Impact of the complexity of surgical procedures and intraoperative interruptions on neurosurgical team workload

Maxime Bretonnier, Estelle Michinov, Estelle Le Pabic, Pierre-Louis Henaux, Pierre Jannin, Xavier Morandi, Laurent Riffaud

Impact of the complexity of surgical procedures and intraoperative interruptions on neurosurgical team workload.

Original article

Maxime Bretonnier [a,b], Estelle Michinov [c], Estelle Le Pabic [d,e], Pierre-Louis Hénaux [a,b], Pierre Jannin [a], Xavier Morandi [a,b], Laurent Riffaud [a,b]

a Univ Rennes, INSERM, LTSI - UMR 1099, F-35000 Rennes, France

b Department of Neurosurgery, Pontchaillou University Hospital, 2 Rue Henri Le Guilloux, 35033 Rennes Cedex 9, France

c Univ Rennes, LP3C (Laboratoire de Psychologie : Cognition, Comportement, Communication) - EA 1285, F-35000 Rennes, France

d Clinical Data Center, Pontchaillou University Hospital, Rennes, France

e INSERM, CIC 1414, F-35000 Rennes, France

Corresponding author:

Dr Maxime Bretonnier, Department of Neurosurgery, Pontchaillou University Hospital, 2 Rue Henri Le Guilloux, 35033 Rennes Cedex 9, France (e-mail: maxime.bretonnier@chu-rennes.fr)

telephone: + 33 2 99 28 42 77, fax: + 33 2 99 28 41 80

Abstract

Background: Neurosurgical teams are exposed to various stressors: complexity of surgical procedures, environment, time pressure and interruptions contribute to increasing the perceived workload.

Objective: This study aimed to evaluate the impact of interruptions and surgical complexity on neurosurgical team workload.

Methods: A prospective observational study was conducted on thirty surgical procedures of graduated complexity recorded in our Department of Neurosurgery. A scale was created and used by neurosurgeons to evaluate the perceived complexity of the surgical procedure. Interruptions and severity of interruptions were noted. The workloads of the neurosurgeon, surgical assistant, scrub nurse and circulating nurse were measured on the Surgery Task Load Index (SURG-TLX) at the end of the procedure.

Results: A mean 24.6 interruptions per hour were recorded. The mean interference level of the interruptions was 3.5/7. Mean surgical complexity was 4.3/10. Mean sterile team workload was 43.4/100. The multiple linear regression model showed that sterile team workload increased with surgical complexity (β = 6.692, $P = .0002$) but decreased in spite of increases in the number of interruptions per hour (β = -0.855, $P = .027$). Neurosurgeon and surgical assistant workload increased with surgical complexity (β = 11.53, $P < 0.0001$ and β = 7.42, $P = 0.0007$, respectively). Scrub nurse workload decreased in spite of increases in the number of interruptions per hour (β = -1.11, $P = .026$).

Conclusion: Our study suggests positive effects of some interruptions during elective neurosurgical procedures with strong team familiarity.

Keywords: complexity; interruptions; neurosurgery; workload

1. Introduction

In 1999, the United States Institute of Medicine published a report distinguishing medical errors as the 8th leading cause of death in the country (98,000 deaths a year) [1]. The same year, another US study reported that 66% of medical adverse effects were related to a surgical procedure [2]. Therefore, improvement of quality and safety in surgery practice remains necessary, particularly in the operating room (OR).

Surgical teams are exposed to various stressors: complexity of surgical procedures, working environment, time pressure and interruptions [3]. All these factors combined may impair surgical performance and cause errors [4]. Workload (WL) is a concept which may be defined as the cost of the task for one or several individuals [5]. Measurement of the WL of a surgical team can be used as the indicator of the demands of the surgical procedure and stressors. WL as perceived by surgical team members can be measured by validated instruments after the surgical procedure: it represents the subjective perception of the temporal, physical and mental demands of the surgical procedure [5,6].

Several studies have been conducted about factors influencing WL, and especially interruptions of the surgical procedure; however, no strong correlation between interruptions and WL has been yet demonstrated [7,8]. Moreover, the impact of surgical complexity on interruptions and WL has never been studied to the best of our knowledge.

The objective of our study was to evaluate factors likely to impact neurosurgical team WL, such as the difficulty of the procedure, and the frequency and types of interruptions.

