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Tasks, multitasking and interruptions among the surgical team in an operating room: a prospective observational study

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ABSTRACT

Objectives The work context of the operating room is considered complex and dynamic with high cognitive demands. A multidimensional view of the complete pre- and intraoperative work process of the surgical team in the OR has been sparsely described. The aim of this study was to describe the type and frequency of tasks, multitasking and interruptions during surgical procedures among the surgical team in the OR.

Design Prospective observational study, using the Work Observation Method By Activity Timing (WOMBAT) tool.

Setting County hospital in Sweden, surgical department.

Participants Operating room nurses (ORNs) (n=10), registered nurse anesthetists (RNAs) (n=8) and surgeons (n=9).

Results The type, frequency and time spent on specific tasks, multitasking and interruptions were measured. From a multidimensional view, the surgical team performed almost 11,000 tasks (64 tasks per hour). Communication represented almost half (n=4968, 45.7%) of all observed tasks. Concerning task time, direct care dominated the surgeons' and ORNs' intra-operative time while in RNAs' work it was intra-indirect care. In total 48.2% of time was spent in multitasking and was most often observed in ORNs' and surgeons' work during communication. Among the total 426 interruptions measured, the largest proportion, 26.7%, was related to equipment. Interruptions were most commonly followed by professional communication.

Conclusions Communication was identified as a major component in the work process of the surgical team. The team constantly dealt with multitasking and interruptions, both with potential impact on patient safety and workflow. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a complex adaptive system. Future research should focus on understanding the complexity of different work processes, and how teams meet the challenges of complex adaptive systems.

Words: 280

Keywords: Complexity, multitasking, interruptions, patient safety, operating room

Ethical registration number
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STRENGHTS AND LIMITATIONS OF THIS STUDY

- This study adds to the knowledge of how complex work is performed in the OR by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team.
- The data collection tool used, WOMBAT, employs a structured observation protocol with an objective definition of “interruption”, which may reduce the risk of potential measurement errors.
- Even though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed ORN, RNA or surgeon, the nature of performed tasks and how often they were interrupted was not recorded, which may be considered a limitation, as the whole surgical team is not represented in this study.
- Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias.
- This study was performed in one hospital only and the observations did not include night shifts, weekend shifts or procedures conducted on Fridays, which may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

BACKGROUND

Clinical work in surgery is often fast-paced, demanding and time- and resource-constrained. It requires specific technical and cognitive skills[1] and involves multiple activities such as organizing care, responding to patients' changing conditions, anticipating needs and performing surgical procedures.[1 2] An operating room (OR) can be considered a complex adaptive system (CAS),[3] where behaviors and team compositions alter and mutate and teams learn over time.[4] It is an interconnected and dynamic environment[3] with an inherent potential for distractions and interruptions.[1 5]

The members of the surgical team are essential actors in the OR,[6] focusing on performing safe surgical care. In addition, components such as suitable environment, functioning equipment, drugs and disposable items to support the intra-operative process are needed.[7] The work process of the surgical team in the OR is mainly described through the surgical procedure and its phases,[8] including sometimes also the phases of anesthesia.[9] The OR context contains considerable potential for interruptions that may interfere with the work of the surgical team.[5 10] Good outcomes are related to individuals' and teams' skills to adjust and adapt to unexpected events and rapidly changing situations, using communication and interaction, i.e. resilience.[11 12] To understand resilience requires deep understanding of the work as it is actually carried out, rather than how it is usually presented with standardized models.[13]

Multitasking has been defined as managing multiple tasks simultaneously,[14 15 16] or tasks completed in parallel.[17 18] Multitasking is a strategy often used by healthcare staff to manage interruptions and competing work demands.[19] Furthermore, it may also result in risk of increased loss of information,[20] reaction delay, prolonged duration of activity, increased workload and reduced quality of care.[2] For surgeons, multitasking increases completion time and length of procedure significantly.[21] Staff in the OR are expected to multitask by being accessible through pagers and telephones during the procedures.[18] Even though in earlier studies multitasking may have contributed to medical errors, lately it has also been recognized as an integral part of and skill for execution of daily practices, especially in acute care. Multitasking may be facilitated for example by providing the professionals with tools for decision support.[20] Previous research on multitasking has been conducted in the emergency department (ED) from the perspective of the team,[20] nurses and physicians,[15 16] showing that nurses multitasked more than physicians.[16] In medical and surgical wards both nurses'[17] and physicians'[15] multitasking has been observed. In one study on multitasking, where the OR was included in observations as a part of the surgical care process, physicians multitasked twice as much as nurses.[22] In addition, various studies of interruptions involved the concept of multitasking, without investigating it further.[23 24]

In general, interruption is a complex phenomenon, which includes the ongoing task, the nature of interruption itself, the cognitive state of the interrupted individual and the environment. These aspects may all affect patient safety and workflow.[25] Interruptions may result in task incompletion,[23 26-28] loss of attention, medication errors[1] and gaps in continuity of care.[28] Relationships have been found between increased interruptions and error rates.[26 29] On the other hand, it has been argued that interruptions such as speaking up in the team about a perceived risk[30 31] are necessary for sustaining a positive outcome for the surgical procedure. In healthcare research, the concepts interruption, disruption, disturbance and distraction are used interchangeably, and interruptions are defined in a variety of ways, which challenges comparisons between studies. A distracting stimulus is defined as any event that can cause diversion from the primary task, observed by orientation away from this task. An interruption occurs when a distraction leads to a break in main task activity.[32] Interruptions are unexpected[33] and caused by external events.[34] Communication has often been associated, on an individual level, with the source of the interruption.[35 36] Some claim that face-to-face interactions or using telephones are the media through which work interruptions are conveyed.[37] Research on interruptions been conducted including different professionals and in different healthcare contexts.[5 22 35 38-42] In the OR interruptions are studied by frequency and duration,[42 43] and/or together with sources and causes of interruptions.[5 9 44] Outcomes have been studied in terms of effects as level of distraction,[43] engagement,[10 32] delay[42] and interference.[5] Interruptions in the OR show the same lack of distinction between concepts, including another context-specific concept, surgical workflow disturbances and disruptions.[9 44] Several OR studies have described communication as an individual source of interruptions in terms of irrelevant, mis- and/or lack of communication.[5 9 10 45 46 47] Communication has also been characterized in terms of flow, mode, topic and form.[48] Since communication is a relevant task that supports interactions in a CAS,[49] it prompts communication to be categorized both as a task and a source of interruption. The definition used in this study is that interruptions occurs when a participant ceases a current task to respond to an observable external stimulus. This definition is coherent with a few previous studies conducted in the OR context.[5 10 47 48 50 51]

To conclude, previous research shows that the OR is a complex environment where interruptions occur, which may affect patient safety, but which also may contribute positively to adaptations in the dynamic work process. Previous research has studied the work process of the surgical team mainly through the surgical and anesthesia process with their phases. There is a lack of knowledge regarding the multi-dimensional view of the pre- and intraoperative work process in the OR with all performed tasks included, i.e. how the work is actually done and time distribution in the surgical team. In addition, multitasking has not been studied in the work process of the surgical team in the OR. Therefore, the aim of this study was to describe the type and frequency of tasks, multitasking and interruptions during surgical procedures among the surgical team in the OR.

METHODS

Setting and sample

This prospective observational study was conducted in a central OR department at a local county hospital in Sweden. The hospital had two surgical wards, with a total of 38 beds. For general surgery, there was one department for ambulatory surgery and one central OR department. During 2016, a total of 4,118 patients underwent surgery at this hospital. The central OR department consisted of six rooms that served both acute and elective orthopedic and surgical patients. In connection to each OR, there was a preparation room where the registered nurse anesthetist (RNA) and/or the anesthesiologist sometimes prepared patients for surgery. Some medications were also stored in this area.

As in many other countries, surgical teams in ORs in Sweden commonly comprise six professionals, namely: RNA,[52] anesthesiologist, operating surgeon (surgeon) and assisting surgeon, operating room nurse (ORN) and a circulating nurse (commonly a licensed practical nurse).[5] For the observations we selected a convenience sample of scheduled general surgical procedures from a case list. To provide coverage and representativeness of common procedures performed at the department across weekdays (Mon–Thu) and shifts (07:30–21:00 hours) the sample included acute and elective general surgical procedures performed on adults. Since the number of people present in the OR is associated with risk for healthcare-associated infections during orthopaedic procedures,[53] such procedures were excluded, as were night shifts. The professionals were informed about the study during workplace meetings and invited to participate.

Tool and definitions

The Work Observation Method By Activity Timing (WOMBAT) software with a portable touchscreen tablet (Lenovo 7 Tab3) was used to collect data. The tool includes different dimensions of work, as well as specific categories of task and subcategories within these dimensions.[54] Information recorded for each observed task included the dimensions: task type (What?), with whom (Who?) the participant interacted (e.g. other members of the surgical team), resources (How?) used (e.g. telephone), multitasking and the observable source (Why?) of any interruptions that occurred. Tasks performed by the participants were recorded by selecting the predefined categories. Multitasking was recorded on the WOMBAT tool when the participant undertook concurrent tasks, e.g. talking to a colleague while preparing medication. Interruption was in this study defined and operationalized to occur when a participant ceased a current task because of an observable interruption, e.g. while preparing infusion, stopping the task when the surgeon asks to change operating table's position.

Adaptation of the WOMBAT tool to the OR context

In order to ensure validity, ORNs', RNAs' and surgeons' work tasks were first mapped and then discussed with one expert from each targeted profession. The researchers – who later carried out the observations – discussed representation of dimensions, categories, subcategories, multitasking, sources and causes to interruptions in WOMBAT, until consensus was reached over mutually exclusive definitions (Table 1). Common sources and causes to interruptions in the OR have been presented in previous taxonomies and frameworks,[5 44 55] and based on the existing literature and pilot observations, categories were developed for observations of interruptions using WOMBAT. These categories where later confirmed by field notes on examples of the observable cause to an interruption. To verify the correct programming of WOMBAT, written dummy cases were developed and tested. Prior to actual data collection, researchers conducted approximately 15 hours each of pilot testing of WOMBAT based on observations of the three professions, during 12 surgical procedures. The categories, subcategories and their task classifications were then once more refined and adapted to the WOMBAT tool. For example, indirect care was divided in two phases (pre and intra) in order to better represent the preparatory phase before patient's arrival at the OR. To further clarify the source of an interruption, broad categories were programmed under an additional dimension: "Why?".

Table 1. Task classifications for the surgical team

Task categories and subcategories	Definitions	Included activities
Pre-indirect care	Tasks indirectly related to patient care prior to patient arrival	
Disinfect		Pre-operative hand washing/disinfection
Organize/arrange		Preparing equipment
Control/Count		Checking equipment, counting instruments, swabs
Read		Reading/searching patient information
Clean		Arranging and cleaning
Protect		Applying sterile gown, gloves, apron
Intra-indirect care	Tasks indirectly related to patient care, when the patient is present	
Observe/monitor		Monitoring patients' vital parameters
Disinfect		Hand washing/disinfection
Organize/arrange		Preparing equipment
Control/count		Controlling equipment, counting instruments, swabs
Read		Reading and reviewing patient information
Clean		Arranging and cleaning
Protect		Applying protective apron or gloves
Direct care	Tasks directly related to patient care	
Skin disinfection		Disinfecting the incision area, including drying time
Drape		Draping the patient
Assist		Assisting another professional
Instrumentation		Instrumentation with surgeon
Perform invasive surgical/ anesthetic procedures		Performing the procedure/intubation, inserting intravenous lines
Perform patient care		Communicating with the patient, mobilizing of the patient, dressing the wound, moving the patient to the bed
Medication	Tasks related to providing medication to a patient	
Prepare		Reading prescriptions, preparing syringes
Administer		Giving medication to the patient
Document		Documenting medication care
Communicate		Discussing medication care and prescriptions, asking for clarification
Documentation	Any recording of patient information on paper or computer	
Communication	Any work-related or social discussion with another staff member	
Professional		Discussions related to the procedure, planning the care of the patient, paging surgeon or anesthesiologist, reporting, completing the WHO checklist
Irrelevant		Case-irrelevant communication
Supervision	Any activity focused on teaching or education	*(Note: When supervision is taking place, all other tasks are "multitasking".)*
Other	Any other task not included above	For example: waiting for a colleague or a decision, when there is no communication
In transit	Any movement between rooms	Transferring the patient into and out of the room Getting equipment needed

Inter-rater reliability

In total, 12 rounds of inter-rater reliability testing were conducted by the researchers independently observing the same participant for 30 minutes.[56] Situations that were difficult to record using the pre-defined task definitions were discussed between sessions to achieve agreement in subsequent observations. Inter-rater reliability was calculated by comparing the number and type of tasks recorded by the two researchers (e.g. direct care, indirect care, communication and other). According to the WOMBAT manual, once an inter-rater reliability ≥ 0.81 has been achieved, data collection may commence.[56] The total Cohen's kappa score for number of tasks (n=2,439) for the three professions in this study was *k*0.86, indicating high observer agreement.[57]

Data collection

Observations were performed between 07:30 and 21:00 on Monday to Thursday from 14 November to 15 December 2016. Prior to the observation sessions, professionals involved in selected surgical procedures provided informed consent and were informed that they might withdraw from the study at any time. Consent was not obtained from patients and other staff, as they were not targeted in the observations. However, they were informed orally about the study and were given the option to deny observations of the procedure they were participating in. If this occurred prior to or during a surgical procedure the observation should stop and already collected data would be excluded from the study. However, this did not occur. Observations of ORNs and RNAs started when the participants began to plan and prepare for the surgical procedure and continued until the patient had left the OR. The RNAs were also observed in the preparation room, which was adjacent to the OR. Observation of the surgeon started when they entered the OR and ended when they left the OR after the surgical procedure. Thus, the surgeons were observed for a total of 37 hours whereas ORNs and RNAs were observed for 66 hours each. The researcher followed the same participant unobtrusively during the whole surgical procedure, registering tasks the participant performed, with whom and how.[58] When an interruption occurred, manifest sources (what could be observed) of the interruption was registered in WOMBAT. The underlying cause, often verbally expressed, of the observable source was written down as field notes. To complete the structured observations with contextual factors such as testing of new medical-technical equipment, field notes were made during and directly after the observations.

Data analysis

Descriptive statistics were used to determine the total observation time, number and proportion of tasks, proportion of category-specific task time and multitasking time based on total observed time per profession and interruption rate per hour of the surgical team. Large-sample normal approximation with Wilson's interval was used to calculate 95% confidence intervals (CIs) for the number of tasks, proportions of category-specific task time and multitasking time. Analysis of the data was performed using Microsoft Excel 2016 and the Statistical Package for Social Sciences, SPSS version 21.

