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RESEARCH

The stress for surgeons: exploring stress entities with the robotic senhance surgical system

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Abstract

Robotic surgery is on its way to revolutionizing traditional surgical procedures, offering precise and minimally invasive techniques hypothesized to shorten recovery times and improve patient outcomes. While there have been multiple publications on robotic systems' medical and procedural achievements, more emphasis should be put on the surgeon's experience, especially in comparison with laparoscopic surgery. The present report aims to systematically examine the stress impact on surgeons by comparing the robotic Senhance Surgical System (Asensus Surgical, Durham, North Carolina, U.S.A) to laparoscopic surgery. The well-established "SURG-TLX" survey is used to measure distinct stress entities. The "SURG-TLX" survey is a modified version of the NASA-TLX, validated for surgery by M. Willson. Based on a comprehensive database from six centers encompassing various disciplines and surgical procedures, our analysis indicates significantly reduced "overall stress" levels for robotic (cockpit) compared to laparoscopic surgeons. Exploring the "SURG-TLX" stress dimensions further between methods (robotic vs. laparoscopic) and surgeon position (laparoscopic, (robotic) bedside, or (robotic) cockpit) resulted in significantly more Mental (p.value < 0.015), less Physical Demands (p.value < 0.001) and less Distraction (p.value < 0.009) for robotic surgery, especially regarding the robotic cockpit surgeons. This finding suggests that robotic surgery with the Senhance Surgical System contributes to a favorable stress profile for surgeons, potentially enhancing their overall well-being and performance.

Keywords Robotic surgery · Robotic urology · Robotic gynaecology · Stress · Surg TLX · Augmented intelligence

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Introduction

Robotic surgery has emerged as a groundbreaking approach in modern medicine, representing a technical evolution of existing surgical procedures. By combining the precision of robotic systems with the dexterity of skilled surgeons, this technology has opened new possibilities for minimally invasive surgeries. While technological advancements have brought numerous patient benefits [1], they have also introduced unique changes. Based on current research, it is found that the ergonomic seating of the robotic surgeon can sustainably contribute to less physical stress and distraction [2]. Physical stress is a chronic issue in traditional surgery, drastically impacting health and work–life balance. A study by Adams and colleagues [3] illustrated that 1/3 of surgeons in gynecology use chronic pain medication multiple days a week to cope

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with muscle pain. Another publication [4] found that 26% of retired surgeons concluded their careers due to work-related physical disabilities caused by pain. However, specific new stressors might add new challenges for robotic surgeons. In detail, surgeons operating robotic platforms might face increased cognitive demands as they adapt to new interfaces and handle complex equipment [5].

Intriguingly, artificial stress scenarios in robotic surgery have been evaluated on stress [6–12], but data based on real stress conditions are sparse [13–15]. Study settings are additionally mostly based on the Da Vinci Robotic System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) [11, 13] and can thus not be generalized for all robotic systems. The Senhance Surgical System (Asensus Surgical, Durham, North Carolina, U.S.A.) is a relatively novel system on the market and was created with several improvements (see below). So far, it has been investigated for diverse aspects of surgery, such as patient outcomes [16, 17]. However, investigations on stress levels with the Senhance Surgical System in present literature are lacking. Given its haptic feedback and eye-tracking camera with 3D vision, it displays remarkable features that might contribute to reduced stress levels during surgery. Especially haptic feedback, which suggests a similar hand-tissue experience as in laparoscopic surgery, enhances the surgeon's confidence during procedures. Furthermore, the open console enhances team communication, while the surgeon's comfortable seating position with an angled footrest provides a relaxing benefit. A small but important aspect is the surgeon's self-management of the robotic arms, including the (eye-tracking) camera, which is likely to add convenience, reduce stress, and minimize distraction. Despite the notable innovation, the technical foundation of robotic surgery is derived from laparoscopy, and its approach closely mimics the principles of laparoscopy. Therefore, experienced surgeons are expected to require a short learning curve, and a 3-day training program helps the transition to robotic surgery with the Senhance Surgical System.