2. Material and methods

2.1 Selection of neurosurgical procedures

We conducted a prospective comparative study of 30 surgical procedures of graduated complexity in our Department of Neurosurgery: elective cranial and spinal procedures, all placed first in the day's schedule, to ensure similar fatigue levels. Procedures performed with personnel external to our department or with a trainee were excluded.

2.2 Perceived complexity of neurosurgical procedures

A scale to evaluate the perceived complexity of the surgical procedure was completed by the neurosurgeon before the procedure using pertinent clinical data. The surgical complexity scale was calculated by averaging all the items on a 10-point scale.

This scale was developed using the Churchill scale validation paradigm [9]. As a first step, semi-structured interviews of 12 professionals (7 surgeons of differing experience and specialty, 2 scrub nurses, 2 anesthesiologists and 1 occupational psychologist) focused on technical and non-technical skills. The interviews enabled us to define 3 dimensions to the scale: technical complexity, non-technical complexity and the risk of surgical complications. Initially, the scale consisted of 23 items but was reduced to 19 items after interviewees gave their opinion (Table A). The phrasing was reviewed by human-factor experts. The scale was then tested and approved by neurosurgeons of our department.

2.3 Interruptions of surgical procedures

Surgical procedures were recorded in video and audio with Zoom Q4n® recorder (Zoom Corporation, Tokyo, Japan), placed so as to include in its field the sterile surgical team and the door of the OR, and equipped with a microphone to record noise in the OR and the various conversations. The neurosurgeon or assistant was equipped with a lapel microphone to record communications between sterile team members. Recordings started with the skin incision and ended with skin closure.

Recordings were analyzed using the Behavioural Observation Research Interactive Software (BORIS) to rate all kind of events [10]. Recording analysis was carried out by two assessors: the first author, who had 4 years' experience in neurosurgery and theoretical knowledge of human behavior, and a PhD student in human behavior and psychology. Inter-rater reliability was assessed using Cohen's kappa coefficient integrated in BORIS. Every interruption of the surgical procedure was noted. The interruptions were then classified according to their type using a validated classification (Table B) [11]. The observed effect of interruptions on the sterile team was also assessed, rating the level of interference on a validated 7-point scale (Table C) [12].

Data extracted from video/audio analyses of surgical procedures comprised: duration of the procedure, number of interruptions per hour, mean level of interference of the interruptions, percentage of total interruptions for each category of interruptions, mean level of interference per category, percentage of total interruptions and mean interference for each professional (anesthesiology team member, neurosurgeon, assistant, scrub nurse, circulating nurse, external staff).

2.4 Evaluation of workload

The 6-item Surgery Task Load Index (SURG-TLX) (Figure A) was used to evaluate surgical team WL: *mental demands, physical demands, temporal demands, task complexity, situational stress,* *distractions* [5]. Each sterile team member filled out the SURG-TLX questionnaire immediately after the end of surgery. Sterile team WL was measured by averaging the SURG-TLX scores of the neurosurgeon, assistant and scrub nurse.

2.5 Endpoints

The primary endpoint was the sterile team WL impact of the number of interruptions per hour, level of interference of interruptions, surgical complexity and duration of the procedure.

Secondary endpoints comprised description of the interruptions and the personnel responsible for interruptions.

2.6 Statistical analysis

Descriptive statistics were calculated for all outcome measures by SAS® software (SAS Institute, Cary, North Carolina, USA). Associations between number of interruptions per hour, mean level of interference of interruptions, duration of surgical procedure and surgical complexity were assessed on Spearman correlation coefficients. Multivariate linear regression was used to explore the relationship between sterile team WL and these 4 factors. The significance threshold was set at $P \leq .05$.

2.7 Ethical approval and information to participants

Participants were informed of the objective and methodology of the study and written consent was collected. The review board of our institution approved the study (Notice n°17.46).

3. Results

3.1 Inter-assessor agreement

Recordings were analyzed out by two assessors for 5 cases, selected randomly. Cohen's kappa coefficient showed high inter-assessor agreement: mean, 0.66; range, 0.61-0.80. As the agreement level was high, the remaining cases were rated by the first author alone.

3.2 Description of surgical procedures

The surgical procedures are described in Table D.