RESULTS

During the data collection period, 199 procedures in general surgery were performed at the OR department and 46 (23.1%) of these were observed. The 46 surgical procedures included in the data collection contained 78 unique recorded observation sessions, including 26 observations per profession. ORNs and RNAs were observed for 66 hours each and surgeons were observed for 37 hours, with a total time of 169 observation hours. Of the 46 surgical procedures, four were acute and the rest were elective. According to type of surgery, 28 of these procedures were laparoscopic and 18 were conducted with open surgery. The surgical procedures, from incision until wound closure, lasted between 38 minutes and 3 hours and 15 minutes (mean time 42 minutes). General anesthesia was administered in 42 of the 46 (91.3%) surgical procedures and regional anesthesia in four (8.7%). Demographic data for the participants are presented in Table 2.

Table 2. Demographic data for operating room nurses (ORNs), registered nurse anesthetists (RNAs), and surgeons during the observed surgical procedures (n=26), by profession

Profession	Observation time, hours	Number of observed participants	Mean age, years (range)	Gender of the participant, female/male, number	Mean experience as specialist, years (range)	Mean experience at the participating hospital, years (range)
ORNs	66	10*	46 (26–60)	9/1	13 (2–39)	10 (0.5–39)
RNAs	66	8*	50 (32–64)	3/5	18 (5–34)	14 (5–28)
Surgeons	37	9*	47 (32–65)	2/7	13 (0–32)	9 (2–28)
Total	**169**	**27**	**47**	**14/13**	**15**	**11**

* Same ORN was observed 1–7 times
* Same RNA was observed 2–6 times
* Same surgeon was observed 1–8 times

Observed tasks and category-specific task time

Before and during surgical procedures surgical teams perform 10,870 tasks in total (64.3 per hour). RNAs performed 4,752 tasks (72.0 per hour), surgeons 2,271 (61.4 per hour) and ORNs 3,847 tasks (58.3 per hour). For the surgical team, communication (n=4,968) are shown to be the most frequent task, followed by intra-indirect care (n=1,935). Regarding proportion of tasks per profession, communication is most frequent for surgeons (84.0%, n=1,908), followed by ORNs (50.6%, n=1948) and RNAs (23.4%, n=1,112) (Table 3). However, the proportion of category-specific task time per total observed time per profession has shown that direct care for surgeons equated with the surgical procedure, despite the low number of tasks dominating the surgeons' (54.1%, n=100) and ORNs' (33.5%, n=615) intra-operative time. For RNAs (41.0%, n=1,079) intra-indirect care had the largest proportion of category-specific task time. Category-specific task time for communication (ORNs 18.0%, RNAs 8.3% and surgeons 37.8%), in comparison with the high frequency of communication, is not as dominant as direct care. This reflects that communication is frequent but short, unlike direct care that is less frequent but ongoing for a longer period of time. Of the total time spent on communication (47 hours and 16 minutes), professional communication represented 38 hours and 32 minutes (81.4%), while case-irrelevant communication comprised 8 hours and 47 minutes (18.6%). Proportions of category-specific task time, i.e. the observed time participants spent performing tasks in a particular category, are reported in Table 3 and Figure 1.

Table 3. Number, frequency and proportion of tasks, proportion of category-specific task time and multitasking for each profession (operating room nurses (ORNs), registered nurse anesthetists (RNAs) and surgeons)

Task category	Number of tasks	Frequency of tasks per total observed time per profession*	Proportion of tasks per profession (%) (95% CI)*	Proportion of category-specific task time per total observed time per profession* (%) (95% CI)*	Proportion of multi-tasking during category-specific task time per total observed time per profession* (%) (95% CI)*
Communication					
ORNs	1,948	29.5	50.6 (49.1–52.2)	18.0 (17.0–19.1)	68.8 (65.8–71.7)
RNAs	1,112	16.8	23.4 (22.2–24.6)	8.3 (7.7–9.0)	84.0 (80.8–86.8)
Surgeons	1,908	51.6	84.0 (82.4–85.5)	37.8 (36.2–39.5)	89.0 (87.2–90.6)
Total	4,968				
Intra-indirect care					
ORNs	743	11.3	19.3 (18.1–20.6)	17.6 (16.5–18.6)	40.7 (37.6–43.9)
RNAs	1,079	16.3	22.7 (21.5–23.9)	41.0 (39.9–42.2)	76.4 (74.8–77.9)
Surgeons	113	3.1	5.0 (4.2–6.0)	2.5 (2.1–3.1)	23.0 (15.4–32.9)
Total	1,935				
Direct care					
ORNs	615	9.3	16.0 (14.9–17.2)	33.5 (32.3–35.0)	44.9 (42.5–47.2)
RNAs	851	12.9	17.9 (16.8–19.0)	11.2 (10.5–12.0)	74.4 (71.3–77.4)
Surgeons	100	2.7	4.4 (3.6–5.3)	54.1 (52.4–55.8)	62.5 (60.3–64.7)
Total	1,566				
Medication					
ORNs	74	1.1	1.9 (1.5–2.4)	0.6 (0.4–0.8)	43.7 (27.4–60.8)
RNAs	942	14.3	19.8 (18.7–21.0)	7.8 (7.1–8.4)	84.8 (81.5–87.6)
Surgeons	85	2.3	3.7 (3.0–4.6)	1.1 (0.8–1.5)	84.3 (69.6–92.6)
Total	1,101				
Documentation					
ORNs	57	0.9	1.5 (1.2–1.9)	1.5 (1.2–1.8)	19.7 (12.2–29.7)
RNAs	453	6.9	9.5 (8.7–10.4)	5.5 (5.0–6.1)	97.8 (96.0–98.9)
Surgeons	24	0.7	1.1 (0.7–1.6)	1.3 (0.9–1.7)	20.2 (11.2–34.5)
Total	534				
Other					
ORNs	240	3.6	6.2 (5.5–7.1)	8.5 (7.8–9.3)	16.4 (13.3–20.2)
RNAs	56	0.9	1.2 (0.9–1.5)	1.1 (0.9–1.3)	26.9 (18.2–38.2)
Surgeons	16	0.4	0.7 (0.4–1.1)	1.1 (0.8–1.5)	15.3 (7.2–31.1)
Total	312				
In transit					
ORNs	89	1.4	2.3 (1.9–2.8)	4.9 (4.4–5.5)	12.8 (9.2–17.3)
RNAs	112	1.7	2.4 (2.0–2.8)	3.6 (3.2–4.1)	49.6 (43.5–55.7)
Surgeons	16	0.4	0.7 (0.4–1.1)	0.7 (0.5–1.1)	0.3
Total	217				
Pre-indirect care					
ORNs	59	0.9	1.5 (1.2–2.0)	2.0 (1.7–2.4)	42.3 (33.1–51.5)
RNAs	93	1.4	2.0 (1.6–2.4)	1.5 (1.3–1.9)	41.3 (32.3–50.6)
Surgeons	-	-	-	-	-
Total	152				
Supervision					
ORNs	22	0.3	0.6 (0.4–0.9)	13.4 (12.5–14.4)	65.9 (62.3–69.3)
RNAs	54	0.8	1.1 (0.9–1.5)	19.9 (19.0–21.0)	89.0 (87.3–90.6)
Surgeons	9	0.2	0.4 (0.2–0.7)	1.4 (1.1–1.9)	99.9 (99.8–100.0)
Total	85				
Total	**10,870**				
ORNs	**3,847**	**58.3** per hour	**35.4%**	**33.6%**	**46.8%**
RNAs	**4,752**	**72.0** per hour	**43.7%**	**44.4%**	**79.1%**
Surgeons	**2,271**	**61.4** per hour	**20.9%**	**22.0%**	**70.8%**

*CI = confidence interval.
*Total observation time per profession was 66 hours each for ORNs and RNAs, whereas surgeons were observed for 37 hours

---- Figure 1. Here ----

Multitasking

During 169 hours of observations, 261 task hours were recorded. The discrepancy between observation time and task hours is explained by multitasking, caused by a professional conducting multiple tasks simultaneously. The observed surgical team spent 48.2% (82 hours 6 minutes) of the total observation time multitasking. The proportion that each profession spent multitasking out of their total observed time per profession was 63.1% (42 hours 2 minutes) for RNAs, 53.8% (20 hours 4 minutes) for surgeons and 30.1% (19 hours 58 minutes) for ORNs. In 74.0% of the observed tasks (n=8,106 out of the total observed tasks n=10,870) the staff engaged in two (n=6,369) and sometimes three (n=1,650) simultaneous tasks. An example of this is observing an ongoing supervision of a student, engaging the team in the same discussion while still monitoring the patient and simultaneously disinfecting hands. Multitasking was most often observed in ORNs' and surgeons' work during communication (68.8% and 89.0% of the task time, respectively) and supervision (65.9% and 99.9%), while for RNAs, multitasking happened mostly during documentation (97.8%) and supervision (89.0%). The proportion of task time spent multitasking for the surgical team is presented in Table 3.

Interruptions, interrupted task, sources of interruption and response after interruption

In total, 426 interruptions were observed and the overall interruption rate across all tasks was 2.5 times per hour. Among professions, RNAs were interrupted most frequently (n=254, 59.6%), 3.8 times per hour (Table 4). The most interrupted task was communication, with 4.7 interruptions per hour. Interruptions were more common during professional communication (5.9 per hour, n=207) than during irrelevant communication (2.9 per hour, n=25). Out of all interruptions, equipment-related, i.e. concerning missing or malfunctioning equipment, were the most common at 114 (26.7%), and the second most common interruptions were related to the procedure, e.g. fog on lens at 95 (22.3%). The ORNs' work was typically interrupted by equipment-related (n=48, 50.5%), and procedure-related issues (n=23, 24.2%). Medication-related interruptions were not common (n=46, 10.7% of all interruptions) and affected only the RNAs' work (18.1%). After medication-related interruptions, the second most prevalent interruption in RNAs' work was related to equipment (n=39, 15.3%). Procedure-related interruptions affected surgeons' work most often (n=35, 45.6%), in addition to equipment-related problems (n=27, 35.1%) (Table 4). The interruptions were most commonly followed by communication (n=150, 39.1%), of which the majority was professional communication (n=138, 92.0%). Additionally, team responded to interruptions with intra-indirect care (n=65, 16.9%) or by providing direct care (n=53, 13.8%). ORNs responded to interruptions by communication (n=37, 39.4%, of which professional n=34, 91.8%) and with intra-indirect care (n=22, 23.4%). The RNAs' responding tasks were most often communication (n=51, 23.8%, of which professional n=44, 86.3%) or medication-related tasks (n=48, 22.4%). Surgeons reacted mostly with communication only (n=62, 81.5%, of which professional n=60, 96.8%).

Table 4. Sources and causes of observed interruptions, giving overall frequency and frequency per hour, for operating room nurses (ORNs), registered nurse anesthetists (RNAs), surgeons* and for the surgical team together

Sources of interruptions	Examples of causes to interruptions	ORNs	RNAs	Surgeons	Total
Equipment, n	Malfunction, missing or wrong equipment Change of OR table	48	39	27	114
Related to procedure, n	Providing additional information Contaminating sterile area Fog on lens	23	37	35	95
Related to medication, n	Missing or wrong medication	0	46	0	46
Change of shift, n	Changing staff for break or lunch during the procedure	7	33	0	40
Alarm, n	Alarm from devices or monitors Indicating high gas pressure	2	31	1	34
External factor, n	External person entering the room to watch the procedure or to discuss test of new equipment	4	22	4	30
Related to patient, n	Changing patient position Changes in patient's vital signs	4	20	4	28
Telephone/pager, n	Searching for surgeons Planning for next procedure	6	16	5	27
Other, n	Wrong action when assisting	1	10	1	12
Total, n		**95**	**254**	**77**	**426**
Interruptions, n, per hour		1.4	3.8	2.0	2.5

*Total observation time per profession was 66 hours each for ORNs and RNAs whereas surgeons were observed for 37 hours

DISCUSSION

This study provided a multidimensional view of the pre- and intraoperative work process of the surgical team in the OR, including the work of ORNs, RNAs and surgeons. In addition to the previous descriptions of the surgical phases and steps, we provide broader and more detailed description of the multitude of tasks, multitasking and interruptions. Communication was the most common task performed by the surgical team and represented almost half of all observed tasks. Multitasking covered a lot of the professionals' time and was most often observed in ORNs' and surgeons' work during communication. Interruptions did not occur frequently in the OR, which differs from previous research findings. Equipment- and procedure-related interruptions were the most prevalent, as compared to phones and pagers reported in other OR studies. Furthermore, RNAs, not the surgeons, were most interrupted, and the interruptions were most commonly responded to by professional communication.

In total, almost 11,000 tasks were recorded during the observations in the OR. The amount of tasks studied in other contexts[39 59-61] makes the ICU most comparable, with more tasks during a corresponding observation time.[61] Communication, and especially professional communication, was the most common task within the surgical team, which is consistent with several other studies from other settings using WOMBAT for data collection.[19 22 38 54 59 61] However, case-irrelevant communication was also observed, such as social conversations to create a team spirit and a positive and open atmosphere. To support clinical work, small talk has been shown to be of importance to elicit large amounts of information and build relationships.[62] As expected, surgeons and ORNs spent half and one third of their time respectively on direct care. In comparison with physicians in the ICU, surgeons performed more direct care, which can be explained by their work operating on the patient.[61] For the RNAs, intra-indirect care accounted for the largest proportion of their time, reflecting the time-consuming task of continuously monitoring the patient's vital signs.

