed that many experienced stress related to resolving intraoperative technical malfunctions due to the lack of available training.[31] Game-based approaches to training would be a great alternative to specialized guides for OR staff, as they could be adapted to target skillsets for specialties they lack expertise in. To tackle these challenges, an engaging alternative to traditional teamwork training, the Robotic-Assisted Surgery Olympics, was recently developed by our team wherein surgical teams can practice robot docking, instrument exchanges, and troubleshooting equipment issues efficiently through a competitive teamwork exercise.[32]

4.1. Limitations

Like most subjective methods, our data may be limited by recall bias as participants' subjective workload is not measured in real-time and is instead collected post-surgery. Our team made every effort to retain a sound methodology, however in real-world settings, the NASA-TLX inevitably presents hidden, methodological challenges that must be considered such as insensitivity to fluctuations in workload and staff rotations.[14] The lack of data from traditional surgical methods such as open or laparoscopic surgery in our study limited our ability to make comparisons between surgical approaches; however, this is something we hope to explore in the future as this area remains underexplored in real-world settings. Individual and extraneous factors such as gender, site-specific differences, and especially the impact of the global coronavirus pandemic (i.e., staff configurations, surgical caseload per day) may have impacted workload perceptions, therefore future studies would certainly benefit by further investigating these factors. Our study did not measure learning curves which could potentially result in higher workload for surgeons who are in the early stages of their learning curve for RAS, nonetheless, surgeons may achieve competence with fewer cases. Differences in workload perceptions may arise due to varying levels of experience among staff. While grouping together surgical and anesthesia trainees with senior-level staff may not be reflective of their respective workload perceptions, it is worth noting that both provide similar care during surgical procedures. Nonetheless, future studies should explore these differences further in RAS amongst other essential surgical staff including surgical or physician assistants.

Despite these shortcomings, our data adds to the growing body of literature exploring the impact of novel technology on ergonomics in real-world surgical settings. This study has important implications for the design and assessment of robotic integration in the OR, and it is important for the entire team to be part of these considerations. In future analyses, we hope to assess the relationship between higher levels of workload and observed performance through observational analyses of workflow disruptions to identify specific RAS configurations that may be jeopardizing safety for surgical teams and patients in the OR.

5. Conclusion

We cannot expect to improve surgical ergonomics, staff wellbeing, and intraoperative performance in RAS without acknowledging and understanding how workload differs for different team members within varied surgical specialties. This study further supports the need for workload optimization and interventions tailored to address the needs of each surgical role unique to more complex RAS specialties, to improve well-being and deliver quality patient care.

Funding

This project was funded under grant number HS026491-01 by the Agency for Healthcare Research and Quality (AHRQ), U.S. Department of Health and Human Services (HHS).

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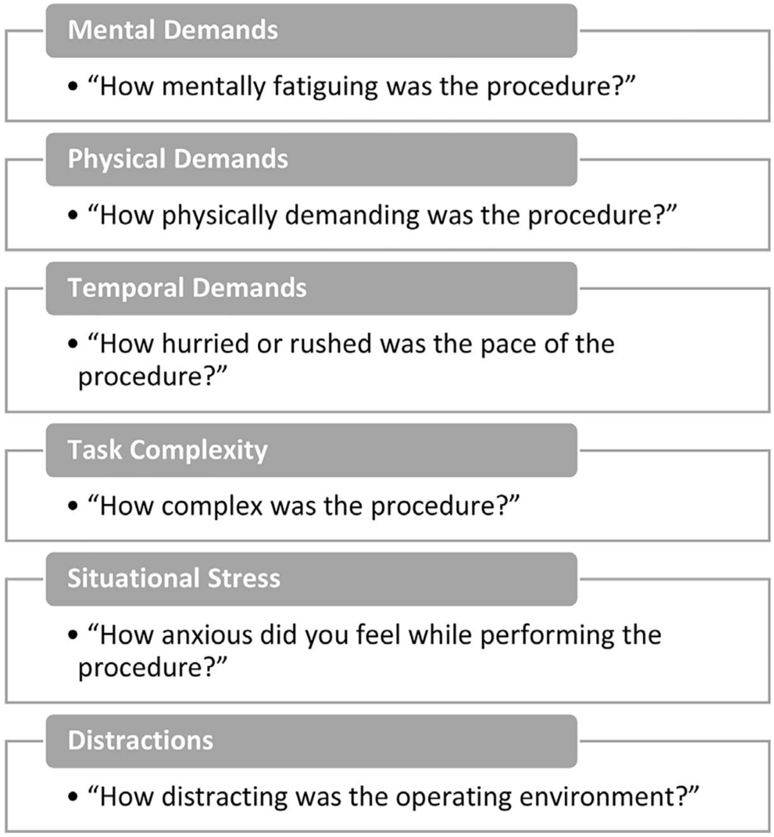