3.3 Description of interruptions

Percentage of total interruptions and mean level of interference per category of interruptions are summarized in Figure B, distinguishing specific distractions and specific interruptions. The most frequent category of interruptions was “distraction” (71.4%). This also showed the lowest level of interference (2.5/7). “OR entry/exit” was the most frequent distraction (45%) but its level of interference was also the lowest (1.4/7). “Case-irrelevant communications” was the second most frequent (15.3%), with a high level of interference (5.4/7). “Other types of distraction” were the third most frequent category (7.8%), with a moderate level of interference (4/7). “Communication” was the fourth most frequent type (7.3%), with a high level of interference (5.9/7). All other categories had percentages below 5% and interference level above 4/7.

3.4 Source of interruptions

Percentage of total interruptions and mean level of interference for sterile and non-sterile team are described in Figure C.

The number of interruptions per hour was low for the sterile team: the neurosurgeon caused 12.1% of the interruptions, the assistant 3.7%, and the scrub nurse 7.8%. But their levels of interference were higher than for other personnel: 6.3/7 for the neurosurgeon, 6/7 for the assistant, and 5.4/7 for the scrub nurse.

The proportion of interruptions was high for non-sterile personnel: the anesthesiologist team member caused 31.1% of all interruptions, the circulating nurse 15%, and external staff 12%. Their level of interference, on the other hand, was low: 1.6/7 for the anesthesiologist, 3.5/7 for the circulating nurse, and 2.3/7 for the external staff.

3.5 Analysis

Mean surgical procedure time was 2.2± 0.9 hours, mean number of interruptions per hour 24.6± 5.4 and mean level of interference 3.5± 0.7/7. Mean sterile team WL (average of neurosurgeon, assistant and scrub nurse) was 43.4± 14.6/100. The three members of this team had similar WLs (neurosurgeon: 41.1 ± 21.8; assistant: 46.8 ± 16.3; scrub nurse: 42.1 ± 14.8) whereas the circulating nurse from the non-sterile personnel had a lower WLs (33.4 ± 14.7). Mean surgical complexity was 4.3±1.3/10.

3.6 Correlation analysis

Correlation analysis demonstrated that surgical procedure time and perceived surgical complexity were positively intercorrelated (r = 0.72, $P < .0001$). No other correlations were found between variables.

3.7 Multiple linear regression analysis

Univariate analysis showed that sterile team WL correlated positively with surgical procedure time (β = 10.65, *P* < .0001) and surgical complexity (β = 7.40, *P* < .0001), and negatively with number of interruptions per hour (β = -1.17, *P* = .017). Sterile team WL did not correlate with the mean level of interference of interruptions (β = -1.77, *P* = .666).

Number of interruptions, mean level of interference of interruptions and surgical complexity were then included in multivariate regression analysis. Surgical procedure time was not included because of its collinearity with surgical complexity. Stepwise multivariate analysis showed that sterile team WL was impacted by surgical complexity and number of interruptions, increasing with surgical complexity (β = 6.70, *P* = .0002) but decreasing with number of interruptions (β = -0.855, *P* = .027); R^2 was 0.52.

Similar analyses were carried out for each member of the sterile team. Univariate analysis showed that neurosurgeon WL correlated positively with surgical procedure time and complexity (Table E). Number of interruptions did not significantly correlate with WL. Multivariate analysis confirmed the relation between surgeon WL and the surgical complexity (β = 11.53, *P* < .0001) (Table F). Univariate analysis showed that assistant WL also correlated positively surgical procedure time and complexity, and negatively with number of interruptions (Table E). Multivariate analysis confirmed that surgical complexity increased the assistant's WL (β = 7.42, *P* = .0007), but the number of interruptions per hour was not a significant variable (Table F). Univariate analysis of scrub nurse WL showed negative correlation with number of interruptions, but no correlation with surgical procedure time or complexity (Table E). Multivariate analysis confirmed that the number of interruptions was a significant variable (β = -1.11, *P* = .026) (Table F).

4. Discussion

The present study aimed to evaluate the impact of perceived surgical complexity, interruptions and their level of interference on the neurosurgical team workload.

