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ORIGINAL SCIENTIFIC REPORT

Relationships Between Expertise, Crew Familiarity and Surgical Workflow Disruptions: An Observational Study

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Abstract

Background Teamwork is an essential factor in reducing workflow disruption (WD) in the operating room. Team familiarity (TF) has been recognized as an antecedent to surgical quality and safety. To date, no study has examined the link between team members' role and expertise, TF and WD in surgical setting. This study aimed to examine the relationships between expertise, surgeon–scrub nurse familiarity and WD.

Methods We observed a convenience sample of 12 elective neurosurgical procedures carried out by 4 surgeons and 11 SN with different levels of expertise and different degrees of familiarity between surgeons and SN. We calculated the number of WD per unit of coding time to control for the duration of operation. We explored the type and frequency of WD, and the differences between the surgeons and SN. We examined the relationships between duration of WD, staff expertise and surgeon–scrub nurse familiarity.

Results 9.91% of the coded surgical time concerned WD. The most frequent causes of WD were distractions (29.7%) and colleagues' interruptions (25.2%). This proportion was seen for SN, whereas teaching moments and colleagues' interruptions were the most frequent WD for surgeons. The WD was less high among expert surgeons and less frequent when surgeon was familiar with SN.

Conclusions The frequency of WD during surgical time can compromise surgical quality and patient safety. WD seems to decrease in teams with high levels of surgeon–scrub nurse familiarity and with development of surgical expertise. Favoring TF and giving feedback to the team about WD issues could be interesting ways to improve teamwork.

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Introduction

"Surgical workflow" is defined as the automation of a whole or a part of a business process in the surgical management of patients, during which documents, information, images or tasks are passed from one participant to another in order to initiate action according to a set of procedural rules [1]. A workflow disruption (WD) is characterized by deviations from the natural progression of an operation, thus possibly compromising operation safety [2, 3]. Disruptions in the operating room (OR) can be subdivided into communication, usability, physical layout, environmental hazards, general interruptions and equipment failures [2, 4, 5]. They may be the result of a number of factors: environmental, teamwork, organizational and institutional policies [2, 4, 6–9]. Communication failures in the OR can occur in approximately 30% of team exchanges, and a third of these causes of WD endanger patient safety [10]. Surgical errors are strongly related to the number of WD [2, 11]. Even if the introduction of the World Health Organization Surgical Safety Checklist has helped decrease surgical morbidity and mortality [12], its incorporation into surgical workflow remains challenging [13]. In addition, WD can lead to increased workload for team members [14].

Whereas a *team* usually refers to individuals interdependently working on a task, OR members form a *crew*, that is a particular type of team involving highly specialized professionals working together synchronously and for a short period on numerous occasions [15]. Teamwork has been shown as an essential means to reduce WD [2]. Research in other high-risk settings such as the aviation field has highlighted the fact that limited familiarity between crew members can lead to negative safety outcomes [16]. Lack of familiarity among prehospital clinician teammates has been associated with greater incidence of workplace injury in emergency care settings [17]. Studies in surgical context have shown that team familiarity (TF) improves team performance [18] and reduces morbidity [19]. From this perspective, transactive memory theory stresses that team members with more experience of working together are more likely to request and accept backup from one another than those with less experience of working together [20].

To the best of our knowledge, no study has focused on the link between TF, crew members' role and expertise and WD in surgical settings. If experts in surgery are well identified in their community, there is a lack of consensus concerning the very essence of their expertise [21]. The aim of this study was to examine the relationships between expertise, surgeon–scrub nurse familiarity and WD.

Materials and methods

Description of the participants and the operative procedure

We made audio and video recordings of 4 neurosurgeons and 11 SN from the same neurosurgical department of the university hospital during surgical approaches for 12 identical surgical procedures. The neurosurgeons were men aged from 32 to 53 years (mean 38.5 years), and the SN were women aged from 26 to 53 years (mean 36.5 years). The recordings began in March and ended in July 2016. The protocol and design of the study were approved by the local ethics committee, and informed consent was obtained from all participants. The procedure was the same in all recordings and consisted in an anterior cervical discectomy and fusion (ACDF). Simple surgical procedures that involved one or two intervertebral disks were included in the study, but more complex procedures such as three disks or C2C3/C7T1 levels were excluded.