The surgical teams in the OR were observed multitasking almost half of the time. In rare cases, as many as three tasks occurred simultaneously, which has also been reported in another study on physicians in general wards.[63] In a study where the surgical care process was observed including the OR and surgical ward, nurses and physicians spent approximately one sixth and one third respectively of their time multitasking.[22] In addition, as the OR department in our study served as a teaching hospital, nursing students were present during 22 sessions, explaining the proportion of supervision in the tasks and also the amount of multitasking. A study of physicians in the ICU[61] showed that, compared with physicians working in medical and surgical wards,[15] they were more likely to multitask (one quarter and one fifth respectively). In the ED, multitasking time varied depending on the profession – 13% for registrars, 23% for physicians, and 12%–28% for nurses.[26 39 54] Since the surgical teams in our study were multitasking almost half of their time, it elucidates the complexity of the OR context, including time pressure and high cognitive demands.[5]

Similar to other studies using WOMBAT for data collection,[17 59 60 63] communication played an important role throughout the surgical procedure in our study. Even though performed simultaneously with e.g. direct care, communication may be seen as a team-coordinating and resilience-enhancing behavior. Maintaining a shared situational awareness[64] within the team is a key function in anticipating possible deviations in the intra-operative process. Since communication in the team was a dominant task involved in multitasking, it may reflect the transfer of important information, and contribute to creating a smooth and efficient care process.[16] Thus restrictions to prevent multitasking may also have unwanted consequences.[15] Training to improve healthcare professionals' skills in dealing with multiple goals and demands, prioritization, and efficient task allocation – for example, when to speak up – may have positive implications for patient safety.[2 15]

Interactions not only predispose the team to multitasking, but they may also lead to interruptions. Interruptions occurring in the OR may lead to loss of information, gaps in continuity, breakdown in adjustments, and adverse events.[11 65] In comparison with other studies, where entering the OR and the telephone/pager were the most common sources of interruptions,[51] our study showed equipment- and procedure-related issues as the most common sources of interruptions. These, together with other sources of interruptions, should be taken into consideration when anticipating and creating shared situation awareness when preparing for the surgical procedure. The RNAs were interrupted most frequently, with 3.8 interruptions per hour. This deviates from findings in other studies, which report that ORNs and surgeons are interrupted most frequently.[5] Our observations also showed that the RNAs often communicated with professionals outside the OR and transferred information back to the surgical team. Surgeons interrupted by telephones or pagers are commonly described in the literature,[5 51] which is not consistent with the relatively low numbers in this study. In the hospital where observations were conducted, restrictions regarding pagers and personal telephones had been implemented in the OR. These restrictions could likely be one reason for the lower interruption rates for surgeons. In ICUs, nurses and physicians have, in general, been reported to be interrupted approximately 3.5 times per hour,[38] and physicians in EDs 6.6 times per hour.[26] In previous studies, interruptions occurred almost ten times per hour on average in the OR.[51 5] In observations conducted that combined the OR and surgical ward, almost 13 interruptions per hour for nurses and physicians were identified,[22] while we found that interruptions occurred 2.5 times per hour. Apart from length and type of the surgical procedure, this disparity may also in part be explained by the fact that most observed procedures were elective.

The observed hospital was small, which may have had a positive influence on the number of interruptions. From the field notes it could be seen that interruptions were not always negative in nature, which also agrees with previous research.[31] Out of all interruptions identified in this study, patient-related and procedure-related interruptions often arose in situations where safe and smooth intra-operative care processes needed to be secured – e.g. when patient positioning was altered for better visibility or changed operative plans required new equipment. This is an example of how team adaptation can counteract the negative impact of increased complexity introduced by interruptions or new medical challenges.

Most interruption research in the OR has described communication as a source of interruption, in terms of miscommunication and lack of communication.[5 10 45-47] For the surgical team, the most interrupted task was communication. In other studied contexts, such as the ICU, the most interrupted task has been documentation.[61] This elucidates that the OR context is a CAS, highly dependent on communication that supports and adjusts the complex interactions between those involved in a surgical procedure. Communication in our study was often observed as a task involved in interruptions and multitasking, in order to advance the pre- and intraoperative work process. Consistent with others,[38] the results also showed that interruptions were most commonly followed by professional communication.

The sometimes unpredictable nature of work in an OR, and the number and complexity of tasks, multitasking and interruptions, requires the surgical team to interact, organize and solve problems through communication or by using information technology. Communication and multitasking both help and hinder task completion. The timing and coordination of activities during a surgical procedure requires communication. During our observations, participants were forced to alter or halt their activities and proceed with different tasks on multiple occasions. Some of these situations may be interpreted as adaptations[30] while others were clear interruptions, which highlights the dual nature of interruptions.[30 31] Our data indicate the existence of a multitude of tasks involved in everyday work in the OR. They also support the notion that, rather than trying to control complexity, it should be embraced and applied as a clarifying lens to understand today's healthcare organizations.[49] The surgical team's ability to overcome and compensate for shortcomings and to adapt to variations and demands must be further explored and understood. Strategies used by professionals when successfully navigating through and recovering from unexpected events and interruptions that occur in a CAS should be studied and used as a central theme for supporting resilience performance.[12]

Strengths and limitations

This study adds to the knowledge of how complex work is performed in the OR by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team. In order to produce an interprofessional view of the teamwork in the OR, the observations included three key professions: ORNs, RNAs and surgeons. However, it should be considered that the total observation time was somewhat less for surgeons, as the time for observations of preparation before the surgical procedures did not include surgeons. The data collection tool used, WOMBAT, employs a structured observation protocol with an objective definition of "interruption", which may reduce the risk of potential measurement errors. Unlike previous WOMBAT studies reporting interrupted tasks and initiated tasks after the interruption, we report the observable source and cause of interruptions (Why). Another strength is that both observers were experienced RNAs and one of the researchers also had experience as an ORN. However, in order to avoid bias, the observations were conducted in a hospital where the researchers had not previously worked.

Surgical teams in Sweden mostly consist of an RNA, anesthesiologist, operating and assistant surgeon, ORN and circulating nurse. Even though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed ORN, RNA or surgeon, the nature of performed tasks and how often they were interrupted was not recorded. This may be considered a limitation, as the whole surgical team is not represented in this study. Regulations concerning the amount of people in the room and the risk for healthcare-associated infections in orthopedic implant surgery[53] contributed to exclusion of these procedures, which may be taken into consideration when interpreting the results. Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias. This study was performed in one hospital only and the observations did not include night shifts, weekend shifts or procedures conducted on Fridays. This may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

Conclusions

Communication was identified as a major component in the multidimensional pre- and intraoperative work process of the surgical team. Work in the OR consists of multiple professionals performing many tasks, with the probability of a high degree of interrelatedness, and therefore may be considered a CAS. In order to accomplish tasks, meet goals, develop and deliver safe care for patients, professionals share information and coordinate through communication. Thus, communication between members of the team seems to be a contributing factor to success during surgical procedures as it may support the safe management of complexity. The team constantly dealt with multitasking and interruptions, both with potential impact on patient safety and workflow. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a CAS. Future patient safety research should focus on understanding the complexity within the system, different work processes, and how teams meet the challenges of a CAS.

Contributorship statement

C.G., M.U., U.N., A.E. and M.E. contributed to the study design. C.G. was the project supervisor and performed the initial exploratory observations. C.G. and K.O. were responsible for identification and definitions of categories, as well as data collection and drafting the manuscript. They also undertook the initial interpretation of the data, which was followed by discussions with M.U., U.N., K.P.H., A.E. and M.E. Drafts of the manuscript were reviewed by M.U., U.N., K.P.H., A.E. and M.E. All authors have read and approved the final manuscript.

Competing interests

The authors report no conflict of interest. The authors alone are responsible for the content and the writing of this paper.

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Data sharing statement

No additional data are available.

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Ethics approval

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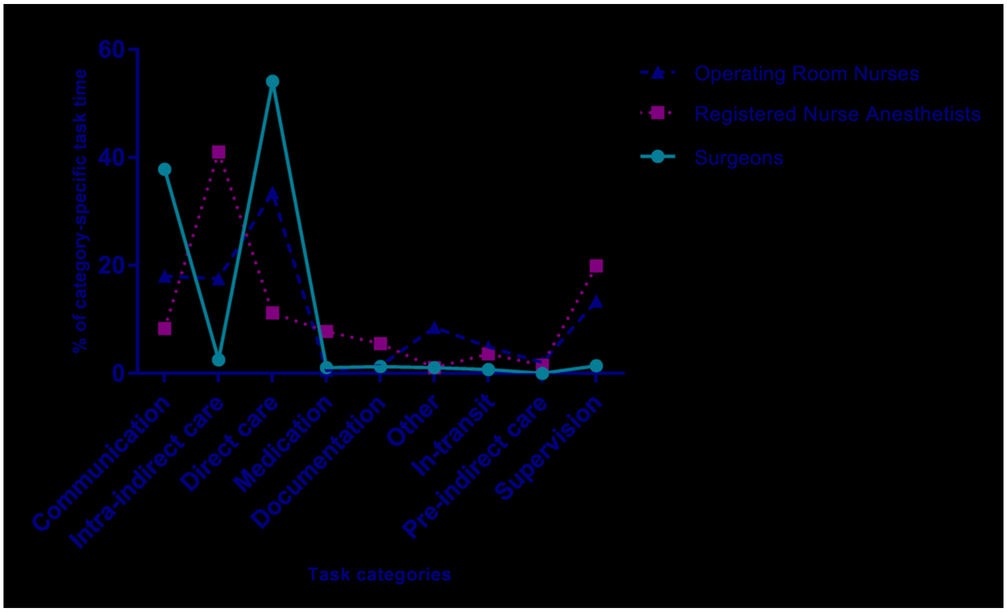

Figure 1. Distribution of the proportion of the observed time* participants spent performing tasks in a particular category
*Total observation time per profession was 66 hours each for ORNs and RNAs, whereas surgeons were observed for 37 hours

94x57mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies.*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#4 - #5
Objectives	3	State specific objectives, including any prespecified hypotheses	#6
Methods			
Study design	4	Present key elements of study design early in the paper	#7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#7 - #9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#5, not fully applicable for this study
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#6, not fully applicable fo rthis study
Bias	9	Describe any efforts to address potential sources of bias	*#19*
Study size	10	Explain how the study size was arrived at	#9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#10
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable for this study
		(*c*) Explain how missing data were addressed	Missing data were

			treated as missing, and not imputed or averaged.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable for this study
		(*e*) Describe any sensitivity analyses	Not applicable for this study
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#11
		(b) Give reasons for non-participation at each stage	#9
		(c) Consider use of a flow diagram	Not applicable for this study
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#11
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable for this study
Outcome data	15*	Report numbers of outcome events or summary measures	#11-#15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#10
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable for this study
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable for this study
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable for this study
Discussion			
Key results	18	Summarise key results with reference to study objectives	#16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#19-#20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from	#16-#19

		similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	#19 - #20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Tasks, multitasking and interruptions among the surgical team in an operating room: a prospective observational study

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Tasks, multitasking and interruptions among the surgical team in an operating room: a prospective observational study

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ABSTRACT

Objectives The work context of the operating room (OR) is considered complex and dynamic with high cognitive demands. A multidimensional view of the complete pre- and intraoperative work process of the surgical team in the OR has been sparsely described. The aim of this study was to describe the type and frequency of tasks, multitasking, interruptions and their causes during surgical procedures from a multi-dimensional perspective on the surgical team in the OR.

Design Prospective observational study, using the Work Observation Method By Activity Timing (WOMBAT) tool.

Setting An OR department at a county hospital in Sweden.

Participants Operating room nurses (ORNs) (n=10), registered nurse anesthetists (RNAs) (n=8) and surgeons (n=9).

Results The type, frequency and time spent on specific tasks, multitasking and interruptions were measured. From a multidimensional view, the surgical team performed 64 tasks per hour. Communication represented almost half (45.7%) of all observed tasks. Concerning task time, direct care dominated the surgeons' and ORNs' intra-operative time, while in RNAs' work it was intra-indirect care. In total, 48.2% of time was spent in multitasking and was most often observed in ORNs' and surgeons' work during communication. Interruptions occurred 3.0 per hour, and the largest proportion, 26.7%, was related to equipment. Interruptions were most commonly followed by professional communication.

Conclusions The surgical team constantly dealt with multitasking and interruptions, both with potential impact on workflow and patient safety. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a complex adaptive system. Future research should focus on understanding the complexity within the system, on the design of different work processes, and on how teams meet the challenges of a complex adaptive systems.

Words: 279

Keywords: Complexity, multitasking, interruptions, patient safety, operating room

Ethical registration number
2016/264

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study adds to the knowledge of how complex work is performed in the operating room by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team.
- The data collection tool used, WOMBAT, employs a structured observation protocol with an operationalized definition of "interruption", which may reduce the risk of potential measurement errors.
- Even though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed operating room nurse, registered nurse anesthetist or surgeon, the nature of performed tasks and how often they were interrupted was not recorded, which may be considered a limitation, as the whole surgical team is not represented in this study.
- Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias.
- This study was performed at one hospital only and the observations did not include night shifts, weekend shifts or procedures conducted on Fridays, which may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

BACKGROUND

Clinical work in surgery is often fast-paced, demanding and time- and resource-constrained. It requires specific technical and cognitive skills[1] and involves multiple activities such as organizing care, responding to patients' changing conditions, anticipating needs, and performing surgical procedures.[1 2] An operating room (OR) can be considered a complex adaptive system (CAS),[3 4] which requires that professionals act and communicate, adapt, learn and self-organize over time.[5] It is an interconnected and dynamic environment[3] with an inherent potential for distractions and interruptions.[1 6]

The members of the surgical team are essential actors in the OR,[7] focused on providing safe surgical care. In addition, components such as a suitable environment, functioning equipment, drugs, and disposable items are needed to support the intra-operative process.[8] The work process of the surgical team in the OR is mainly described through the surgical procedure and its phases,[9] sometimes including the phases of anesthesia.[10] The OR context has considerable potential for interruptions that may interfere with the work of the surgical team.[6 11] Good outcomes often rely on individuals' and teams' skills in adjusting and adapting to unexpected events and rapidly changing situations, using communication and interaction, i.e., resilient performance.[12 13] Understanding resilience requires a deep understanding of the work as it is actually carried out, rather than how it is usually presented in standardized models.[14]

Multitasking can be defined as managing multiple tasks simultaneously.[15 16] However, inconsistencies in definitions and methods make it difficult to make comparisons between studies.[16] Multitasking is one strategy used to cope with increased work density[17 18] and prioritize between tasks.[19] It is often expressed as an integral part of daily practices and a skill often used by professionals, especially in the emergency department (ED).[17] To ensure immediate communication and information seeking, multitasking can be appropriate.[20] Professionals working in emergency care settings usually do not perceive multitasking as stressful, but see it as related to safe and efficient task completion.[21]

Previous research has showed that physicians are frequently required to multitask, which may affect their work process and potentially impact on patient safety.[22] A recent study showed associations between multitasking and increased rates of prescription errors among physicians in the ED.[23] It has also been reported that even though nurses manage multitasking and interruptions well, errors still occur.[24] In addition, professionals in the OR are expected to multitask by being available through pagers and telephones during the surgical procedures.[25] Research on multitasking has mostly been conducted in EDs, hospital wards and intensive care units (ICUs), primarily involving nurses and physicians, and the results show that multitasking occurs frequently.[18 22 26 27] However, multitasking in the OR has been studied only rarely.[28] Although multitasking is common, knowledge about the impact on patient safety and outcomes is sparse.[16]

Interruption is a complex phenomenon, and can be described as a process of suspension of a current (primary) task to attend to and work on another (secondary) task. Interruptions can involve multiple interconnected components, such as equipment, organizational factors, task characteristics and external environmental conditions.[29] In research, different terms such as interruption, disruption, disturbance, and distraction are used interchangeably. Interruptions have been defined in a variety of ways, which is a challenge to comparisons between studies.[30 31] Interruptions may contribute to task incompletion,[15 32-34] loss of attention, medication errors[35] and gaps in continuity of care.[36] Previous work has mostly focused on interruptions from a negative perspective, where minimizing or preventing interruptions has been the main concern.[31] Associations have been found between interruptions and medication prescription errors in the ED.[23] However, interventions to reduce interruptions have shown limited effectiveness.[37] Healthcare processes affected by interruptions can be of diverse nature.[29 30] Recent research claims that interruptions may also have a positive impact on patient safety when they entail, for example, obtaining advice from a colleague, or receiving timely[38] and relevant information about a patient.[39] Several studies have described communication as a source of interruptions.[40 41] Additionally, in the OR, communication has been described in terms of being irrelevant or miscommunication.[6 10 11 42 43] Since communication is a relevant task that supports interactions in a CAS,[5] it should be seen both as a means of supporting clinical work and as a source of interruptions.