A first finding was that interruptions during neurosurgical procedures were common with a mean frequency of 24.6 per hour. Distractions were the most frequent interruptions with the lowest level of interference, these findings being consistent with previously published studies. Weigl et al. observed 9.8 interruptions per hour in a series of 56 general and orthopedic surgical procedures [7]; the most common interruptions were people entering/exiting the OR (31%) and telephone/beeper calls (24%), with a low level of interference (4/9 and 3/9 respectively)., while the least frequent interruptions were equipment/environment issues (15%) and procedural questions (10%), with the highest interference level (6/9 and 5/9 respectively). In another study of 90 general surgery cases, Wheelock et al. reported similar results, with 6.7 interruptions per hour, and "entering/exiting the OR" and "case-irrelevant communications" as the principal interruptions [8]; the highest interference level was also caused by equipment and procedural issues. Finally, Healey et al. also came to the same conclusions in 50 general surgical procedures, with 17 interruptions per hour [13].

An important result was that sterile team WL decreased with increasing number of interruptions, particularly for the scrub nurse. This finding was not expected since interruptions in surgery have been commonly described as a potential source of error [14], although positive correlation between interruptions and WL was not shown in other studies. Weigl et al. found that interruptions correlated with higher levels of perceived distraction but not with mental fatigue or situational stress [7]. Wheelock et al. found no correlation between distractions and WL except for some case-irrelevant communications which correlated with lower WL [8]. This absence of negative impact of interruptions on sterile team WL gives rise to several hypotheses. One explanation could be the surgical procedures selected in our study: we included only elective procedures, in a context of strong team familiarity and trained staff. Previous studies demonstrated that familiarity in the surgical team made for better performance. Kurmann et al. showed that better familiarity between surgeon and assistant led to better quality of teamwork and reduced surgical morbidity [15]. El Bardissi et al. showed that team familiarity reduced operating time [16], and Kang et al. found that team familiarity enhanced the scrub nurse's non-technical performance [17]. In a context of routine practice, we suppose that interruptions may have no significant impact on the surgeon, who remains self-regulated on automatic pilot. In the same way, team familiarity decreased the number of interruptions, likely contributing to improved surgical performance [18,19]. Types of interruptions could be another explanation for this result. Some studies highlighted categories of interruption which could be prejudicial, such as equipment and environmental issues, deviation from procedure or lack of planning and preparation [13,20-22]. In our study, these types of interruption were very rare, at less than 5% of total interruptions. A third reason could be that some of the recorded interruptions had a real positive impact on teamwork. A potential positive effect of interruptions in surgery has not previously been described in the literature, but the present study suggests that it may exist. Case-irrelevant communications were the second most frequent type of interruption, causing severe interruption in most cases (interference scale: 5.4/7). This type of interruption could be the expression of less stressful phases of the surgical procedure such as closure, or the reflection of lower surgical complexity [23]. We assumed that case-irrelevant communications could promote team-bonding and decrease team WL. Another example was training, which we rarely observed as a cause of interruption (4.1%). It may be assumed that it does not increase the WL and appears beneficial to the surgical process. A final explanation could be that interruptions were common during surgical procedures, so that surgeons and nurses developed the ability to cope with and adapt to them [24]: when interruptions were "benign", the impact on WL was non-existent.

We developed a dedicated surgical complexity scale for the study to evaluate the level of perceived difficulty of surgical procedures. Surgical complexity was the strongest predictor of sterile team WL. Using such a scale in routine practice could have significant implications for safety. It is agreed that lack of non-technical skills in the surgical team can be a source of errors in the OR [25]. This kind of scale could improve non-technical performance, with improved interpersonal skills (communication, leadership, planning, resource management) and cognitive skills (situation awareness, mental readiness, risk assessment, anticipation of problems) [26]. The scale can be used in surgical planning, to improve the mental preparation of the nursing and anesthesiology teams, resource management and work organization by focusing on distribution of skills.

Our study had several limitations. Firstly, the complexity scale developed for this study was not validated. The validation process is long and complex, and we are currently continuing this process. In the first validation stages, we created a 23-item scale, reduced to 19 after consultation with various professionals (human factor experts, surgeons of differing experience and specialty, anesthesiologists). Secondly, the surgical procedure sample was limited and several kinds of surgical procedure were not included; this limitation is inherent in the observational approach in a natural environment. Thirdly, we did not assess the experience of the surgical team or team familiarity.

Future research should focus on the potential positive impact of some interruptions in surgery.