In the present report, we aim to systematically examine the impact of stress on surgeons in the context of robotic surgery with the Senhance Surgical System, also compared to laparoscopic surgery. By employing the "SURG-TLX" survey, we aim to measure and evaluate the overall stress experience in its various entities. The "SURG-TLX" survey is based on the well-established subjective workload assessment NASA Task load index ("NASA TLX", 18) and was modified and validated for surgery by Mark R. Wilson [19]. Based on a multi-sited survey, we seek to conclude results that display representable stress for distinct surgical procedures and different disciplines (e.g., general surgery, urology, and gynecology) with the Senhance Surgical System, also compared to laparoscopic surgery.

Methods

Procedure

Surgeons who conducted procedures in general surgery (Cholecystectomy, Inguinal Hernia (Uni- and Bilateral), Right Hemicolectomy, Left-Sided Colorectal Resections, Fundoplication, Sleeve gastrectomy, Hiatal Hernia), urology (Radical Prostatectomy), and gynecology (Total Hysterectomy) with the Senhance Surgical System or via laparoscopic surgery were asked to answer the "SURG-TLX" survey questionnaire (see below) within 15 min after completing surgery. The included procedures rank amongst the most frequently performed ones with the Senhance Surgical System. Data were collected from senior surgeons in six centers, including the Evangelisches Hospital Wesel, Wesel, Germany; Hospital Landshut-Achdorf, Landshut, Germany; Hospital Esslingen, Esslingen, Germany; University Hospital Center Zagreb, Zagreb, Croatia; Klaipeda University Hospital, Klaipeda, Lithuania; Mount Sinai Hospital, Chicago, IL, US. These centers (besides Mount Sinai Hospital) form the TRUST Registry group (The TransEnterix European Patient Registry for Robotic-assisted Laparoscopic Procedures in Urology, Abdominal Surgery, Thoracic, and Gynecologic Surgery). The TRUST Registry is an open-label, prospective, and retrospective multicenter registry study and aims to explore safety and efficacy of the Senhance Surgical System. In context of the survey, patient data were not collected nor investigated.

Questionnaire

The "SURG-TLX" questionnaire consists of three parts. The first part defines the procedure, procedural method (robotic or laparoscopic surgery), and surgeon's role during procedure (laparoscopic, (robotic) bedside, or (robotic) cockpit), as well as identifies the surgeon. Of note, the laparoscopic role combines both laparoscopic main and assistant surgeon. In the second part, the surgeon rates overall situational stress experience in its various entities. Stress levels of six dimensions are indicated on a rating scale ranging from 0 to 100, with 0 meaning non-existing stress and 100 representing maximal stress. The following presents the six stress categories with the related questions: Mental Demands (How mentally fatiguing was the procedure?), Physical Demands (How physically fatiguing was the procedure?), Temporal Demands (How hurried or rushed was the pace of the procedure?), Task Complexity (How complex was the procedure?) Situational Stress (How anxious did you feel while performing the procedure?), Distractions (How distracting was the operating environment?). Each entity stands alone, describing distinct situations, and is evaluated individually. In the final part, all 6 categories are paired with each of the other categories, which lead to 15 questions in total, displaying the paired superiority questionnaires. These either–or questions are answered by selecting which one of the two was weighed more important for the particular procedure. The “superiority” (i.e., more important) entity was then counted for each of the 15 answers, leading to a result not apparent to the surgeon answering the questions. The superiority number (0–5) for each stress entity is multiplied by the rating scale (0–100). Therefore, results can range from 0 to 500. For the “Overall Stress” score, the results of all the 15 multiplications are added and divided by 15.

Besides presenting the overall outcome of the "SURG-TLX" questionnaire and the outcome for the six questionnaire dimensions, we compared stress categories by methods per distinct procedures. We opted to include only those procedures registered with $N \geq 10$ (applied for robotic and laparoscopic surgery).