The frequency, duration,[44 45] sources or causes of interruptions have been studied in the OR.[6 10 46] Outcomes of interruptions have been studied in terms of effects on professionals´ levels of distraction,[44] engagement,[11 47] delay,[45] and interference in the work process.[6] These findings reveal interruptions to be a predominantly negative phenomenon in the OR. Studies in the OR with a team perspective and a coherent definition are few.[11 48]

To conclude, previous research has studied the work process of the surgical team mainly during surgery and anesthesia. The OR is a CAS, where interruptions with diverse nature frequently occur and multitasking is expected, which may affect workflow and patient safety. However, multitasking with a team perspective has not been studied in the OR. Thus, there is a lack of knowledge regarding the multi-dimensional view of the pre- and intraoperative work process in the OR focusing on all performed tasks, multitasking, interruptions and their causes, i.e., how the work is actually done in the surgical team. Therefore, the aim of this study was to describe the type and frequency of tasks, multitasking, interruptions and their causes from a multi-dimensional perspective for the surgical team in the OR.

METHODS

Setting and sample

This prospective observational study was conducted in a central OR department at a local county hospital in Sweden. The hospital had two surgical wards, with a total of 38 beds. For general surgery, there was one department for ambulatory surgery and one central OR department. During 2016, a total of 4,118 patients underwent surgery at this hospital. The central OR department consisted of six rooms that served both acute and elective orthopedic and surgical patients. In connection to each OR, there was a preparation room where the registered nurse anesthetist (RNA) and/or the anesthesiologist sometimes prepared patients for surgery. Some medications were also stored in this area.

As in many other countries, surgical teams in ORs in Sweden commonly comprise six professionals, namely: RNA,[49] anesthesiologist, operating surgeon and assisting surgeon, operating room nurse (ORN) and a circulating nurse (commonly a licensed practical nurse).[6] For the observations we selected a convenience sample of scheduled general surgical procedures from a case list. To provide coverage and representativeness of common procedures performed at the department across weekdays (Mon–Thu) and shifts (07:30–21:00 hours) the sample included acute and elective general surgical procedures performed on adults. Since the number of people present in the OR is associated with risk for healthcare-associated infections during orthopaedic procedures,[50] such procedures were excluded, as were night shifts. The professionals were informed about the study during workplace meetings and invited to participate.

Patient and public involvement

Patients or the public were not involved in this study.

Tool and definitions

The Work Observation Method By Activity Timing (WOMBAT) software with a portable touchscreen tablet (Lenovo 7 Tab3) was used to collect data. The tool includes different dimensions of work, as well as specific categories of task and subcategories within these dimensions,[51] which were customized by the researchers to fit the context of this study. Information recorded for each observed task included the dimensions: task type (What?), with whom (Who?) the participant interacted (e.g. other members of the surgical team), resources (How?) used (e.g. telephone), multitasking and the observable cause (Why?) of any interruptions that occurred. Tasks performed by the participants were recorded by selecting the predefined categories. A clear statement of definitions being used is considered crucial.[30] The concepts used in this study, with associated operationalized definitions, are presented in Table 1.

Table 1. Used concepts and their operational definitions

Concepts	Operational definitions
Multitasking	When a member of the surgical team carried out observable multiple tasks simultaneously e.g. talking to a colleague while preparing medication
Interruption	When a member of the surgical team ceased a current task because of an observable external stimulus e.g. paused to prepare an infusion when a surgeon asks to change the position of the operating table
Cause of interruptions	Describes the cause to an observable interruption
Interrupting task	Task that interrupts an ongoing task or task(s)
Interrupted task	The ongoing task that is being interrupted
Task after interruption	Tasks initiated after an interruption

Adaptation of the WOMBAT tool to the OR context

In order to ensure validity, ORNs', RNAs' and surgeons' work tasks were first mapped and then discussed with one expert from each targeted profession. The researchers – who later carried out the observations – discussed representation of dimensions, categories, subcategories, multitasking, causes of interruptions in WOMBAT, until consensus was reached over mutually exclusive definitions (Table 2). Common causes of interruptions in the OR have been presented in previous taxonomies and frameworks,[6 46 52] and based on the existing literature and pilot observations, categories were developed for observations of interruptions using WOMBAT. These categories where later confirmed by field notes on examples of the observable cause to an interruption. To verify the correct programming of WOMBAT, written dummy cases were developed and tested. Prior to actual data collection, researchers conducted approximately 15 hours each of pilot testing of WOMBAT based on observations of the three professions, during 12 surgical procedures. The categories, subcategories and their task classifications were then once more refined and adapted to the WOMBAT tool. For example, indirect care was divided in two phases (pre and intra) in order to better identify the preparatory phase before patient's arrival at the OR. To further clarify the cause of an interruption, broad categories were programmed under an additional dimension: "Why?".

Table 2. Task classifications for the surgical team

Task categories and subcategories	Definitions	Included activities
Pre-indirect care	Tasks indirectly related to patient care prior to patient arrival	
Disinfect		Pre-operative hand washing/disinfection
Organize/arrange		Preparing equipment
Control/Count		Checking equipment, counting instruments, swabs
Read		Reading/searching patient information
Clean		Arranging and cleaning
Protect		Applying sterile gown, gloves, apron
Intra-indirect care	Tasks indirectly related to patient care, when the patient is present	
Observe/monitor		Monitoring patients' vital parameters
Disinfect		Hand washing/disinfection
Organize/arrange		Preparing equipment
Control/count		Controlling equipment, counting instruments, swabs
Read		Reading and reviewing patient information
Clean		Arranging and cleaning
Protect		Applying protective apron or gloves
Direct care	Tasks directly related to patient care	
Skin disinfection		Disinfecting the incision area, including drying time
Drape		Draping the patient
Assist		Assisting another professional
Instrumentation		Instrumentation with surgeon
Perform invasive surgical/ anesthetic procedures		Performing the procedure/intubation, inserting intravenous lines
Perform patient care		Communicating with the patient, mobilizing of the patient, dressing the wound, moving the patient to the bed
Medication	Tasks related to providing medication to a patient	
Prepare		Reading prescriptions, preparing syringes
Administer		Giving medication to the patient
Document		Documenting medication care
Communicate		Discussing medication care and prescriptions, asking for clarification
Documentation	Any recording of patient information on paper or computer	
Communication	Any work-related or social discussion with another staff member	
Professional		Discussions related to the procedure, planning the care of the patient, paging surgeon or anesthesiologist, reporting, completing the WHO checklist
Irrelevant		Case-irrelevant communication
Supervision	Any activity focused on teaching or education	*(Note: When supervision is taking place, all other tasks are "multitasking".)*
Other	Any other task not included above	For example: waiting for a colleague or a decision, when there is no communication
In transit	Any movement between rooms	Transferring the patient into and out of the room Getting equipment needed

Inter-rater reliability

Inter-rater reliability (IRR) was tested during pilot observations, with the researchers independently observing the same participant for 30 minutes.[53] Situations that were difficult to record using the pre-defined task definitions were discussed between sessions to achieve agreement in subsequent observations. During the last three pilot observations, adequate Cohen's kappa value (≥ 0.81)[53] on most observed tasks were achieved (0.85 for indirect care (pre and intra), 0.87 for direct care, 0.93 for medication and 0.82 for communication).[54] During the pilot observations only few interruptions occurred, so calculating kappa was not feasible. However, the observers had identified the interruptions, interrupting task and their causes similarly. Additionally, IRR was assessed using the intra-class correlation (ICC). The proportions of tasks between observers, as well as proportions of time within task categories were examined.[23] Two-way mixed model was used to measure ICC and it was 0.96 (95% CI, 0.83 to 0.99) indicating a high IRR.

Data collection

Observations were performed between 07:30 and 21:00 on Monday to Thursday from 14 November to 15 December 2016. Prior to the observation sessions, professionals involved in selected surgical procedures provided informed consent and were informed that they might withdraw from the study at any time. Consent was not obtained from patients and other professionals, as they were not targeted in the observations. However, they were informed orally about the study and were given the option to deny observations of the procedure they were participating in. If this occurred prior to or during a surgical procedure the observation should stop and already collected data would be excluded from the study. However, this did not occur. Observations of ORNs and RNAs started when the participants began to plan and prepare for the surgical procedure and continued until the patient had left the OR. The RNAs were also observed in the preparation room, which was adjacent to the OR. Observation of the surgeon started when they entered the OR and ended when they left the OR after the surgical procedure. Thus, the surgeons were observed for a total of 37 hours whereas ORNs and RNAs were observed for 66 hours each. The researcher followed the same participant unobtrusively during the whole surgical procedure, registering tasks the participant performed, with whom and how.[55] When an interruption occurred, manifest causes (what could be observed) of the interruption were registered in WOMBAT. The underlying cause, often verbally expressed, was written down in the field notes, as were examples of what the observable cause could be. To complete the structured observations with contextual factors such as testing of new medical-technical equipment, field notes were made during and directly after the observations.

Ethics

This study was conducted in accordance with international research standards under the Declaration of Helsinki and was approved by the Regional Ethical Review Board in Uppsala, Sweden (No. 2016/264).

Data analysis

Descriptive statistics were used to determine the total observation time, number and proportion of tasks, proportion of category-specific task time and multitasking time based on total observed time per profession and interruption rate per hour of the surgical team. Calculation of proportion of task, summation of time on task, proportion of time on task, and confidence interval (CI) were calculated based on the WOMBAT analysis guide, with slight modifications for the latter. In the literature, some have reported a large sample approximation for calculating the CI.[56] Considering the problem of interval estimation of proportion and the erratic behavior of the large sample approximation (the Wald interval) we have employed the Wilson's confidence interval. The CI from the Wald interval often has inadequate coverage, particularly for small sample size and values of proportions close to 0 or 1, while the Wilson interval is appropriate for both smaller and larger sample sizes and provides more reliable coverage than other alternatives. The Wilson interval uses the estimated standard error instead of the "null standard error".[57] Since our data include both small and large sample sizes and lower and higher proportions, we felt that the Wilson's interval as a viable alternative for interval estimate of the proportions. Analysis of the data was performed using Microsoft Excel 2016 and the Statistical Package for Social Sciences, SPSS version21.

RESULTS

During the data collection period, 199 procedures in general surgery were performed at the OR department and 46 (23.1%) of these were observed. The 46 surgical procedures included in the data collection contained 78 unique recorded observation sessions, including 26 observations per profession. ORNs and RNAs were observed for 66 hours each and surgeons were observed for 37 hours, with a total time of 169 observation hours. Of the 46 surgical procedures, four were acute and the rest were elective. According to type of surgery, 28 of these procedures were laparoscopic and 18 were conducted with open surgery. The surgical procedures, from incision until wound closure, lasted between 38 minutes and 3 hours and 15 minutes (mean time 42 minutes). General anesthesia was administered in 42 of the 46 (91.3%) surgical procedures and regional anesthesia in four (8.7%). Demographic data for the participants is presented in Table 3.

Table 3. Demographic data for operating room nurses (ORNs), registered nurse anesthetists (RNAs), and surgeons during the observed surgical procedures (n=26), by profession

Profession	Observation time, hours	Number of observed participants	Mean age, years (range)	Gender of the participant, female/male, number	Mean experience as specialist, years (range)	Mean experience at the participating hospital, years (range)
ORNs	66	10*	46 (26–60)	9/1	13 (2–39)	10 (0.5–39)
RNAs	66	8*	50 (32–64)	3/5	18 (5–34)	14 (5–28)
Surgeons	37	9*	47 (32–65)	2/7	13 (0–32)	9 (2–28)
Total	**169**	**27**	**47**	**14/13**	**15**	**11**

* Same ORN was observed 1–7 times
* Same RNA was observed 2–6 times
* Same surgeon was observed 1–8 times

Observed tasks and category-specific task time

During the observation the surgical team performed in average 64.4 tasks per hour. RNAs performed 72.0, surgeons 61.4 and ORNs 58.3 tasks per hour. Regarding proportion of tasks per profession, communication was most frequent for surgeons (84.0%, n=1,908), followed by ORNs (50.6%, n=1,948) and RNAs (23.4%, n=1,112) (Table 4). However, the proportion of category-specific task time per total observed time per profession has shown that direct care for surgeons equated with the surgical procedure, despite the low number of tasks dominating the surgeons' (54.1%, n=100) and ORNs' (33.5%, n=615) intra-operative time. For RNAs (41.0%, n=1,079) intra-indirect care had the largest proportion of category-specific task time. Category-specific task time for communication (ORNs 18.0%, RNAs 8.3% and surgeons 37.8%), in comparison with the high frequency of communication, is not as dominant as direct care. This reflects that communication is frequent but short, unlike direct care that is less frequent but ongoing for a longer period of time. Of the total time spent on communication (47 hours and 16 minutes), professional communication represented 38 hours and 32 minutes (81.4%), while case-irrelevant communication comprised 8 hours and 47 minutes (18.6%). Proportions of category-specific task time, i.e. the observed time participants spent performing tasks in a particular category, are reported in Table 4 and Figure 1.