Fig. 1.
The SURG-TLX questionnaire administered to participants.

Fig. 2.

A plot of the relationship between aggregate TLX scores and operative duration, highlighting those exceeding a threshold of 50 or higher.

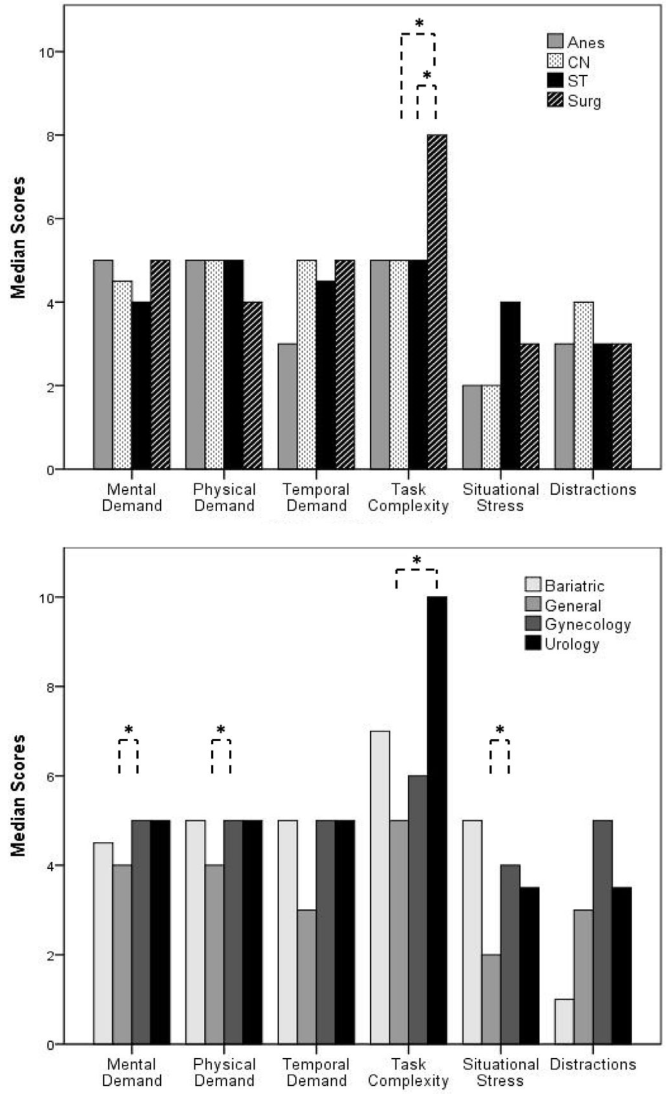

Fig. 3.

Median SURG-TLX workload scores by surgical role and specialty, broken down by the six domains on a scale of 0–20. Significant pairwise comparisons ($p < 0.05$) are marked with an asterisk (*).

Table 1

Distribution of cases included by specialty per site, distribution of questionnaires collected by surgical role per site, and mean duration for each specialty and overall.