Description of the recorded data

Workflow disruptions

Recordings were analyzed using the Observer® XT 12 software (Noldus Information Technologies, Wageningen, The Netherlands). The two coders observing the video recordings were two doctoral students in human factors and psychology. They coded the first part of the procedure comprising the approach to the cervical spine by anterolateral cervicotomy. This phase of the surgery represented the phase where the communication and coordination of the crew members were the strongest. The taxonomy was developed from tools used in previous studies on flow interruptions in OR [4, 5, 22] and enriched by pilot observations of the dyad surgeon–SN in our department. For instance, four out of six main categories of the RIP-CHORD-TWA (Realising Improved Patient Care through Human-Centered Operating Room Design—Threat Window Analysis) framework presented by Cohen et al. [22] appear in our coding scheme, i.e., communication, coordination, equipment and interruptions. Nevertheless, elements of those tools were adapted to fit the observation of the surgeon and scrub nurse dyad, instead of the entire team. Our observation tool distinguishes five flow disruption categories: (1) verbal communication issues; (2) coordination issues; (3) equipment issues; (4) interruptions from environment; (5) distractions, and includes a total of 11 elements (Table 1).

Coding of the video recordings started after training of the two coders in the use of the Observer®. A random

Table 1 Taxonomy developed for coding workflow disruptions including categories, elements with definitions and examples

Categories	Elements	Definition and examples
Communication issues	Repetition	Participants have to repeat a sentence For example, the surgeon repeats because the SN did not hear the first time
	Misunderstanding	Erroneous comprehension or poor interpretation of a request For example, the SN does not give the tool requested by the surgeon
Coordination issues	Lack of response	Delay or absence of response from a member of the dyad For example, the SN is taking some time; the surgeon looks up
	Confusion	Doubt or clumsiness in the manipulation of a tool For example, the surgeon drops a tool. The SN hesitates before giving a tool
	Problem of (or poor) anticipation	Gap between the expectations of the participants For example, the SN prepares an instrument, whereas the surgeon requests another one
Equipment issues	Equipment dysfunction	An instrument is not operational For example, a rongeur is blocked
	Lack of equipment	A tool is missing or unavailable For example, the surgeon needs a tool which has not been sterilized yet
Interruptions	Interruption by colleagues	Another member of the staff disturbs the workflow For example, the circulating nurse asks the SN a question while giving her a tool. The surgeon looks at another team member because they are talking
	Interruption by beeper/phone/alarm (alerts)	A participant is interrupted by a phone call, a beeper or the alarm of an instrument in the OR For example, the alarm of an anesthetic instrument is ringing, the surgeon asks for information
	Teaching moment	The surgeon explains something to the resident For example, the resident asks for details about a part of the surgical procedure
Distractions	Distraction	The participant is not focused on its task or is showing signs of fatigue or boredom For example, the surgeon is looking away (at the clock, the window). The SN is yawning

SN scrub nurse

Table 2 Disagreements between the two coders

	Video 1	Video 2	Video 3	Video 4
Kappa coefficients	0.55	0.78	0.76	0.71
Disagreements numbers	14	8	6	8
Disagreements types	Distractions (10), lack of equipment (4)	Distractions (5), teaching moments (3)	Distractions (3), interruption by colleagues (3)	Distractions (3), interruption by colleagues (5)

sample of four videos was coded by two doctoral students in human factors and psychology in order to test inter-rater reliability. The analyses of the two coders were compared, and the inter-observer agreement was calculated. This inter-rater reliability was achieved by calculating Cohen's kappa coefficients and by using confusion matrix from the Observer®. The reliability analysis showed that kappa coefficients were acceptable (average kappa = 0.70). Kappa coefficients were 0.55 for video 1, 0.78 for video 2, 0.76 for video 3 and 0.71 for video 4. Analysis of the confusion matrix for each video showed that disagreements between the two coders concerned mainly the video 1, for "distractions" (10 disagreements) and "lack of equipment" (4 disagreements). For video 2, we observed 8 disagreements between coders, for "distractions" (5 disagreements) and "teaching moments" (3 disagreements). For video 3, we observed 6 disagreements between coders for "distractions" (3 disagreements) and "interruption by colleagues" (3 disagreements). For video 4, we observed 8 disagreements between coders for "distractions" (3 disagreements) and "interruption by colleagues" (5 disagreements) (Table 2).