Table 4. Number, frequency and proportion of tasks, proportion of category-specific task time and multitasking for each profession (operating room nurses (ORNs), registered nurse anesthetists (RNAs) and surgeons), per profession-specific total observation time.*

Task category	Number of tasks	Frequency of tasks (n/hour)	Proportion of tasks (%) (95% CI)* *	Proportion of category-specific task time (%) (95% CI)* *	Proportion of multi-tasking during category-specific task time (%) (95% CI)* *
Communication					
ORNs	1,948	29.5	50.6 (49.1–52.2)	18.0 (17.0–19.1)	68.7 (65.8–71.7)
RNAs	1,112	16.8	23.4 (22.2–24.6)	8.3 (7.7–9.0)	84.0 (80.8–86.8)
Surgeons	1,908	51.6	84.0 (82.4–85.5)	37.8 (36.2–39.5)	89.0 (87.2–90.6)
Total	4,968				
Intra-indirect care					
ORNs	743	11.3	19.3 (18.1–20.6)	17.5 (16.5–18.6)	40.4 (37.6–43.9)
RNAs	1,079	16.3	22.7 (21.5–23.9)	41.0 (39.9–42.2)	76.4 (74.8–77.9)
Surgeons	113	3.1	5.0 (4.2–6.0)	2.5 (2.1–3.1)	23.0 (15.4–32.9)
Total	1,935				
Direct care					
ORNs	615	9.3	16.0 (14.9–17.2)	33.5 (32.3–35.0)	44.9 (42.5–47.2)
RNAs	851	12.9	17.9 (16.8–19.0)	11.2 (10.5–12.0)	74.3 (71.3–77.4)
Surgeons	100	2.7	4.4 (3.6–5.3)	54.2 (52.4–55.8)	62.5 (60.3–64.7)
Total	1,566				
Medication					
ORNs	74	1.1	1.9 (1.5–2.4)	0.6 (0.4–0.8)	43.7 (27.4–60.8)
RNAs	942	14.3	19.8 (18.7–21.0)	7.7 (7.1–8.4)	84.8 (81.5–87.6)
Surgeons	85	2.3	3.7 (3.0–4.6)	1.1 (0.8–1.5)	84.3 (69.6–92.6)
Total	1,101				
Documentation					
ORNs	57	0.9	1.5 (1.2–1.9)	1.5 (1.2–1.8)	19.7 (12.2–29.7)
RNAs	453	6.9	9.5 (8.7–10.4)	5.5 (5.0–6.1)	97.8 (96.0–98.9)
Surgeons	24	0.7	1.1 (0.7–1.6)	1.3 (0.9–1.7)	20.2 (11.2–34.5)
Total	534				
Other					
ORNs	240	3.6	6.2 (5.5–7.1)	8.5 (7.8–9.3)	16.4 (13.3–20.2)
RNAs	56	0.9	1.2 (0.9–1.5)	1.1 (0.9–1.3)	26.9 (18.2–38.2)
Surgeons	16	0.4	0.7 (0.4–1.1)	1.1 (0.8–1.5)	15.3 (7.2–31.1)
Total	312				
In transit					
ORNs	89	1.4	2.3 (1.9–2.8)	4.9 (4.4–5.5)	12.8 (9.2–17.3)
RNAs	112	1.7	2.4 (2.0–2.8)	3.6 (3.2–4.1)	49.6 (43.5–55.7)
Surgeons	16	0.4	0.7 (0.4–1.1)	0.7 (0.5–1.1)	0.3
Total	217				
Pre-indirect care					
ORNs	59	0.9	1.5 (1.2–2.0)	2.0 (1.7–2.4)	42.3 (33.1–51.5)
RNAs	93	1.4	2.0 (1.6–2.4)	1.5 (1.3–1.9)	41.3 (32.3–50.6)
Surgeons	-	-	-	-	-
Total	152				
Supervision					
ORNs	22	0.3	0.6 (0.4–0.9)	13.4 (12.5–14.4)	65.9 (62.3–69.3)
RNAs	54	0.8	1.1 (0.9–1.5)	19.9 (19.0–21.0)	89.0 (87.3–90.6)
Surgeons	9	0.2	0.4 (0.2–0.7)	1.4 (1.1–1.9)	99.9 (99.8–100.0)
Total	85				
Total	**10,870**				
ORNs	**3,847**	**58.3** per hour	**35.4%**		**46.8%**
RNAs	**4,752**	**72.0** per hour	**43.7%**		**79.1%**
Surgeons	**2,271**	**61.4** per hour	**20.9%**		**70.8%**

*Total observation time per profession was 66 hours each for the ORNs and RNAs, whereas the surgeons were observed for 37 hours
**CI, confidence interval

---- Figure 1. Here ----

Multitasking

During 169 hours of observations, 261 task hours were recorded. The discrepancy between observation time and task hours is explained by multitasking. The observed surgical team spent 48.2% (82 hours and 6 minutes, with 173 hours and 46 minutes of category-specific multitasking time) of the total observation time multitasking. The proportion that each profession spent multitasking out of their total observed time per profession was 63.1% (42 hours 2 minutes) for RNAs, 53.8% (20 hours 4 minutes) for surgeons and 30.1% (19 hours 58 minutes) for ORNs. In 74.0% of the observed tasks (n=8,106 out of the total observed tasks n=10,870) the professionals engaged in two (n=6,369) and sometimes three (n=1,650) simultaneous tasks. An example of this is observing an ongoing supervision of a student, engaging the team in the same discussion while still monitoring the patient and simultaneously disinfecting hands. Multitasking was most often observed in ORNs' and surgeons' work during communication (68.8% and 89.0% of the task time, respectively) and supervision (65.9% and 99.9%), while for RNAs, multitasking happened mostly during documentation (97.8%) and supervision (89.0%). The proportion of task time spent multitasking for the surgical team is presented in Table 4.

Interruptions, interrupted task, causes of interruptions and task after interruption

The overall interruption rate across all tasks was 3.0 per hour (n=511). Among professions, RNAs were interrupted most frequently (n=309, 60.5%), 4.6 times per hour. The most interrupted task was documentation, with 3.8 interruptions per hour. Moreover, interruptions were common during intra-indirect care (2.8 per hour, n=181) and during direct care (2.1 per hour, n=156). Out of all observed causes of interruptions (n=426), equipment-related, i.e. concerning missing or malfunctioning equipment, were the most common at 114 (26.7%), and the second most common causes were related to the procedure, e.g. fog on lens at 95 (22.3%). The ORNs' work was typically interrupted by equipment-related (n=48, 50.5%), and procedure-related issues (n=23, 24.2%). Medication-related causes were not common (n=46, 10.7% of all causes) and affected only the RNAs' work (18.1%). After medication-related causes, the second most prevalent in RNAs' work was related to equipment (n=39, 15.3%). Procedure-related causes affected surgeons' work most often (n=35, 45.6%), in addition to equipment-related problems (n=27, 35.1%) (Table 5). The tasks following interruptions were most often communication (n=150, 39.1%), of which the majority was professional communication (n=138, 92.0%). Additionally, team responded to interruptions with intra-indirect care (n=65, 16.9%) or by providing direct care (n=53, 13.8%). ORNs responded to interruptions by communication (n=37, 39.4%, of which professional n=34, 91.8%) and with intra-indirect care (n=22, 23.4%). The RNAs' responding tasks were most often communication (n=51, 23.8%, of which professional n=44, 86.3%) or medication-related tasks (n=48, 22.4%). Surgeons reacted mostly with communication only (n=62, 81.5%, of which professional n=60, 96.8%).

Table 5. Causes of observed interruptions giving overall frequency and proportion, and frequency per hour, for operating room nurses (ORNs), registered nurse anesthetists (RNAs), surgeons* and for the surgical team as a whole.

Causes of interruptions	Examples of causes of interruptions	ORNs n (%)	RNAs n (%)	Surgeons n (%)	Total n (%)
Equipment	Malfunction, missing or wrong equipment Change of OR table	48 (50.5)	39 (15.3)	27	114 (26.8)
Related to procedure	Providing additional information Contaminating sterile area Fog on lens	23 (24.2)	37 (14.6)	35 (45.4)	95 (22.3)
Related to medication	Missing or wrong medication	0	46 (18.1)	0	46 (10.8)
Change of shift	Changing staff for break or lunch during the procedure	7 (7.4)	33 (13.0)	0	40 (9.4)
Alarm	Alarm from devices or monitors Indicating high gas pressure	2 (2.1)	31 (12.2)	1 (1.3)	34 (8.0)
External factor	External person entering the room to watch the procedure or to discuss test of new equipment	4 (4.2)	22 (8.7)	4 (5.2)	30 (7.0)
Related to patient	Changing patient position Changes in patient's vital signs	4 (4.2)	20 (7.9)	4 (5.2)	28 (6.6)
Telephone/pager	Searching for surgeons Planning for next procedure	6 6.3)	16 (6.3)	5 (6.5)	27 (6.3)
Other	Wrong action when assisting	1 (1.1)	10 (3.9)	1 (1.3)	12 (2.8)
Causes to observed interruptions		**95 (22.3)**	**254 (59.6)**	**77 (18.1)**	**426 (100)**

*Total observation time per profession was 66 hours each for ORNs and RNAs whereas surgeons were observed for 37 hours

DISCUSSION

This study provides a multidimensional view of the pre- and intraoperative work process of the surgical team in the OR, including the specialized work of ORNs, RNAs and surgeons. In addition to the previous descriptions of the surgical phases and steps, we provide a broader and more detailed description of the multitude of tasks, multitasking, and interruptions and their causes. Multitasking covered a lot of the professionals' time and, in ORNs' and surgeons' work, was most often observed during communication in the team. Interruptions did not occur frequently, which differs from previous research findings from the OR. Equipment- and procedure-related interruptions were the most prevalent, while phones and pagers have been reported as such in other OR studies. Furthermore, the RNAs were those interrupted most frequently, and the most common response to interruptions was professional communication.

In the observations of the surgical teams, multitasking occurred during almost half of their working time. Multitasking seemed relevant to safe performance of patient care, which implies that it is an integral part of the surgical process. Communication was a dominant task in multitasking, which may reflect the transfer of important information between professionals, contributing to creating a smooth and efficient care process.[20] Much like in other studies using WOMBAT for data collection,[56 58-60] communication played an important role throughout the surgical procedure in our study. Even when performed simultaneously with, e.g., direct care, communication may be seen as a team-coordinating[61 62] and resilience-enhancing behavior. In addition, maintaining a shared situational awareness[63] within the team is key to anticipating possible deviations in the intra-operative process, which is a prerequisite for working in a CAS.[4] The amount of multitasking may be a result of the complexity of the OR context, which includes time pressure and high cognitive demands.[6] In rare cases, as many as three tasks occurred simultaneously, which has also been reported in another study on physicians in general wards.[59] However, when comparing with other settings such as EDs, the OR has several expected routine tasks and procedures, which may make multitasking less cognitively challenging in a normal situation. In our study, the professionals had relatively long work experience (mean 15 years), which may have affected the results. It has been argued that as professionals become more experienced, commonly performed deliberate tasks become more automatic, which may make multitasking easier.[2] Additionally, as the OR department in our study served as a teaching hospital, nursing students were present during 22 sessions, explaining the proportion of supervision in the tasks and also contributing to the amount of multitasking. Preventing multitasking might have unwanted consequences, [58] and impede situational awareness and adaptation to changes in a care process.[61]

Interactions not only predispose a team to multitasking, but may also lead to interruptions. Compared with in other studies,[6 28 64] the interruption rate was lower in this particular setting. Leaving aside the lengths and types of surgical procedures, this disparity may also in part be explained by the fact that most of the observed procedures were elective. The studied hospital was small and the staff turnover was fairly low, which may have had a positive effect on the number of interruptions.[42] Surgeons being interrupted by telephones or pagers are commonly described in literature,[6 64] which is not consistent with the relatively low numbers in our study, where equipment- and procedure-related issues were the most common causes of interruptions. Restrictions regarding pagers and personal telephone use have been implemented in the participating OR, which may be a reason for the lower interruption rates for surgeons. This restriction could be considered noteworthy for future development and research interventions. A control function to test the equipment prior to the start of a surgical procedure could be a way to decrease interruptions. However, implementing more barriers may result in additional, unwanted complexity, and the balance between filtering harmful consequences and the increasing the number of interactions should be addressed when designing work processes.

Among professions in the surgical team, the RNAs were those who were most exposed to interruptions. Our results deviate from those of another study, in which ORNs and surgeons were interrupted more frequently than RNAs.[6] In this study, the observations revealed that the RNAs and the circulating nurse often communicated with professionals outside the OR and transferred information back to the surgical team. Previous research in the OR has predominantly described communication as a source of interruptions.[6 11 42 43] Grundgeiger[30] considered it a default assumption that interruptions are an inherently undesirable form of communication. However, the clinical value of information transfer, i.e., interruptive communication, has been referred to as essential for promoting patient safety,[39] in terms of the progression of patient care,[65] and important for patient treatment and workload management.[38] In our study, communication was the most frequently observed interrupting task, but not the actual cause of interruption, as implied by other studies[42 43]. Consistent with other results,[66] communication was the most frequent task following an interruption. Therefore, communication seems to be an important skill in adapting to the emerging situations causing interruptions.[38 39] This also elucidates the OR context as a CAS,[4] which is highly dependent on communication to support and adjust to complex interactions[5] within the surgical team.

The sometimes unpredictable nature of work in an OR, and the number and complexity of tasks, multitasking, and interruptions, requires the surgical team to interact, self-organize and solve problems through communication or by using information technology. Communication and multitasking both help and hinder task completion. The timing and coordination of activities during a surgical procedure requires communication. During our observations, participants were on multiple occasions forced to alter or halt their activities and proceed with different tasks. Some of these situations may be interpreted as adaptations[39] while others were clear interruptions, which highlights the diverse nature of interruptions.[39 67] Patient- and procedure-related interruptions often arose in situations where safe and smooth intra-operative care processes needed to be safeguarded – e.g., when patient positioning was altered for better visibility or when changed operative plans required new equipment. This illustrated resilient performance through how team adaptations counteracted the increased complexity introduced by interruptions or new medical challenges.[61]

Our findings indicate that there is a multitude of tasks involved in everyday work in the OR. The observations also show that the impact of interruptions and multitasking can both sustain and disrupt safe care. This supports the notion that attempts should not be made to control complexity; rather it should be embraced and applied as a clarifying lens through which to understand today's healthcare organizations.[5] As multitasking is expected in the OR context, controlling variation and adding more barriers to the work process may instead result in even further increases to complexity. Multitasking and interrupting other team members should be accepted and done when necessary, with awareness of patient safety. The surgical team's ability to overcome and compensate for shortcomings and to adapt to variations and demands needs to be further explored. Strategies used by professionals when successfully navigating through and recovering from unexpected events and interruptions that occur in a CAS should be studied to support resilient performance.[13]

Strengths and limitations

This study adds to the knowledge of how complex work is performed in the OR by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team. In order to produce an interprofessional view of the teamwork in the OR, the observations included three key professions: ORNs, RNAs and surgeons. However, the total observation time was somewhat lower for surgeons, as the time for observations of preparation before the surgical procedures did not include surgeons. The data collection tool used, WOMBAT, employs a structured observation protocol with an operationalized definition of "interruption", which may reduce the risk of potential measurement errors. Unlike previous WOMBAT studies reporting interrupted tasks and initiated tasks after the interruption, we include a report on the observable causes of interruptions (Why) with examples. Another strength is that both observers were experienced RNAs and one of the researchers also had experience as an ORN. However, in order to avoid bias, the observations were conducted at a hospital where the researchers had not previously worked.