Finally, we also compared differences in stress scores between surgeon positions (laparoscopic vs. (robotic) bedside and laparoscopic vs. (robotic) cockpit) to further explore differences in stress experience and exposure.

Statistics

Statistics were performed by a senior statistician. The parametric *t*-test was used for statistical analysis, and results were displayed as mean and standard deviation (sd). Statistical relevance was defined as p-value ≤ 0.05. Procedures were counted and summed per method (robotic vs. laparoscopic surgery). The stress dimension scores were calculated per method (robotic vs. laparoscopic surgery, laparoscopic vs. (robotic) bedside, and laparoscopic vs. (robotic) cockpit) and compared between the methods. Results were not available until data collection was completed.

Results

Procedure

A total of 33 surgeons performed 350 surgeries, resulting in respective 350 "SURG-TLX" questionnaires. 287 surgeries were performed with the Senhance Surgical System, while 63 were operated via laparoscopic surgery. Regarding the surgeon’s role in robotic surgery, 97 questionnaires were obtained from a bedside role and 190 from a cockpit surgeon. In Table 1**,** procedures and case distribution are presented.

Table 1 Overview of performed procedures

Procedure	Total $N=350$	Robotic $N=287$	Laparoscopic $N=63$
Radical Prostatectomy	126	113	13
Cholecystectomy	57	42	15
Fundoplication	36	35	1
Left-sided colorectal resections	36	28	8
Total hysterectomy	25	11	14
Inguinal hernia bilateral	25	23	2
Inguinal hernia unilateral	24	15	9
Right hemicolectomy	9	8	1
Inguinal hernia	9	9	–
Sleeve gastrectomy	2	2	–
Hiatal hernia	1	1	–

Displayed as a total and summed per method. Robotic = robotic surgery with Senhance Surgical System. Laparoscopic = laparoscopic surgery

Questionnaire outcome

Robotic vs. laparoscopic

Our results show that most stress in robotic surgery (cockpit and bedside surgeon) was experienced regarding Task Complexity (mean = 143 ± 108.25) and Mental Demands (mean = 83.64 ± 83.13). With a focus on laparoscopic surgery (laparoscopic main and assistant surgeon), we found the highest stress ratings for Physical Demands (mean = 140 ± 126.78) and Task Complexity (mean = 126.59 ± 103.81). In contrast, Mental Demands scored the lowest (mean = 46.97 ± 56.44). A full overview can be found in Table 2. Comparing both methods, our results presented no significant difference in the “Overall Stress” level between robotic (cockpit and bedside surgeon) and laparoscopic (main and assistant surgeon) surgery (Robotic: mean = 31.94 ± 18.18, Laparoscopic: mean = 34.3 ± 21.75, p.value = 0.427). However, Mental Demands were significantly higher in robotic surgery compared to laparoscopic surgery (Robotic: mean = 83.64 ± 83.13, Laparoscopic: mean = 46.97 ± 56.44, p.value < 0.001), while Physical Demands were reduced considerably in robotic surgery (Robotic: mean = 67.21 ± 99.03, Laparoscopic: mean = 140.35 ± 126.78, p.value < 0.001). Distraction showed a trend of lower robotic than laparoscopic ratings (Robotic: mean = 62.58 ± 77.23, Laparoscopic: mean = 81.38 ± 89.12, p.value = 0.090). Stress levels for Temporal Demands, Task Complexity, and Situational Stress were insignificant between groups (p.value ≥ 0.273). A respective overview can be found in Table 2.