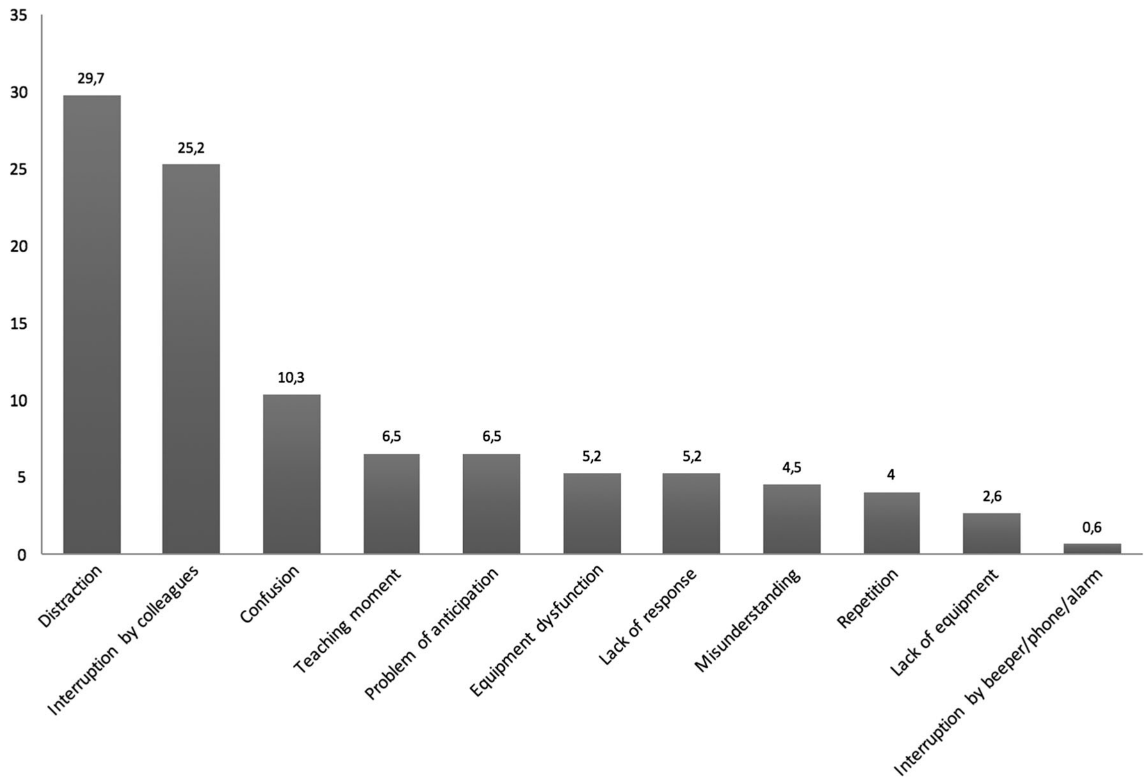

Fig. 1 Percentages of workflow disruptions (percentage global)

Degree of expertise of the participants

We determined the level of experience from the number of ACDF interventions carried out during the previous 6 months in our specific sample and by the evaluations of the members of the unit. In our sample, we distinguish three levels of expertise. One junior surgeon has carried out 5 ACDF interventions and 4 scrub nurses fewer than 5 interventions during the last 6 months (low level of expertise). Two surgeons have carried out 13 and 15 ACDF interventions and 3 scrub nurses from 6 to 8 ACDF interventions (intermediate level of expertise). One senior surgeon has carried out 40 ACDF interventions and 3 scrub nurses more than 10 ACDF interventions (high level of expertise).

Degree of surgeon–scrub nurse familiarity

The degree of familiarity between the surgeons and SN was defined according to the number of times one participant worked with the other during the 6 months before the study, according to operating logs [20]. The degree of familiarity was a continuous variable and varied from 1 to 5 joint surgeries (mean 2.7, SD 0.98).