Surgical teams in Sweden usually consist of a RNA, an anesthesiologist, an operating and assistant surgeon, an ORN and a circulating nurse. Though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed ORN, RNA or surgeon, the nature of their performed tasks and how often they were interrupted were not recorded. This may be considered a limitation, as the whole surgical team is not represented in this study. Regulations concerning the number of people in the room and the risk of healthcare-associated infections in orthopedic implant surgery[50] contributed to exclusion of these procedures, which could be taken into consideration when interpreting the results. Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias. This study was performed at one hospital only and did not include night shifts, weekend shifts, or procedures conducted on Fridays. This may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

Conclusions

Work in the OR consists of many tasks performed by multiple professionals, with the probability of a high degree of interrelatedness. The OR may therefore be considered a CAS. In order to accomplish tasks, meet goals, and develop and deliver safe care for patients, professionals share information and coordinate their work through communication. This seems to be a factor contributing to success during surgical procedures, as it may support the safe management of complexity. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a CAS. The impact of multitasking and interruptions on the work processes can be positive, negative or neutral. This contributes to difficulties in drawing conclusions on simple solutions. Instead of studying tasks, multitasking and interruptions separately, it may be beneficial to study these phenomena from a team perspective and as a complex process, in order to fully understand clinical work. Future patient safety research should focus on understanding the complexity within the system, the design of different work processes, and how teams meet the challenges within a CAS.

Contributorship statement

CG, MU, UN, AE and ME contributed to the study design. CG was the project supervisor and performed the initial exploratory observations. CG and KO were responsible for identification and definitions of categories, as well as data collection and drafting the manuscript. They also undertook the initial interpretation and statistical analysis of the data, which was followed by discussions with MU, UN, KPH, AE and ME. The CI, IRR and ICC were calculated by MKT. Drafts of the manuscript were reviewed by MU, KPH, AE, MKT, UN and ME. All authors have read and approved the final manuscript.

Competing interests

The authors report no conflict of interest. The authors alone are responsible for the content and the writing of this paper.

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Data sharing statement

No additional data are available.

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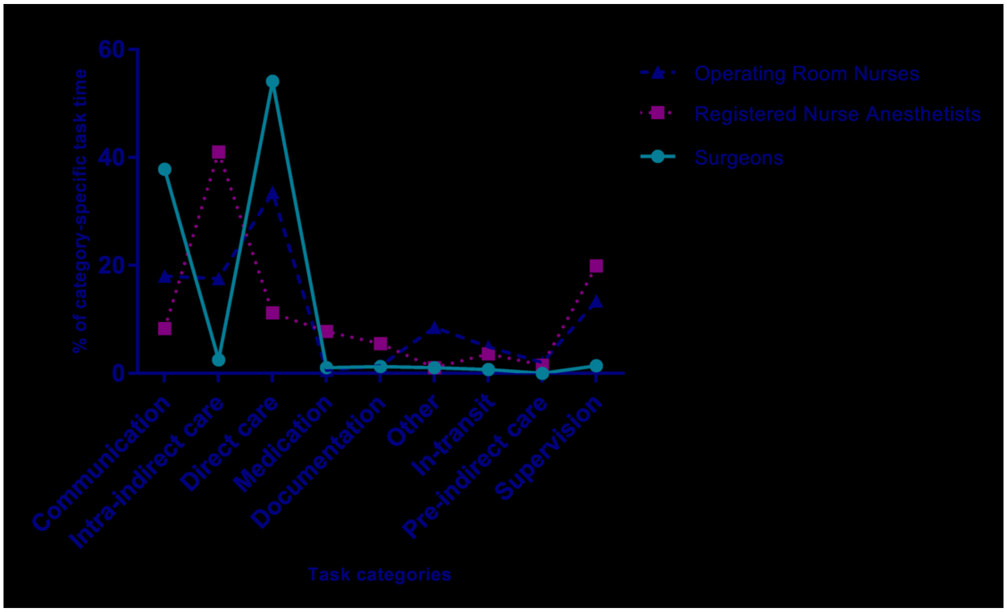
Figure Legends

Figure 1. Distribution of the proportion of the observed time* participants spent performing tasks in a particular category

*Total observation time per profession was 66 hours each for ORNs and RNAs, whereas surgeons were observed for 37 hours



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94x57mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies.*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#4 - #6
Objectives	3	State specific objectives, including any prespecified hypotheses	#5 - #6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6 - #9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#5-#6, not fully applicable for this study
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#6-#7, not fully applicable for this study
Bias	9	Describe any efforts to address potential sources of bias	#17
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#10
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable for this study

		(*c*) Explain how missing data were addressed	Missing data were treated as missing, and not imputed or averaged.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable for this study
		(*e*) Describe any sensitivity analyses	Not applicable for this study
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#11
		(b) Give reasons for non-participation at each stage	#9
		(c) Consider use of a flow diagram	Not applicable for this study
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#11
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable for this study
Outcome data	15*	Report numbers of outcome events or summary measures	#11-#14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#10
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable for this study
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable for this study
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable for this study
Discussion			
Key results	18	Summarise key results with reference to study objectives	#15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#17-#18

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#17-#18
Generalisability	21	Discuss the generalisability (external validity) of the study results	#18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Tasks, multitasking and interruptions among the surgical team in an operating room: a prospective observational study

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Tasks, multitasking and interruptions among the surgical team in an operating room: a prospective observational study

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ABSTRACT

Objectives The work context of the operating room (OR) is considered complex and dynamic with high cognitive demands. A multidimensional view of the complete pre- and intraoperative work process of the surgical team in the OR has been sparsely described. The aim of this study was to describe the type and frequency of tasks, multitasking, interruptions and their causes during surgical procedures from a multi-dimensional perspective on the surgical team in the OR.

Design Prospective observational study, using the Work Observation Method By Activity Timing (WOMBAT) tool.

Setting An OR department at a county hospital in Sweden.

Participants Operating room nurses (ORNs) (n=10), registered nurse anesthetists (RNAs) (n=8) and surgeons (n=9).

Results The type, frequency and time spent on specific tasks, multitasking and interruptions were measured. From a multidimensional view, the surgical team performed 64 tasks per hour. Communication represented almost half (45.7%) of all observed tasks. Concerning task time, direct care dominated the surgeons' and ORNs' intra-operative time while in RNAs' work it was intra-indirect care. In total 48.2% of time was spent in multitasking and was most often observed in ORNs' and surgeons' work during communication. Interruptions occurred 3.0 per hour, and the largest proportion, 26.7%, was related to equipment. Interruptions were most commonly followed by professional communication.

Conclusions The surgical team constantly dealt with multitasking and interruptions, both with potential impact on workflow and patient safety. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a complex adaptive system. Future research should focus on understanding the complexity within the system, on the design of different work processes, and on how teams meet the challenges of a complex adaptive systems.

Words: 279

Keywords: Complexity, multitasking, interruptions, patient safety, operating room

Ethical registration number
2016/264

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study adds to the knowledge of how complex work is performed in the operating room by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team.
- The data collection tool used, WOMBAT, employs a structured observation protocol with an operationalized definition of "interruption", which may reduce the risk of potential measurement errors.
- Even though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed operating room nurse, registered nurse anesthetist or surgeon, the nature of performed tasks and how often they were interrupted was not recorded, which may be considered a limitation, as the whole surgical team is not represented in this study.
- Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias.
- This study was performed at one hospital only and the observations did not include night shifts, weekend shifts or procedures conducted on Fridays, which may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

BACKGROUND

Clinical work in surgery is often fast-paced, demanding and time- and resource-constrained. It requires specific technical and cognitive skills[1] and involves multiple activities such as organizing care, responding to patients' changing conditions, anticipating needs, and performing surgical procedures.[1 2] An operating room (OR) can be considered a complex adaptive system (CAS),[3 4] which requires that professionals act and communicate, adapt, learn and self-organize over time.[5] It is an interconnected and dynamic environment[3] with an inherent potential for distractions and interruptions.[1 6]

The members of the surgical team are essential actors in the OR,[7] focused on providing safe surgical care. In addition, components such as a suitable environment, functioning equipment, drugs, and disposable items are needed to support the intra-operative process.[8] The work process of the surgical team in the OR is mainly described through the surgical procedure and its phases,[9] sometimes including the phases of anesthesia.[10] The OR context has considerable potential for interruptions that may interfere with the work of the surgical team.[6 11] Good outcomes often rely on individuals' and teams' skills in adjusting and adapting to unexpected events and rapidly changing situations, using communication and interaction, i.e., resilient performance.[12 13] Understanding resilience requires a deep understanding of the work as it is actually carried out, rather than how it is usually presented in standardized models.[14]

Multitasking can be defined as managing multiple tasks simultaneously.[15 16] However, inconsistencies in definitions and methods make it difficult to make comparisons between studies.[16] Multitasking is one strategy used to cope with increased work density[17 18] and prioritize between tasks.[19] It is often expressed as an integral part of daily practices and a skill often used by professionals, especially in the emergency department (ED).[17] To ensure immediate communication and information seeking, multitasking can be appropriate.[20] Professionals working in emergency care settings usually do not perceive multitasking as stressful, but see it as related to safe and efficient task completion.[21]

Previous research has showed that physicians are frequently required to multitask, which may affect their work process and potentially impact on patient safety.[22] A recent study showed associations between multitasking and increased rates of prescription errors among physicians in the ED.[23] It has also been reported that even though nurses manage multitasking and interruptions well, errors still occur.[24] In addition, professionals in the OR are expected to multitask by being available through pagers and telephones during the surgical procedures.[25] Research on multitasking has mostly been conducted in EDs, hospital wards and intensive care units (ICUs), primarily involving nurses and physicians, and the results show that multitasking occurs frequently.[18 22 26 27] However, multitasking in the OR has been studied only rarely.[28] Although multitasking is common, knowledge about the impact on patient safety and outcomes is sparse.[16]

Interruption is a complex phenomenon, and can be described as a process of suspension of a current (primary) task to attend to and work on another (secondary) task. Interruptions can involve multiple interconnected components, such as equipment, organizational factors, task characteristics and external environmental conditions.[29] Interruptions may contribute to task incompletion,[15 30-32] loss of attention, medication errors[33] and gaps in continuity of care.[34] Associations have been found between interruptions and medication prescription errors in the ED.[23] However, interventions to reduce interruptions have shown limited effectiveness.[35] The frequency, duration,[36 37] sources or causes of interruptions and effects on professionals[11] and work processes have been studied in the OR.[6 10 38] Previous work has mostly focused on interruptions from a negative perspective, where minimizing or preventing interruptions has been the main concern.[39] Recent research claims that interruptions may also have a positive impact on patient safety when they entail, for example, obtaining advice from a colleague, or receiving timely[40] and relevant information about a patient.[41] Several studies have described communication as a source of interruptions.[42 43] Additionally, in the OR, communication has been described in terms of being irrelevant or miscommunication.[6 10 11 44 45] Since communication is a relevant task that supports interactions in a CAS,[5] it should be seen both as a means of supporting clinical work and as a source of interruptions. These findings reveal that interruptions are not well understood in the OR.

To conclude, previous research has studied the work process of the surgical team mainly during surgery and anesthesia. The OR is a CAS, where interruptions with diverse nature frequently occur and multitasking is expected, which may affect workflow and patient safety. However, multitasking with a team perspective has not been studied in the OR. Thus, there is a lack of knowledge regarding the multi-dimensional view of the pre- and intraoperative work process in the OR focusing on all performed tasks, multitasking, interruptions and their causes, i.e., how the work is actually done in the surgical team. Therefore, the aim of this study was to describe the type and frequency of tasks, multitasking, interruptions and their causes from a multi-dimensional perspective for the surgical team in the OR.

METHODS

Setting and sample

This prospective observational study was conducted in a central OR department at a local county hospital in Sweden. The hospital had two surgical wards, with a total of 38 beds. For general surgery, there was one department for ambulatory surgery and one central OR department. During 2016, a total of 4,118 patients underwent surgery at this hospital. The central OR department consisted of six rooms that served both acute and elective orthopedic and surgical patients. In connection to each OR, there was a preparation room where the registered nurse anesthetist (RNA) and/or the anesthesiologist sometimes prepared patients for surgery. Some medications were also stored in this area.

As in many other countries, surgical teams in ORs in Sweden commonly comprise six professionals, namely: RNA,[46] anesthesiologist, operating surgeon and assisting surgeon, operating room nurse (ORN) and a circulating nurse (commonly a licensed practical nurse).[6] For the observations we selected a convenience sample of scheduled general surgical procedures from a case list. To provide coverage and representativeness of common procedures performed at the department across weekdays (Mon–Thu) and shifts (07:30–21:00 hours) the sample included acute and elective general surgical procedures performed on adults. Since the number of people present in the OR is associated with risk for healthcare-associated infections during orthopaedic procedures,[47] such procedures were excluded, as were night shifts. The professionals were informed about the study during workplace meetings and invited to participate.

Patient and public involvement

Patients or the public were not involved in this study.

Tool and definitions

The Work Observation Method By Activity Timing (WOMBAT) software with a portable touchscreen tablet (Lenovo 7 Tab3) was used to collect data. The tool includes different dimensions of work, as well as specific categories of task and subcategories within these dimensions,[48] which were customized by the researchers to fit the context of this study. Information recorded for each observed task included the dimensions: task type (What?), with whom (Who?) the participant interacted (e.g. other members of the surgical team), resources (How?) used (e.g. telephone), multitasking and the observable cause (Why?) of any interruptions that occurred. Tasks performed by the participants were recorded by selecting the predefined categories. A clear statement of definitions being used is considered crucial.[49] The concepts used in this study, with associated operationalized definitions, are presented in Table 1.

Table 1. Used concepts and their operational definitions

Concepts	**Operational definitions**
Multitasking	When a member of the surgical team carried out observable multiple tasks simultaneously e.g. talking to a colleague while preparing medication
Primary task	The ongoing task which is being interrupted
Interruption	When a member of the surgical team suspended a current task because of an observable external stimulus e.g. paused to prepare an infusion when a surgeon asks to change the position of the operating table
Cause of interruptions	Describes the cause to an observable interruption
Secondary task	Task that interrupts an ongoing task or tasks
Task after secondary task	Tasks initiated after secondary task

Adaptation of the WOMBAT tool to the OR context

In order to ensure validity, ORNs', RNAs' and surgeons' work tasks were first mapped and then discussed with one expert from each targeted profession. The researchers – who later carried out the observations – discussed representation of dimensions, categories, subcategories, multitasking, causes of interruptions in WOMBAT, until consensus was reached over mutually exclusive definitions (Table 2). Common causes of interruptions in the OR have been presented in previous taxonomies and frameworks,[6 38 50] and based on the existing literature and pilot observations, categories were developed for observations of interruptions using WOMBAT. The observable cause has in other studies been named as ´alert for the secondary task´[51] or ´external prompt´[40]. These categories where later confirmed by field notes on examples of the observable cause to an interruption. To verify the correct programming of WOMBAT, written dummy cases were developed and tested. Prior to actual data collection, researchers conducted approximately 15 hours each of pilot testing of WOMBAT based on observations of the three professions, during 12 surgical procedures. The categories, subcategories and their task classifications were then once more refined and adapted to the WOMBAT tool. For example, indirect care was divided in two phases (pre and intra) in order to better identify the preparatory phase before patient's arrival at the OR. To further clarify the cause of an interruption, broad categories were programmed under an additional dimension: "Why?".