Table 2 Overview of stress category result

Stress category	Method	Mean	Sd	*p*.value[a]
Overall stress	Robotic	31.94	18.18	0.427
	Laparascopic	34.3	21.75	
Mental demands	Robotic	83.64	83.13	**< 0.001**
	Laparascopic	46.97	56.44	
Physical demands	Robotic	67.21	99.03	**< 0.001**
	Laparascopic	140.35	126.78	
Temporal demands	Robotic	56.32	80.02	0.702
	Laparascopic	52.87	60.68	
Task complexity	Robotic	143	108.25	0.273
	Laparascopic	126.59	103.81	
Situational stress	Robotic	66.43	62.6	0.989
	Laparascopic	66.27	81.22	
Distractions	Robotic	62.58	77.23	0.09
	Laparascopic	81.38	89.12	

Displayed as mean and sd per method. Robotic = robotic surgery with Senhance Surgical System. Laparoscopic = laparoscopic surgery

[a]Based on Welch Two Sample *t*-test

Bold value indicates statistical different value $p < 0.001$

Methods per distinct procedures

A further step in analysis was to compare the stress category results by methods per distinct procedures. This resulted in comparing three procedures: Cholecystectomy, Radical Prostatectomy, and Total Hysterectomy. Our results revealed Radical Prostatectomy to be the overall most stressful procedure in both robotic and laparoscopic surgery, with significantly lower ratings for robotic surgery (Robotic: mean = 44.07 ± 19.37, Laparoscopic: mean = 63.79 ± 14.28, p.value ≤ 0.001, see Fig. 1). Regarding the stress dimensions, Physical Demands (Robotic: mean = 122.7 ± 127.6, Laparoscopic: mean = 228.46 ± 146.26, p.value = 0.006) and Distraction (Robotic: mean = 87.35 ± 102.05, Laparoscopic: mean = 207.69 ± 103.03, p.value ≤ 0.001) during Radical Prostatectomy presented significantly reduced scores in robotic surgery (Fig. 1). Total Hysterectomy and Cholecystectomy showed below-average stress results (compared to Table 2, see Supplementary Table 1) and did not differ between methods for most stress entities (p.value ≥ 0.057). Only Cholecystectomy showed significantly higher Task Complexity for laparoscopic surgery (Robotic: mean = 55.48 ± 60.73, Laparoscopic:

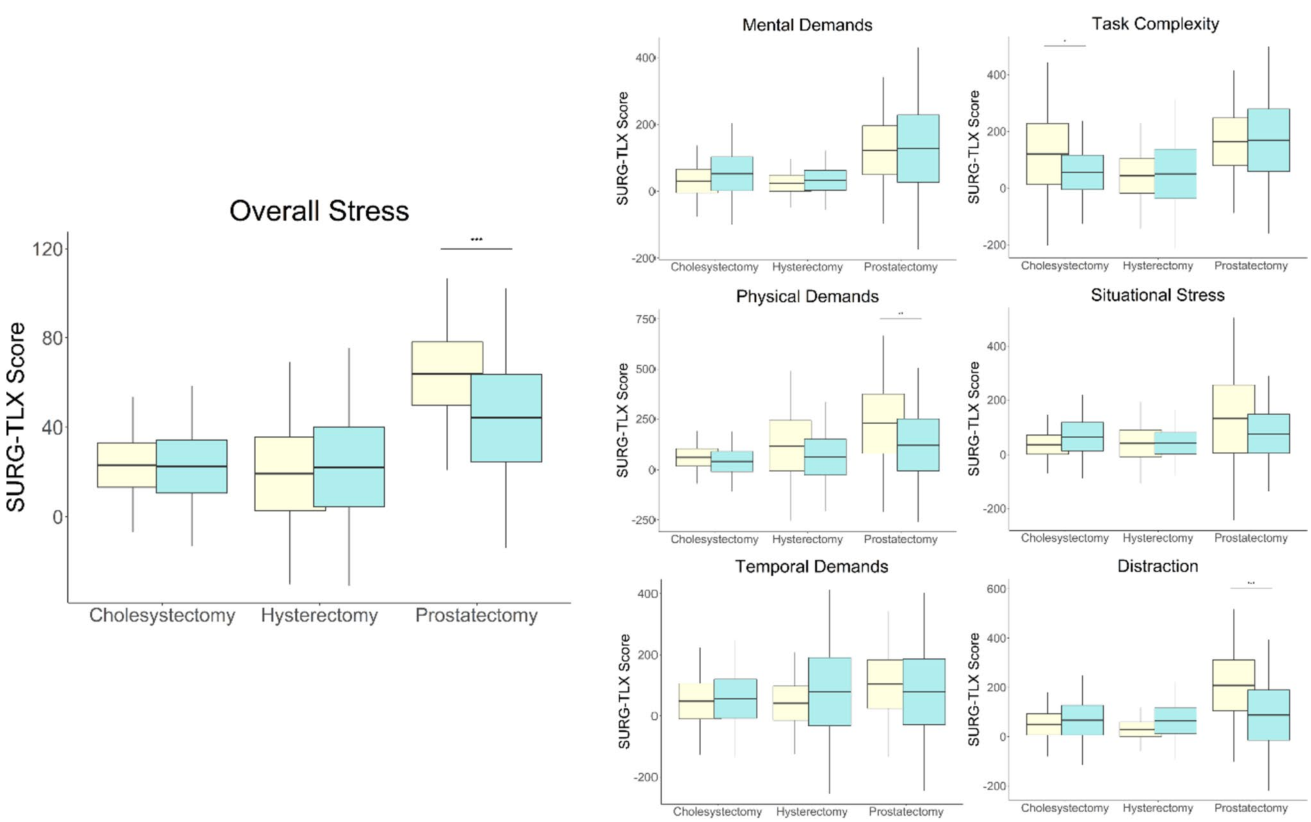

Fig. 1 Boxplots presenting scores for Overall Stress and the six stress dimensions. Based on the SURG-TLX questionnaire. Yellow boxplots present laparoscopic surgery scores, while blue presents robotic surgery scores with the Senhance Surgical System. A significant difference is indicated with a horizontal line. *Represents p.value < 0.05, **p.value < 0.01, ***p.value < 0.001

mean = 120.33 ± 107.55, p.value = 0.041). A detailed overview can be found in Supplementary Table 1.

Surgeon position

Additionally, we explored experienced stress between laparoscopic, (robotic) bedside, and (robotic) cockpit surgeons. Addressing the "Overall Stress" score, cockpit surgeons experienced significantly less stress than laparoscopic surgeons (Cockpit: mean = 27.13 ± 14.96, Laparoscopic: mean = 34.30 ± 21.75, p.value = 0.018). Mental Demands indicated significantly higher scores (Cockpit: mean = 69.79 ± 80.14, Laparoscopic: mean = 46.97 ± 56.44, p.value = 0.015), while Physical Demands were reduced (Cockpit: mean = 34.45 ± 61.00, Laparoscopic: mean = 140,35 ± 126,78, p.value < 0.001) in cockpit surgeons compared to laparoscopic surgeons. Further, the trend of reduced Distraction for robotic surgery (p.value = 0.090, Table 2) reached significance when comparing only cockpit and laparoscopic surgeons (Cockpit: mean = 54.18 ± 60.16, Laparoscopic: 81.38 ± 89.12, p.value = 0.0270). Bedside and laparoscopic surgeons presented an insignificant "Overall Stress" difference (p.value = 0.065). Solely Mental Demands reached significance between methods, presenting higher scores for bedside surgeons (Bedside: mean = 104.03 ± 77.90, Laparoscopic: mean = 46.97 ± 56.44, p.value < 0.001). Table 3 displays results from cockpit (N = 190) and laparoscopic (N = 63) surgeons, representing the surgeons in charge of the procedure (presented in Table 1).