Statistical analyses

All statistical analyses were performed using SPSS with a significance level of $p < 0.05$. The total number of WD and their cumulative duration per unit of coded time was computed and related to the length of each surgical approach in order to estimate the percentage devoted to WD. Dyadic communication between the surgeon and SN was analyzed first by calculating the total number of WD across all 12 surgical procedures. Thereafter, frequency of each element within each of the WD categories was computed. Frequency of each WD element according to the chronology of the surgical approach (i.e., "beginning, middle or end") was also calculated. Number, type and duration of WD were evaluated, respectively, for surgeons and SN in order to identify potential differences between these two specific populations. For this study, ANOVAs or nonparametric tests (Chi-square test, χ^2) were used. Furthermore, correlational analysis was conducted to analyze the relationships between the duration of WD and the surgeons' and nurses' expertise, surgeon–scrub nurse familiarity, the duration of the surgery and the time of day.

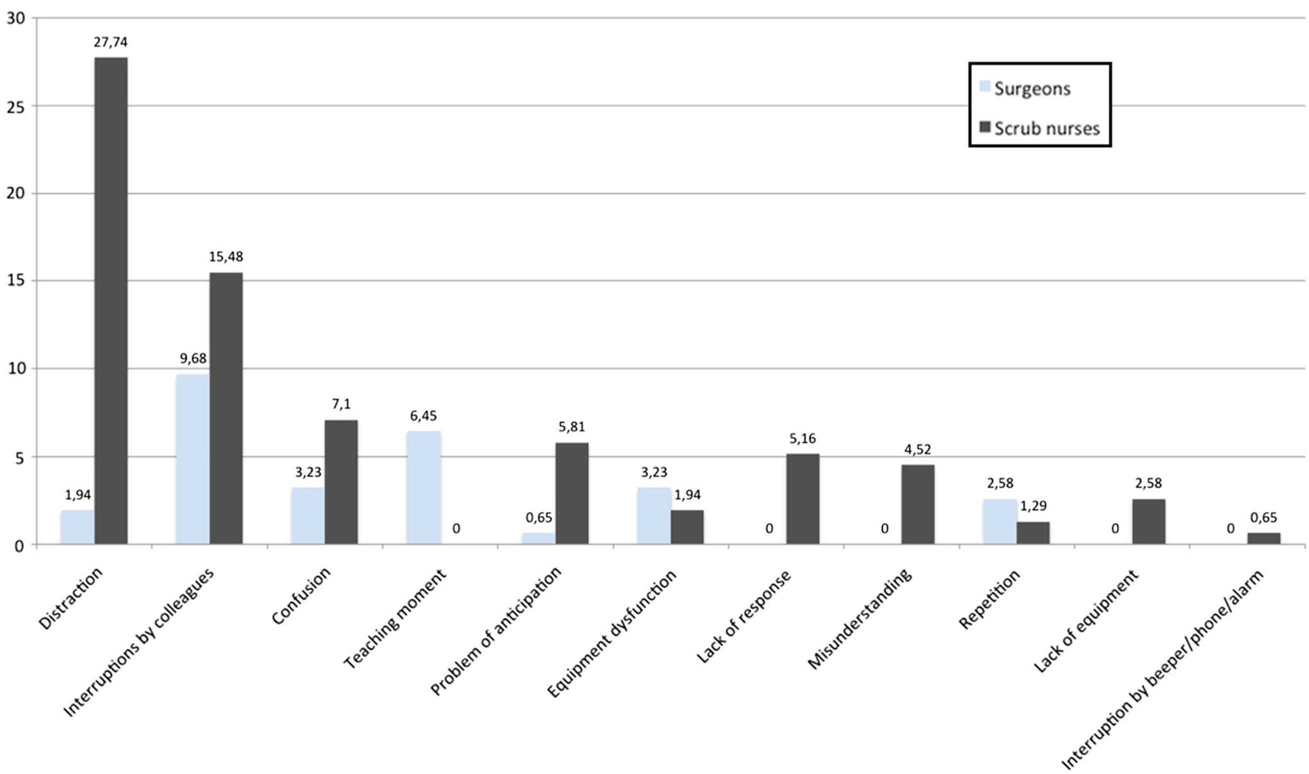

Fig. 2 Variations of workflow disruptions among surgeons and scrub nurses

Results

Duration and frequency of workflow disruptions

The total surgical time coded was 180 min (mean = 15.42 min, with a variation for each case from 10 to 18 min). 9.91% of the coded surgical time concerned WD. Among the 12 surgical procedures, the cumulative duration of WD was 17.84 min (mean = 1.49 min, with a variation for each case from 0.52 to 4.45 min, only 2 cases with 2.60 min and 4.45 min).