Table 2. Task classifications for the surgical team

Task categories and subcategories	Definitions	Included activities
Pre-indirect care	Tasks indirectly related to patient care prior to patient arrival	
Disinfect		Pre-operative hand washing/disinfection
Organize/arrange		Preparing equipment
Control/Count		Checking equipment, counting instruments, swabs
Read		Reading/searching patient information
Clean		Arranging and cleaning
Protect		Applying sterile gown, gloves, apron
Intra-indirect care	Tasks indirectly related to patient care, when the patient is present	
Observe/monitor		Monitoring patients' vital parameters
Disinfect		Hand washing/disinfection
Organize/arrange		Preparing equipment
Control/count		Controlling equipment, counting instruments, swabs
Read		Reading and reviewing patient information
Clean		Arranging and cleaning
Protect		Applying protective apron or gloves
Direct care	Tasks directly related to patient care	
Skin disinfection		Disinfecting the incision area, including drying time
Drape		Draping the patient
Assist		Assisting another professional
Instrumentation		Instrumentation with surgeon
Perform invasive surgical/ anesthetic procedures		Performing the procedure/intubation, inserting intravenous lines
Perform patient care		Communicating with the patient, mobilizing of the patient, dressing the wound, moving the patient to the bed
Medication	Tasks related to providing medication to a patient	
Prepare		Reading prescriptions, preparing syringes
Administer		Giving medication to the patient
Document		Documenting medication care
Communicate		Discussing medication care and prescriptions, asking for clarification
Documentation	Any recording of patient information on paper or computer	
Communication	Any work-related or social discussion with another staff member	
Professional		Discussions related to the procedure, planning the care of the patient, paging surgeon or anesthesiologist, reporting, completing the WHO checklist
Irrelevant		Case-irrelevant communication
Supervision	Any activity focused on teaching or education	*(Note: When supervision is taking place, all other tasks are "multitasking".)*
Other	Any other task not included above	For example: waiting for a colleague or a decision, when there is no communication
In transit	Any movement between rooms	Transferring the patient into and out of the room Getting equipment needed

Inter-rater reliability

Inter-rater reliability (IRR) was tested during pilot observations, with the researchers independently observing the same participant for 30 minutes.[52] Situations that were difficult to record using the pre-defined task definitions were discussed between sessions to achieve agreement in subsequent observations. During the last three pilot observations, adequate Cohen's kappa value (≥ 0.81)[52] on most observed tasks were achieved (0.85 for indirect care (pre and intra), 0.87 for direct care, 0.93 for medication and 0.82 for communication).[53] This required alignment of both observers' independent observations side by side and comparison of tasks by task classification, duration and temporal order. During the pilot observations only few interruptions occurred, so calculating kappa was not feasible. However, the observers had identified the interruptions, interrupting task and their causes similarly. Additionally, IRR was assessed using the intra-class correlation (ICC). The proportions of tasks between observers, as well as proportions of time within task categories were examined.[23] Two-way mixed model was used to measure ICC and it was 0.96 (95% CI, 0.83 to 0.99) indicating a high IRR.

Data collection

Observations were performed between 07:30 and 21:00 on Monday to Thursday from 14 November to 15 December 2016. Prior to the observation sessions, professionals involved in selected surgical procedures provided informed consent and were informed that they might withdraw from the study at any time. Consent was not obtained from patients and other professionals, as they were not targeted in the observations. However, they were informed orally about the study and were given the option to deny observations of the procedure they were participating in. If this occurred prior to or during a surgical procedure the observation should stop and already collected data would be excluded from the study. However, this did not occur. Observations of ORNs and RNAs started when the participants began to plan and prepare for the surgical procedure and continued until the patient had left the OR. The RNAs were also observed in the preparation room, which was adjacent to the OR. Observation of the surgeon started when they entered the OR and ended when they left the OR after the surgical procedure. Thus, the surgeons were observed for a total of 37 hours whereas ORNs and RNAs were observed for 66 hours each. The researcher followed the same participant unobtrusively during the whole surgical procedure, registering tasks the participant performed, with whom and how.[54] When an interruption occurred, manifest causes (what could be observed) of the interruption were registered in WOMBAT. The underlying cause, often verbally expressed, was written down in the field notes, as were examples of what the observable cause could be. To complete the structured observations with contextual factors such as testing of new medical-technical equipment, field notes were made during and directly after the observations.

Ethics

This study was conducted in accordance with international research standards under the Declaration of Helsinki and was approved by the Regional Ethical Review Board in Uppsala, Sweden (No. 2016/264).

Data analysis

Descriptive statistics were used to determine the total observation time, number and proportion of tasks, proportion of category-specific task time and multitasking time based on total observed time per profession and interruption rate per hour of the surgical team. Calculation of proportion of task, summation of time on task, proportion of time on task, and confidence interval (CI) were calculated based on the WOMBAT analysis guide[55], with slight modifications for the latter. In the literature some have reported a large sample approximation for calculating the CI.[56] Considering the problem of interval estimation of proportion and the erratic behavior of the large sample approximation (the Wald interval) we have employed the Wilson's confidence interval. The CI from the Wald interval often has inadequate coverage, particularly for small sample size and values of proportions close to 0 or 1, while the Wilson interval is appropriate for both smaller and larger sample sizes and provides more reliable coverage than other alternatives. The Wilson interval uses the estimated standard error instead of the "null standard error".[57] Since our data include both small and large sample sizes and lower and higher proportions, we felt that the Wilson's interval as a viable alternative for interval estimate of the proportions. Analysis of the data was performed using Microsoft Excel 2016 and the Statistical Package for Social Sciences, SPSS version21.

RESULTS

During the data collection period, 199 procedures in general surgery were performed at the OR department and 46 (23.1%) of these were observed. The 46 surgical procedures included in the data collection contained 78 unique recorded observation sessions, including 26 observations per profession. ORNs and RNAs were observed for 66 hours each and surgeons were observed for 37 hours, with a total time of 169 observation hours. Of the 46 surgical procedures, four were acute and the rest were elective. According to type of surgery, 28 of these procedures were laparoscopic and 18 were conducted with open surgery. The surgical procedures, from incision until wound closure, lasted between 38 minutes and 3 hours and 15 minutes (mean time 42 minutes). General anesthesia was administered in 42 of the 46 (91.3%) surgical procedures and regional anesthesia in four (8.7%). Demographic data for the participants is presented in Table 3.

Table 3. Demographic data for operating room nurses (ORNs), registered nurse anesthetists (RNAs), and surgeons during the observed surgical procedures (n=26), by profession

Profession	Observation time, hours	Number of observed participants	Mean age, years (range)	Gender of the participant, female/male, number	Mean experience as specialist, years (range)	Mean experience at the participating hospital, years (range)
ORNs	66	10*	46 (26–60)	9/1	13 (2–39)	10 (0.5–39)
RNAs	66	8*	50 (32–64)	3/5	18 (5–34)	14 (5–28)
Surgeons	37	9*	47 (32–65)	2/7	13 (0–32)	9 (2–28)
Total	**169**	**27**	**47**	**14/13**	**15**	**11**

* Same ORN was observed 1–7 times
* Same RNA was observed 2–6 times
* Same surgeon was observed 1–8 times

Observed tasks and category-specific task time

During the observation the surgical team performed in average 64.4 tasks per hour. RNAs performed 72.0, surgeons 61.4 and ORNs 58.3 tasks per hour. Regarding proportion of tasks per profession, communication is most frequent for surgeons (84.0%, n=1,908), followed by ORNs (50.6%, n=1,948) and RNAs (23.4%, n=1,112) (Table 4). However, the proportion of category-specific task time per total observed time per profession has shown that direct care for surgeons equated with the surgical procedure, despite the low number of tasks dominating the surgeons' (54.1%, n=100) and ORNs' (33.5%, n=615) intra-operative time. For RNAs (41.0%, n=1,079) intra-indirect care had the largest proportion of category-specific task time. Category-specific task time for communication (ORNs 18.0%, RNAs 8.3% and surgeons 37.8%), in comparison with the high frequency of communication, is not as dominant as direct care. This reflects that communication is frequent but short, unlike direct care that is less frequent but ongoing for a longer period of time. Of the total time spent on communication (47 hours and 16 minutes), professional communication represented 38 hours and 32 minutes (81.4%), while case-irrelevant communication comprised 8 hours and 47 minutes (18.6%). Proportions of category-specific task time, i.e. the observed time participants spent performing tasks in a particular category, are reported in Table 4 and Figure 1.

Table 4. Number, frequency and proportion of tasks, proportion of category-specific task time and multitasking for each profession (operating room nurses (ORNs), registered nurse anesthetists (RNAs) and surgeons), per profession-specific total observation time.*

Task category	Number of tasks	Frequency of tasks (n/hour)	Proportion of tasks (%) (95% CI)* *	Proportion of category-specific task time (%) (95% CI)* *	Proportion of multi-tasking during category-specific task time (%) (95% CI)* *
Communication					
ORNs	1,948	29.5	50.6 (49.1–52.2)	18.0 (17.0–19.1)	68.7 (65.8–71.7)
RNAs	1,112	16.8	23.4 (22.2–24.6)	8.3 (7.7–9.0)	84.0 (80.8–86.8)
Surgeons	1,908	51.6	84.0 (82.4–85.5)	37.8 (36.2–39.5)	89.0 (87.2–90.6)
Total	4,968				
Intra-indirect care					
ORNs	743	11.3	19.3 (18.1–20.6)	17.5 (16.5–18.6)	40.4 (37.6–43.9)
RNAs	1,079	16.3	22.7 (21.5–23.9)	41.0 (39.9–42.2)	76.4 (74.8–77.9)
Surgeons	113	3.1	5.0 (4.2–6.0)	2.5 (2.1–3.1)	23.0 (15.4–32.9)
Total	1,935				
Direct care					
ORNs	615	9.3	16.0 (14.9–17.2)	33.5 (32.3–35.0)	44.9 (42.5–47.2)
RNAs	851	12.9	17.9 (16.8–19.0)	11.2 (10.5–12.0)	74.3 (71.3–77.4)
Surgeons	100	2.7	4.4 (3.6–5.3)	54.2 (52.4–55.8)	62.5 (60.3–64.7)
Total	1,566				
Medication					
ORNs	74	1.1	1.9 (1.5–2.4)	0.6 (0.4–0.8)	43.7 (27.4–60.8)
RNAs	942	14.3	19.8 (18.7–21.0)	7.7 (7.1–8.4)	84.8 (81.5–87.6)
Surgeons	85	2.3	3.7 (3.0–4.6)	1.1 (0.8–1.5)	84.3 (69.6–92.6)
Total	1,101				
Documentation					
ORNs	57	0.9	1.5 (1.2–1.9)	1.5 (1.2–1.8)	19.7 (12.2–29.7)
RNAs	453	6.9	9.5 (8.7–10.4)	5.5 (5.0–6.1)	97.8 (96.0–98.9)
Surgeons	24	0.7	1.1 (0.7–1.6)	1.3 (0.9–1.7)	20.2 (11.2–34.5)
Total	534				
Other					
ORNs	240	3.6	6.2 (5.5–7.1)	8.5 (7.8–9.3)	16.4 (13.3–20.2)
RNAs	56	0.9	1.2 (0.9–1.5)	1.1 (0.9–1.3)	26.9 (18.2–38.2)
Surgeons	16	0.4	0.7 (0.4–1.1)	1.1 (0.8–1.5)	15.3 (7.2–31.1)
Total	312				
In transit					
ORNs	89	1.4	2.3 (1.9–2.8)	4.9 (4.4–5.5)	12.8 (9.2–17.3)
RNAs	112	1.7	2.4 (2.0–2.8)	3.6 (3.2–4.1)	49.6 (43.5–55.7)
Surgeons	16	0.4	0.7 (0.4–1.1)	0.7 (0.5–1.1)	0.3
Total	217				
Pre-indirect care					
ORNs	59	0.9	1.5 (1.2–2.0)	2.0 (1.7–2.4)	42.3 (33.1–51.5)
RNAs	93	1.4	2.0 (1.6–2.4)	1.5 (1.3–1.9)	41.3 (32.3–50.6)
Surgeons	-	-	-	-	-
Total	152				
Supervision					
ORNs	22	0.3	0.6 (0.4–0.9)	13.4 (12.5–14.4)	65.9 (62.3–69.3)
RNAs	54	0.8	1.1 (0.9–1.5)	19.9 (19.0–21.0)	89.0 (87.3–90.6)
Surgeons	9	0.2	0.4 (0.2–0.7)	1.4 (1.1–1.9)	99.9 (99.8–100.0)
Total	85				
Total	**10,870**				
ORNs	**3,847**	**58.3** per hour	**35.4%**		**46.8%**
RNAs	**4,752**	**72.0** per hour	**43.7%**		**79.1%**
Surgeons	**2,271**	**61.4** per hour	**20.9%**		**70.8%**

* Total observation time per profession was 66 hours each for the ORNs and RNAs, whereas the surgeons were observed for 37 hours
**CI, confidence interval

---- Figure 1. Here ----

Multitasking

During 169 hours of observations, 261 task hours were recorded. The discrepancy between observation time and task hours is explained by multitasking. The observed surgical team spent 48.2% (82 hours and 6 minutes, with 173 hours and 46 minutes of category-specific multitasking time) of the total observation time multitasking. The proportion that each profession spent multitasking out of their total observed time per profession was 63.1% (42 hours 2 minutes) for RNAs, 53.8% (20 hours 4 minutes) for surgeons and 30.1% (19 hours 58 minutes) for ORNs. In 74.0% of the observed tasks (n=8,106 out of the total observed tasks n=10,870) the professionals engaged in two (n=6,369) and sometimes three (n=1,650) simultaneous tasks. An example of this is observing an ongoing supervision of a student, engaging the team in the same discussion while still monitoring the patient and simultaneously disinfecting hands. Multitasking was most often observed in ORNs' and surgeons' work during communication (68.8% and 89.0% of the task time, respectively) and supervision (65.9% and 99.9%), while for RNAs, multitasking happened mostly during documentation (97.8%) and supervision (89.0%). The proportion of task time spent multitasking for the surgical team is presented in Table 4.

Interruptions, interrupted primary tasks, causes of interruptions and task after secondary task.