Table 3 Overview of stress category result

Stress category	Surgeon position	Mean	Sd	p.value[a]
Overall stress	Cockpit	27.13	14.96	**0.018**
	Laparascopic	34.3	21.75	
Mental demands	Cockpit	69.79	80.14	**0.015**
	Laparascopic	46.97	56.44	
Physical demands	Cockpit	34.45	61	**< 0.001**
	Laparascopic	140.35	126.78	
Temporal demands	Cockpit	47.78	59.41	0.56
	Laparascopic	52.87	60.68	
Task complexity	Cockpit	131.89	96.96	0.714
	Laparascopic	126.59	103.81	
Situational stress	Cockpit	68.87	64.88	0.818
	Laparascopic	66.27	81.22	
Distractions	Cockpit	54.18	60.16	**0.027**
	Laparascopic	81.38	89.12	

Displayed as mean and sd per surgeon position during surgery. Cockpit = robotic cockpit surgeon. Laparoscopic = laparoscopic surgeon

[a]Based on Welch Two Sample t-test

Bold value indicates statistical different value p < 0.00

Discussion

Advantage of comfort

The present results indicate that robotic surgery with the Senhance Surgical System offers significant advantages in reducing physical stress compared to laparoscopic surgery, especially for cockpit surgeons. This finding aligns with other literature, for example, evidenced by a systematic review on ergonomics conducted by Wee et al. [2]. Additionally, an experimental study investigating the ergonomic setup showed significantly lower Heart rate (p. value = 0.004) for robotic compared to laparoscopic surgery [6]. Although the comfort advantage is consequently not specific to the Senhance Surgical System, it is worth noting that the Senhance Surgical System contributes to an improved ergonomically friendly working environment. The surgeon's seating position and control mechanisms, such as the angled foot pedals and joystick, promote good posture and minimize physical strain. Given the declining interest of physicians in surgical disciplines [20], this aspect offers two significant advantages. Firstly, it can provide a comfortable working environment for older surgeons considering retirement due to physical strain. Secondly, it may make surgery a more appealing choice for younger doctors. In conclusion, the ergonomic features enhance the surgeon's comfort and are likely to contribute to improved surgical precision, overall performance, and, eventually better patient outcomes.

Disadvantage of complex equipment

The Senhance Surgical System has advanced technical features, including haptic feedback and a 3D eye-tracking camera. These features are undoubtedly prone to enhance the cockpit surgeon's capabilities during surgery. However, it is important to acknowledge that operating the system requires the cockpit surgeon to simultaneously navigate through two mediums: the robotic arms and the console. This advanced arm and foot movement coordination may complicate the surgical procedure. Additionally, robotic bedside surgeons experienced more Mental Demand than laparoscopic surgeons, most likely due to physical separation from the cockpit surgeon and greater individual responsibility. Similar to our findings of significant differences in Mental Demands, studies, e.g., conducted by Shugaba and colleagues [5], have shown that robotic systems impose a greater cognitive demand on surgeons than laparoscopic surgery. As reported by Spagnolo and colleagues [14], stress levels for Mental Demands (p. value = 0.021), Physical Demands (p.value = 0.03), and total workload (p.value = 0.025) were significantly lower when the technique was routinely performed. Consequently, it is reasonable to assume that stress related to Mental Demands could decrease with further routine in complex procedures. Furthermore, in future robotic settings, integrated augmented reality and artificial intelligence could support a reduced mental load [21].

Physical separation and focus

Our results further suggest reduced Distraction in robotic surgery compared to laparoscopic surgery. This finding principally applies to the cockpit surgeon and can be attributed to various factors. One possible explanation is the physical separation between the cockpit surgeon and the surgical team. This physical distance may create a conducive environment for the surgeon to focus on the surgical task. Additionally, the ergonomic seating and the system's improved physical comfort with 3D vision may contribute to the surgeon's overall relaxation, further minimizing distraction stress. Furthermore, the eye-tracking camera with 3D vision allows the surgeon to maintain continuous and self-guided visual focus. This feature enables enhanced situational awareness and precise maneuvering, promoting concentration and reducing the likelihood of errors. In case of distraction or loss of focus, the surgeon can allow a short break and release the cockpit paddle with the camera and instruments remaining completely stable. This enables surgeons to seamlessly resume from where they left off. Overall, the combination of physical separation, ergonomic seating with an eye-tracking camera, and 3D vision may collectively contribute to a more focused and concentrated surgical experience, thereby reducing distraction-related stress.