5. Conclusions

The present study showed that interruptions were routinely observed in the operating room, without consequences on workload, in the particular context of elective neurosurgical procedures with strong team familiarity. Moreover, positive effects were observed for some specific interruptions such as case-irrelevant communications for assistants and scrub nurses. For surgeons, the perceived complexity of the surgical procedure was the most important factor influencing workload.

Compliance with ethical requirements:

The authors declare no conflict of interest.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

The authors thank Mrs Deirdre McKeown for her help with the English language.

References

1. Institute of Medicine (US) Committee on Quality of Health Care in America. *To Err is Human: Building a Safer Health System*. Washington, DC: National Academies Press; 2000.
2. Gawande AA, Thomas EJ, Zinner MJ, Brennan TA. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery*. 1999;126:66–75.
3. Arora S, Sevdalis N, Nestel D, Woloshynowych M, Darzi A, Kneebone R. The impact of stress on surgical performance: A systematic review of the literature. *Surgery*. 2010;147:318–330.
4. Gawande AA, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery*. 2003;133:614–621.
5. Wilson MR, Poolton JM, Malhotra N, Ngo K, Bright E, Masters RSW. Development and validation of a surgical workload measure: The Surgery Task Load Index (SURG-TLX). *World J Surg*. 2011;35:1961–1969.
6. Hart SG, Staveland LE. *Development of NASA-TLX (Task Load Index): results of empirical and theoretical research*. In: Hancock PA, Meshkati N, eds. *Human mental workload*. Amsterdam: Elsevier; 1988;139–183.
7. Weigl M, Antoniadis S, Chiapponi C, Bruns C, Sevdalis N. The impact of intra-operative interruptions on surgeons' perceived workload: an observational study in elective general and orthopedic surgery. *Surg Endosc*. 2015;29:145–153.
8. Wheelock A, Suliman A, Wharton R, et al. The impact of operating room distractions on stress, workload, and teamwork. *Ann Surg*. 2015;261:1079–1084.
9. Churchill G-A. A paradigm for developing better measures of marketing constructs. *J Mark Res*. 1979;16:64-73.
10. Friard O, Gamba M. BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods Ecol Evol*. 2016;7:1325-1330.
11. Morgan L, Robertson E, Hadi M, et al. Capturing intraoperative process deviations using a direct observational approach: the glitch method. *BMJ open*. 2013;3:e003519.

12. Persoon MC, Broos HJHP, Witjes JA, Hendrikx AJM, Scherpbier AJJM. The effect of distractions in the operating room during endourological procedures. *Surg Endosc*. 2011;25:437–443.

13. Healey AN, Sevdalis N, Vincent CA. Measuring intra-operative interference from distraction and interruption observed in the operating theatre. *Ergonomics*. 2006;49:589–604.

14. 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;142:658–665.

15. Kurmann A, Keller S, Tschan-Semmer F, et al. Impact of team familiarity in the operating room on surgical complications. *World J Surg*. 2014;38:3047–3052.

16. ElBardissi AW, Duclos A, Rawn JD, Orgill DP, Carty MJ. Cumulative team experience matters more than individual surgeon experience in cardiac surgery. *J Thorac and Cardiovasc Surg*. 2013;145:328–333.

17. Kang E, Massey D, Gillespie BM. Factors that influence the non-technical skills performance of scrub nurses: a prospective study. *J Adv Nurs*. 2015;71:2846–2857.

18. Gillespie BM, Chaboyer W, Fairweather N. Interruptions and miscommunications in surgery: an observational study. *AORN J*. 2012;95:576–590.

19. Henaux PL, Michinov E, Rochat J, Hémon B, Jannin P, Riffaud L. Relationships between expertise, crew familiarity and surgical workflow disruptions: an observational study. *World J Surg*. 2018;43:431–438.

20. Antoniadis S, Passauer-Baierl S, Baschnegger H, Weigl M. Identification and interference of intraoperative distractions and interruptions in operating rooms. *J Surg Res*. 2014;188:21–29.

21. Healey AN, Olsen S, Davis R, Vincent CA. A method for measuring work interference in surgical teams. *Cogn Tech Work*. 2008;10:305-312.

22. Healey AN, Primus CP, Koutantji M. Quantifying distraction and interruption in urological surgery. *Qual Saf Health Care*. 2007;16:135–139.