The overall interruption rate across all tasks was 3.0 per hour (n=511). Among professions, RNAs were interrupted most frequently (n=309, 60.5%), 4.6 times per hour. The most interrupted primary task was documentation, with 3.8 interruptions per hour. Moreover, interruptions were common during intra- indirect care (2.8 per hour, n=181) and during direct care (2.1 per hour, n=156). Out of all observed causes of interruptions (n=426), equipment-related, i.e. concerning missing or malfunctioning equipment, were the most common at 114 (26.7%), and the second most common causes were related to the procedure, e.g. fog on lens at 95 (22.3%). The ORNs' work was typically interrupted by equipment-related (n=48, 50.5%), and procedure-related issues (n=23, 24.2%). Medication-related causes were not common (n=46, 10.7% of all causes) and affected only the RNAs' work (18.1%). After medication-related causes, the second most prevalent in RNAs' work was related to equipment (n=39, 15.3%). Procedure-related causes affected surgeons' work most often (n=35, 45.6%), in addition to equipment-related problems (n=27, 35.1%) (Table 5). The tasks following secondary tasks were most often communication (n=150, 39.1%), of which the majority was professional communication (n=138, 92.0%). Additionally, team responded to interruptions with intra-indirect care (n=65, 16.9%) or by providing direct care (n=53, 13.8%). ORNs responded to interruptions by communication (n=37, 39.4%, of which professional n=34, 91.8%) and with intra-indirect care (n=22, 23.4%). The RNAs' responding tasks were most often communication (n=51, 23.8%, of which professional n=44, 86.3%) or medication-related tasks (n=48, 22.4%). Surgeons reacted mostly with communication only (n=62, 81.5%, of which professional n=60, 96.8%).

Table 5. Causes of observed interruptions giving overall frequency and proportion, and frequency per hour, for operating room nurses (ORNs), registered nurse anesthetists (RNAs), surgeons* and for the surgical team as a whole.

Causes of interruptions	Examples of causes of interruptions	ORNs n (%)	RNAs n (%)	Surgeons n (%)	Total n (%)
Equipment	Malfunction, missing or wrong equipment Change of OR table	48 (50.5)	39 (15.3)	27 (35.1)	114 (26.8)
Related to procedure	Providing additional information Contaminating sterile area Fog on lens	23 (24.2)	37 (14.6)	35 (45.4)	95 (22.3)
Related to medication	Missing or wrong medication	0	46 (18.1)	0	46 (10.8)
Change of shift	Changing staff for break or lunch during the procedure	7 (7.4)	33 (13.0)	0	40 (9.4)
Alarm	Alarm from devices or monitors Indicating high gas pressure	2 (2.1)	31 (12.2)	1 (1.3)	34 (8.0)
External factor	External person entering the room to watch the procedure or to discuss test of new equipment	4 (4.2)	22 (8.7)	4 (5.2)	30 (7.0)
Related to patient	Changing patient position Changes in patient's vital signs	4 (4.2)	20 (7.9)	4 (5.2)	28 (6.6)
Telephone/pager	Searching for surgeons Planning for next procedure	6 (6.3)	16 (6.3)	5 (6.5)	27 (6.3)
Other	Wrong action when assisting	1 (1.1)	10 (3.9)	1 (1.3)	12 (2.8)
Causes to observed interruptions		**95 (22.3)**	**254 (59.6)**	**77 (18.1)**	**426 (100)**

*Total observation time per profession was 66 hours each for ORNs and RNAs whereas surgeons were observed for 37 hours

DISCUSSION

This study provides a multidimensional view of the pre- and intraoperative work process of the surgical team in the OR, including the specialized work of ORNs, RNAs and surgeons. In addition to the previous descriptions of the surgical phases and steps, we provide a broader and more detailed description of the multitude of tasks, multitasking, and interruptions and their causes. Multitasking covered a lot of the professionals' time and, in ORNs' and surgeons' work, was most often observed during communication in the team. Interruptions did not occur frequently, which differs from previous research findings from the OR. Equipment- and procedure-related interruptions were the most prevalent, while phones and pagers have been reported as such in other OR studies. Furthermore, the RNAs were those interrupted most frequently, and the most common response to interruptions was professional communication.

In the observations of the surgical teams, multitasking occurred during almost half of their working time. Multitasking seemed relevant to safe performance of patient care, which implies that it is an integral part of the surgical process. Communication was a dominant task in multitasking, which may reflect the transfer of important information between professionals, contributing to creating a smooth and efficient care process.[20] Much like in other studies using WOMBAT for data collection,[56 58-60] communication played an important role throughout the surgical procedure in our study. Even when performed simultaneously with, e.g., direct care, communication may be seen as a team-coordinating[61 62] and resilience-enhancing behavior. In addition, maintaining a shared situational awareness[63] within the team is key to anticipating possible deviations in the intra-operative process, which is a prerequisite for working in a CAS.[4] The amount of multitasking may be a result of the complexity of the OR context, which includes time pressure and high cognitive demands.[6] In rare cases, as many as three tasks occurred simultaneously, which has also been reported in another study on physicians in general wards.[59] However, when comparing with other settings such as EDs, the OR has several expected routine tasks and procedures, which may make multitasking less cognitively challenging in a normal situation. In our study, the professionals had relatively long work experience (mean 15 years), which may have affected the results. It has been argued that as professionals become more experienced, commonly performed deliberate tasks become more automatic, which may make multitasking easier.[2] Additionally, as the OR department in our study served as a teaching hospital, nursing students were present during 22 sessions, explaining the proportion of supervision in the tasks and also contributing to the amount of multitasking. Preventing multitasking might have unwanted consequences, [58] and impede situational awareness and adaptation to changes in a care process.[61]

Interactions not only predispose a team to multitasking, but may also lead to interruptions. Compared with in other studies,[6 28 64] the interruption rate was lower in this particular setting. Leaving aside the lengths and types of surgical procedures, this disparity may also in part be explained by the fact that most of the observed procedures were elective. The studied hospital was small and the staff turnover was fairly low, which may have had a positive effect on the number of interruptions.[44] Surgeons being interrupted by telephones or pagers are commonly described in literature,[6 64] which is not consistent with the relatively low numbers in our study, where equipment- and procedure-related issues were the most common causes of interruptions. Restrictions regarding pagers and personal telephone use have been implemented in the participating OR, which may be a reason for the lower interruption rates for surgeons. This restriction could be considered noteworthy for future development and research interventions. A control function to test the equipment prior to the start of a surgical procedure could be a way to decrease interruptions. However, implementing more barriers may result in additional, unwanted complexity, and the balance between filtering harmful consequences and the increasing the number of interactions should be addressed when designing work processes.

Among professions in the surgical team, the RNAs were those who were most exposed to interruptions. Our results deviate from those of another study, in which ORNs and surgeons were interrupted more frequently than RNAs.[6] In this study, the observations revealed that the RNAs and the circulating nurse often communicated with professionals outside the OR and transferred information back to the surgical team. Previous research in the OR has predominantly described communication as a source of interruptions.[6 11 44 45] Grundgeiger[49] considered it a default assumption that interruptions are an inherently undesirable form of communication. However, the clinical value of information transfer, i.e., interruptive communication, has been referred to as essential for promoting patient safety,[41] in terms of the progression of patient care,[65] and important for patient treatment and workload management.[40] In our study, communication was the most frequently observed secondary, interrupting task, but not the actual cause of interruption, as implied by other studies[44 45]. Consistent with other results,[66] communication was the most frequent task following a secondary task, after an interruption. Therefore, communication seems to be an important skill in adapting to the emerging situations causing interruptions.[40 41] This also elucidates the OR context as a CAS,[4] which is highly dependent on communication to support and adjust to complex interactions[5] within the surgical team.

The sometimes unpredictable nature of work in an OR, and the number and complexity of tasks, multitasking, and interruptions, requires the surgical team to interact, self-organize and solve problems through communication or by using information technology. Communication and multitasking both help and hinder task completion. The timing and coordination of activities during a surgical procedure requires communication. During our observations, participants were on multiple occasions forced to alter or halt their activities and proceed with different tasks. Some of these situations may be interpreted as adaptations[41] while others were clear interruptions, which highlights the diverse nature of interruptions.[41 67] Patient- and procedure-related interruptions often arose in situations where safe and smooth intra-operative care processes needed to be safeguarded – e.g., when patient positioning was altered for better visibility or when changed operative plans required new equipment. This illustrated resilient performance through how team adaptations counteracted the increased complexity introduced by interruptions or new medical challenges.[61]

Our findings indicate that there is a multitude of tasks involved in everyday work in the OR. The observations also show that the impact of interruptions and multitasking can both sustain and disrupt safe care. This supports the notion that attempts should not be made to control complexity; rather it should be embraced and applied as a clarifying lens through which to understand today's healthcare organizations.[5] As multitasking is expected in the OR context, controlling variation and adding more barriers to the work process may instead result in even further increases to complexity. Multitasking and interrupting other team members should be accepted and done when necessary, with awareness of patient safety. The surgical team's ability to overcome and compensate for shortcomings and to adapt to variations and demands needs to be further explored. Strategies used by professionals when successfully navigating through and recovering from unexpected events and interruptions that occur in a CAS should be studied to support resilient performance.[13]

Strengths and limitations

This study adds to the knowledge of how complex work is performed in the OR by providing a multidimensional view of the complete pre- and intraoperative work process of the surgical team. In order to produce an interprofessional view of the teamwork in the OR, the observations included three key professions: ORNs, RNAs and surgeons. However, the total observation time was somewhat lower for surgeons, as the time for observations of preparation before the surgical procedures did not include surgeons. The data collection tool used, WOMBAT, employs a structured observation protocol with an operationalized definition of "interruption", which may reduce the risk of potential measurement errors. Unlike previous WOMBAT studies reporting interrupted tasks and initiated tasks after the interruption, we include a report on the observable causes of interruptions (Why) with examples. Another strength is that both observers were experienced RNAs and one of the researchers also had experience as an ORN. However, in order to avoid bias, the observations were conducted at a hospital where the researchers had not previously worked.

Surgical teams in Sweden usually consist of a RNA, an anesthesiologist, an operating and assistant surgeon, an ORN and a circulating nurse. Though the assistant surgeon, anesthesiologist and the circulating nurse were observed indirectly when interacting with the observed ORN, RNA or surgeon, the nature of their performed tasks and how often they were interrupted were not recorded. This may be considered a limitation, as the whole surgical team is not represented in this study. Regulations concerning the number of people in the room and the risk of healthcare-associated infections in orthopedic implant surgery[47] contributed to exclusion of these procedures, which could be taken into consideration when interpreting the results. Some participants were also observed on several occasions, which may imply a potential risk for a systematic bias. This study was performed at one hospital only and did not include night shifts, weekend shifts, or procedures conducted on Fridays. This may limit the representativeness for different work shifts and may reduce the generalizability of the findings.

Conclusions

Work in the OR consists of many tasks performed by multiple professionals, with the probability of a high degree of interrelatedness. The OR may therefore be considered a CAS. In order to accomplish tasks, meet goals, and develop and deliver safe care for patients, professionals share information and coordinate their work through communication. This seems to be a factor contributing to success during surgical procedures, as it may support the safe management of complexity. Interruptions were commonly followed by professional communication, which may reflect the interactions and constant adaptations in a CAS. The impact of multitasking and interruptions on the work processes can be positive, negative or neutral. This contributes to difficulties in drawing conclusions on simple solutions. Instead of studying tasks, multitasking and interruptions separately, it may be beneficial to study these phenomena from a team perspective and as a complex process, in order to fully understand clinical work. Future patient safety research should focus on understanding the complexity within the system, the design of different work processes, and how teams meet the challenges within a CAS.

Contributorship statement

CG, MU, UN, AE and ME contributed to the study design. CG was the project supervisor and performed the initial exploratory observations. CG and KO were responsible for identification and definitions of categories, as well as data collection and drafting the manuscript. They also undertook the initial interpretation and statistical analysis of the data, which was followed by discussions with MU, UN, KPH, AE and ME. The CI, IRR and ICC were calculated by MKT. Drafts of the manuscript were reviewed by MU, KPH, AE, MKT, UN and ME. All authors have read and approved the final manuscript.

Competing interests

The authors report no conflict of interest. The authors alone are responsible for the content and the writing of this paper.

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Data sharing statement

No additional data are available.

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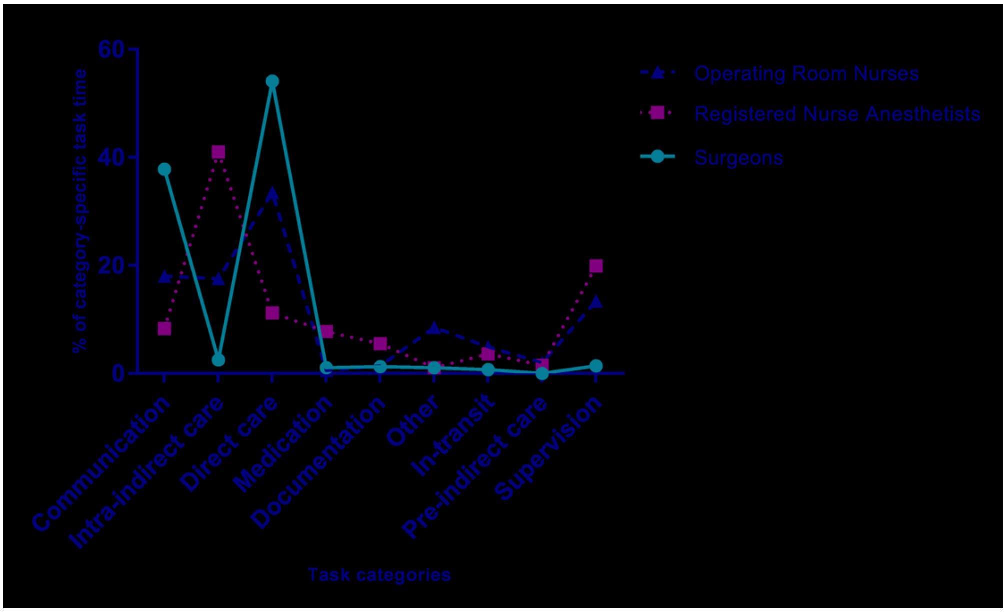
Figure Legends

Figure 1. Distribution of the proportion of the observed time* participants spent performing tasks in a particular category

*Total observation time per profession was 66 hours each for ORNs and RNAs, whereas surgeons were observed for 37 hours



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies.*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#4 - #6
Objectives	3	State specific objectives, including any prespecified hypotheses	#5 - #6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6 - #9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#5-#6, not fully applicable for this study
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#6-#7, not fully applicable for this study
Bias	9	Describe any efforts to address potential sources of bias	#17
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#10
		(*b*) Describe any methods used to examine subgroups and interactions	Not applicable for this study

		(*c*) Explain how missing data were addressed	Missing data were treated as missing, and not imputed or averaged.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable for this study
		(*e*) Describe any sensitivity analyses	Not applicable for this study
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#11
		(b) Give reasons for non-participation at each stage	#9
		(c) Consider use of a flow diagram	Not applicable for this study
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#11
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable for this study
Outcome data	15*	Report numbers of outcome events or summary measures	#11-#14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#10
		(*b*) Report category boundaries when continuous variables were categorized	Not applicable for this study
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable for this study
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable for this study
Discussion			
Key results	18	Summarise key results with reference to study objectives	#15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#17-#18

Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#17-#18
Generalisability	21	Discuss the generalisability (external validity) of the study results	#18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.