Equal complexity and anxiety

Our findings regarding Temporal Demands, Task Complexity, and Situational Stress suggest no significant differences between robotic and laparoscopic surgery. This indicates that surgeons experience these stress entities similarly. This finding is particularly insightful, as it challenges the assumption that robotic surgery is inherently more complex or anxiety-inducing than laparoscopic surgery [13, 22]. In the present results, surgeons did not perceive robotic procedures as significantly more challenging, suggesting they can adapt to the unique aspects of robotic surgery with the Senhance Surgical System. This finding highlights the adaptability and competence of surgeons in incorporating robotic systems into their surgical practice, which is supported by published studies [23, 24].

Procedure and discipline

Radical Prostatectomy emerged as the most stressful procedure from a surgeon's perspective. However, it is crucial to note that the stress level experienced by surgeons differed depending on the specialty and methods employed. It was significantly reduced when performing with the Senhance Surgical System. As a result, it is reasonable to assume that Radical Prostatectomy is a difficult procedure for urologists with a high incidence of stress. Therefore, stress reduction could be achieved by applying the robotic Senhance Surgical System. Regarding general surgery, stress levels for procedures such as Cholecystectomy appear to be at or below the average. Especially, complicated cases were performed laparoscopically, given the greater expertise associated with this approach. This could explain higher task complexity scores for laparoscopic cholecystectomy (Fig. 1). Also, certain procedure steps and methods (clip applier, adhesiolysis, camera angling) are easier in laparoscopic surgery, potentially resulting in a preference among surgeons for this method in challenging cholecystectomy cases. Furthermore, laparoscopic cholecystectomy was regularly performed in emergencies. In future settings, it will be interesting if emergency cases could be performed robotically. In the case of gynecology, stress levels for Total Hysterectomy were found to be below average, with no significant differences observed across both methods. An explanatory factor could be that surgeons experienced higher comfort with this procedure, making them perceive it as rather effortless. This suggests that, as a procedure, Total Hysterectomy may generally present lower stress levels for surgeons than other surgical interventions.

Limitation

The present results have several limitations. Firstly, the survey was not randomized, and our results cannot be directly compared to other publications [e.g., [13–15]] due to the use of different stress measurement scales (i.e., a 21-gradation scale [13] or a 20-point Likert scale [14]). Moreover, the recorded procedures varied significantly with low case numbers, challenging definitive conclusions. Additionally, it is important to note that we did not assess "level of comfort" but focused on how physically fatiguing the procedure was. As a result, our assumptions on comfort are inferred rather than explicitly stated. We also did not explore reasons for reduced physical stress in robotic surgery. Therefore, larger studies examining physical stress and discomfort are needed. In conclusion, we recommend conducting larger randomized surveys with independent participants to gain a more comprehensive understanding of the relationship between surgeons' stress and robotic surgery, as well as the differences between robotic vs. laparoscopic and even robotic vs. open surgery.

Conclusion

The present investigation focused on the crucial issue of stress in robotic surgery with the Senhance Surgical System compared to laparoscopic surgery. We found reduced "Overall Stress" for cockpit surgeons compared to laparoscopic surgeons. Additionally, we indicate significantly more Mental less Physical Demands and less Distraction for robotic surgery with the Senhance Surgical System. A variance through procedures was recognized, and stress levels varied depending on the procedure and surgical specialty. In conclusion, an advantage of robotic surgery with the Senhance Surgical System compared to laparoscopic surgery could be the reduced surgeons' stress. This represents a huge health benefit, a better, longer work–life balance, and enhanced patient outcome.

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Author contributions All authors, performed surgery and filled out the Surg TLX questionnaire after surgery, either robotic or laparoscopic. V. M. wrote the main manuscript text. The analysis was performed by the senior statiscian, CRO Dr Tanja Kottmann, who is not in the author list, nor in the acknowledgements, since she works for the industry partner Asensus. The figures are made by V.M., with the help of Dr. Tanja Kottmann. All authors reviewed the manuscript.

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Data availability The data used in this research is available upon request. No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no conflict of interest.

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