Site	Bariatric	General	Gynecology	Urology	Total Per Site
1	2	23	15	21	61
2	2	10	3	4	19
3	1	9	0	0	10
Total Cases	**5**	**42**	**18**	**25**	**90**
Mean Duration (SD)	170.97 (30.64)	180.77 (62.17)	262.54 (67.35)	278.39 (52.84)	223.70 (74.92)
Site	***Anes*: Anesthesia Provider**	***CN*: Circulating Nurse**	***ST*: Surgical Technician**	***Surg*: Surgeon**	**Total Per Site**
1	19	47	23	27	116
2	6	10	13	16	45
3	5	7	6	9	27
Total Collected	**30**	**64**	**42**	**52**	**188**

Table 2

Average SURG-TLX and average domain workload scores per procedure type for each surgical role, reported as M (SD). Bolded values refer to the highest average workload score reported per role.

Role	Specialty	Aggregate TLX	Mental Demand	Physical Demand	Temporal Demand	Task Complexity	Situational Stress	Distractions
Surgeon	*Bariatric*	25.00 (4.24)	4.50 (0.71)	5.50 (2.12)	4.00 (4.24)	6.00 (1.41)	4.00 (4.24)	1.00 (0.00)
	General	27.44 (15.04)	5.26 (4.65)	3.89 (3.03)	3.74 (2.82)	7.81 (4.08)	3.63 (3.84)	3.11 (2.69)
	Gynecology	43.00 (14.43)	8.13 (4.67)	7.63 (3.54)	4.88 (2.59)	9.38 (3.50)	6.50 (5.53)	6.50 (2.67)
	Urology	**45.13 (15.66)**	8.07 (4.85)	7.00 (4.29)	6.87 (3.72)	12.00 (4.60)	6.80 (4.62)	4.40 (3.31)
Anesthesia Provider	*Bariatric*	**33.00 (28.61)**	5.75 (6.40)	6.75 (7.04)	4.75 (3.86)	7.25 (4.92)	5.25 (4.43)	3.25 (4.50)
	General	25.00 (17.82)	4.50 (4.27)	5.08 (4.48)	3.42 (3.34)	5.83 (5.17)	2.50 (2.81)	3.67 (4.16)
	Gynecology	28.44 (15.29)	5.11 (1.83)	5.00 (2.00)	4.11 (2.80)	4.56 (1.59)	4.44 (5.29)	5.22 (4.21)
	Urology	31.20 (11.17)	6.40 (2.51)	5.20 (2.28)	2.40 (1.95)	9.00 (2.00)	3.80 (2.17)	4.40 (3.71)
Circulating Nurse	*Bariatric*	33.25 (18.14)	5.50 (3.70)	6.75 (3.86)	5.00 (3.74)	7.00 (2.94)	3.50 (3.7)	5.50 (4.12)
	General	27.13 (18.78)	4.37 (3.56)	5.17 (4.09)	5.07 (4.51)	5.00 (4.09)	3.27 (3.76)	4.27 (3.71)
	Gynecology	34.77 (14.21)	6.15 (4.54)	7.31 (4.29)	4.92 (2.90)	6.23 (3.77)	5.00 (4.06)	5.15 (4.83)
	Urology	**38.94 (25.12)**	6.29 (4.40)	6.12 (5.18)	7.00 (5.79)	9.41 (6.11)	4.59 (4.74)	5.53 (4.94)
Surgical Technician	*Bariatric*	37.25 (27.50)	5.00 (3.56)	7.50 (8.43)	8.50 (8.10)	4.25 (2.22)	8.50 (8.19)	3.50 (4.51)
	General	31.42 (18.58)	5.08 (4.29)	5.42 (4.23)	4.83 (4.29)	5.21 (2.89)	5.25 (5.97)	5.63 (5.27)
	Gynecology	**41.71 (20.76)**	6.43 (4.58)	6.14 (4.56)	7.00 (5.54)	7.71 (3.50)	9.00 (6.48)	5.43 (2.76)
	Urology	32.29 (22.19)	3.86 (3.13)	6.14 (6.57)	7.57 (7.52)	9.00 (8.56)	3.00 (3.32)	2.71 (3.35)