23. Tschan F, Seelandt JC, Keller S, et al. Impact of case-relevant and case-irrelevant communication within the surgical team on surgical-site infection. *Br J Surg*. 2015;102:1718-1725.

24. Szafranski C, Kahol K, Ghaemmaghami V, Smith M, Ferrara JJ. Distractions and surgical proficiency: an educational perspective. *Am J Surg*. 2009;198:804–810.

25. Shouhed D, Gewertz B, Wiegmann D, Catchpole K. Integrating human factors

research and surgery: a review. *Arch Surg*. 2012;147:1141-1146.

26. Yule S, Flin R, Paterson-Brown S, Maran N. Non-technical skills for surgeons in the operating room: a review of the literature. *Surgery*. 2006;139:140-149.

Appendices

Figure legends

Figure. A The Surgery Task Load Index (SURG-TLX)

Figure. A Percentage and mean level of interference for each category of interruption

Figure. B Percentage of total interruptions and the mean level of interference for each source of interruption

Table A. Surgical complexity scale

Technical complexity	
Patient: what is the degree of complexity related to the pathophysiological characteristics of the patient? *	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Installation: what is the degree of complexity of the installation of the patient for this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Equipment and technology: what is the degree of dependence on the equipment/technology required for this surgical procedure (instruments, implants, surgical aids)?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Approach and exposure: what is the degree of complexity of the approach and exposure of the surgical site?	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Gestural: what is the degree of gestural difficulty during this surgical procedure (gestural precision)?	1 2 3 4 5 6 7 8 9 10 Not at all Very difficult difficult
Non-technical complexity	

Planning: How important is preoperative planning for this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Experience of the surgical team: how important is the experience of the surgical team (surgeon, assistant)?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Experience of the nursing team: how important is the experience of the nursing team (scrub and circulating nurses)?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Experience of the anesthesiology team: how important is the experience of the anesthesiology team?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Physical fatigue: what is the degree of complexity related to the physical fatigue induced by the surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Mental fatigue: what is the degree of complexity related to the mental fatigue induced by the surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Duration of the surgical procedure: what is the degree of complexity induced by the duration of this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very complex complex
Communication: how important is the communication between the actors (surgeon, anesthesiologist, nurses) for this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Coordination: how important is the coordination of actions between the actors (surgeon, anesthesiologist, nurses) for this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Leadership: How important is the surgeon's leadership for this surgical procedure?	1 2 3 4 5 6 7 8 9 10

	Not at all Very important important
Interruptions: during a surgical procedure, the sterile surgical team can be interrupted; what is the impact of these interruptions on the complexity of this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very important important
Stress: what is the degree of stress generated for the surgeon during this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very stressful stressful
Risk of perioperative complications	
Intraoperative complications: what is the degree of risk of occurrence of an intraoperative complication for this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very risky risky
Postoperative complications: what is the degree of risk of occurrence of a postoperative complication or disability following this surgical procedure?	1 2 3 4 5 6 7 8 9 10 Not at all Very risky risky
Items not included in the final surgical complexity scale	
What is the degree of concentration required for the success of the surgical procedure?	
What is the degree of complexity of operative anatomy?	
How complex is the management of a surgical complication in this surgery?	
How difficult is the use of technological tools for this surgery?	

* patient: refers to the morphological characteristics and the patient's history. Example: obesity, surgical revision, anticoagulant or antiplatelet treatment

Table B. Categories of interruptions

Category	Code	Definition
Absence	1	Absence of theater staff member, when required
Communication	2	Difficulties in communication between team members
Distractions	3 Phone/beeper 4 OR entry/exit 5 Case-irrelevant communications 6 Other distractions	Anything causing distraction from task
Environment	7	Aspects of the working environment causing difficulties
Equipment design	8	Issues arising from equipment design, that would not otherwise be corrected with training or maintenance
Maintenance	9	Faulty or poorly maintained equipment
Health and safety	10	Any observed physical risk to personnel
Planning and preparation	11	Instances that might otherwise have been avoided with appropriate prior planning and preparation
Patient-related	12	Issues relating to the physiological status of the patient
Process deviation	13	Incomplete or reordered completion of standard tasks
Slips	14	Psychomotor errors
Training	15	Repetition or delay of operative steps due to training
Workspace	16	Equipment or theater layout issues

Adapted from Morgan et al.[11]

Table C. Interference level of interruptions

Rating	Observed effects
1	Potentially distracting stimuli: events with the potential to distract the sterile team
2	Sterile team member momentarily distracted: possible involvement of a single sterile member in an event not related to the primary task: e.g., a short head turn in response to visual or auditory stimulus
3	Sterile team member engages in distraction: similar distraction in 2 but the sterile member engages with the source of distraction by verbally responding while maintaining primary task activity (multitasking)
4	Sterile team member's primary task interrupted: a single team member ceases his/her current tasks to engage entirely with the distracting stimulus
5	Sterile team momentarily distracted: two or more sterile team members respond to a stimulus with a short head turn, no verbal response
6	Sterile team engage in secondary tasks: two or more team members engage with the source of distraction by verbally responding while maintaining primary task activity
7	Sterile team's work interrupted, operation flow disrupted: interruption of the current primary task of the sterile team, the operation flow is disrupted

From Persoon et al.[12]

Table D. Description of neurosurgical procedures

Case	Surgical procedure	Surgical complexity scale (/10)
1	Endoscopic transsphenoidal resection of a non-functioning pituitary macroadenoma	4.2
2	Resection of right middle cranial fossa meningioma	4.1
3	Endoscopic third ventriculostomy	3.4
4	Anterior cervical interbody fusion	3.6
5	Resection of right high-grade temporo-insular glioma	4.8
6	Anterior cervical interbody fusion	3.5
7	Resection of right Koos grade III vestibular schwannoma	6
8	Endoscopic transsphenoidal resection of a non-functioning pituitary macroadenoma	4.3
9	Resection of right posterior petrous bone meningioma	6.1
10	Endoscopic transsphenoidal resection of a non-functioning pituitary macroadenoma	4.6
11	Resection of anterior cranial fossa meningioma	6.1
12	Resection of a fourth ventricle tumor	5.5
13	Endoscopic transsphenoidal resection of a non-functioning pituitary macroadenoma	4.4
14	Resection of left pterional meningioma	3.8
15	Resection of left occipital convexity meningioma	3.1
16	Removal of spinal instrumentation	1.7
17	Resection of right middle cranial fossa meningioma	3.3
18	Anterior cervical interbody fusion	2.7
19	Anterior cervical interbody fusion	2.9
20	Anterior cervical interbody fusion	4
21	Anterior cervical interbody fusion	3.1
22	Resection of left pterional meningioma	3.9
23	Resection of right frontal low-grade glioma	4.6
24	Laminectomy for lumbar stenosis	3
25	Resection of anterior clinoid meningioma	5.3
26	Resection of third ventricle colloid cyst by transcallosal approach	5.1
27	Resection of right spheno-orbital osteomeningioma	7.1
28	Resection of right spheno-orbital osteomeningioma	3.8
29	Resection of right high-grade occipitotemporal glioma	5.5
30	Resection of posterior cranial fossa tumor	6.9

Table E. Univariate linear regression analysis for each member of the sterile team WL

Variable	Surgeon WL β (*P* value)	Assistant WL β (*P* value)	Scrub nurse WL β (*P* value)
Surgical procedure time	14.40 * (*P* = .0003)	12.62 * (*P* < .0001)	4.96 (*P* = .092)
Number of interruptions per hour	-1.17 (*P* = .118)	-1.21 * (*P* = .027)	-1.11 * (*P* = .026)
Level of interference of interruptions	-3.86 (*P* = .526)	-1.45 (*P* = .751)	-0.08 (*P* = .985)
Surgical complexity scale	11.53 * (*P* < .0001)	7.42 * (*P* = .0007)	3.30 (*P* = .123)

* significant correlation at *P* < 0.05

Table F. Multivariate linear regression analysis for each member of the sterile team WL

Variable	Surgeon workload β (*P* value) R^2	Assistant workload β (*P* value) R^2	Scrub nurse workload β (*P* value) R^2
Surgical complexity scale	11.53 ($P < .0001$) $R^2 = 0.46$	7.42 ($P = .0007$) $R^2 = 0.34$	-
Number of interruptions per hour	-	-	-1.11 ($P = .026$) $R^2 = .17$