The total number of WD was 155 (mean = 12.92, with a variation for each case from 5 to 22 WD). The data revealed some variability between WD categories (Fig. 1). More than half of observed WD were caused by distractions (29.7%) and interruptions by colleagues (25.2%).

Workflow disruptions according to chronology of the surgical approach

Frequency of certain WD categories and elements varied according to the section time of the surgical approach (χ^2 (20, 155) = 32.15 $p < .04$). Equipment dysfunctions were more frequent at the beginning than in the middle/end of the surgical approach (beginning: $n = 5$; middle: $n = 1$; end: $n = 2$). Communication and coordination issues were more frequent in the middle/end than at the beginning (misunderstanding: beginning: $n = 0$; middle: $n = 3$; end: $n = 4$/problem of anticipation: beginning: $n = 0$; middle: $n = 6$; end: $n = 4$/lack of response: beginning: $n = 1$; middle: $n = 1$; end: $n = 6$). No differences were observed for the remaining WD categories and elements.

Variations of workflow disruptions among surgeons and scrub nurses

Additional analyses showed that the duration of WD varied significantly between the two groups of participants (F (1, 154) = 3.82, $p < .05$): duration of WD was significantly longer in the group of surgeons ($M = 9.69$, SD = 13.45) than in the group of scrub nurses ($M = 5.83$, SD = 9.91). Interruptions by colleagues were the most common disrupting factor for both groups, but the distribution of WD behaviors differed significantly between the two groups (χ^2 (10, 155) = 57.32, $p < .0001$). As we can see in Fig. 2, SN demonstrated both a greater frequency of WD ($n = 112$) and a different distribution of these WDs compared to surgeons: circumstances of distraction ($n = 43$) and interruptions by colleagues ($n = 24$) were overrepresented. On the other hand, WD among the group of surgeons were 3 times less frequent ($n = 43$) and mainly represented by

Table 3 Relationships between expertise, team familiarity, duration of workflow disruptions, duration of surgical approach and time of the day (Spearman correlation)

	1	2	3	4	5	6
1. Expertise of surgeons[a]	1					
2. Expertise of scrub nurses[a]	−.44 (p < .0001)	1				
3. Familiarity	.82 (p < .0001)	−.18 (p < .05)	1			
4. Duration of workflow disruptions	−.18 (p < .05)	.05	−.19 (p < .01)	1		
5. Duration of surgical approach	−.27 (p < .01)	−.02	.06	.12	1	
6. Time of the day[b]	−.11	−.12	−.12	−14	−.35 (p < .0001)	1

N = 155

[a]Expertise: 1 = low level, 2 = intermediate level, 3 = expert

[b]Time of day: 1 = morning, 2 = afternoon

interruptions by colleagues (n = 15) and teaching moments.

Relationships between expertise, surgeon–scrub nurse familiarity and workflow disruptions

Results of the correlational analysis (Table 3) revealed that the expertise of surgeons correlated negatively with the duration of WD (r = − .18, CI 95% [−0.328, −0.024]) and the duration of surgical approach (r = − .27, CI 95% [−0.41, −0.118]). In other words, duration of WD and duration of the surgical procedure were significantly shorter in expert surgeons. The duration of surgical approach was also negatively correlated with the time of day (r = − .35, CI 95% [−0.481, −0.204]): in the afternoon, the duration of the intervention was shorter than that in the morning.

The degree of expertise among surgeons–SN dyads was negatively correlated (r = − .44, CI 95% [−.558, −0.304]), and the familiarity among these dyads was positively related (r = .82, CI 95% [−0.865, −0.761]). Similarly, familiarity was low in dyads consisting of SN with high levels of expertise and surgeons with low levels of expertise (r = − .18, CI 95% [−0.328, −0.024]).

Finally, as expected, familiarity between surgeons and SN correlated negatively with duration of WD (r = − .19, CI 95% [−0.337, −0.034]): WD was less frequent when surgeon was familiar with SN.

Discussion

This study aimed to examine surgeons–scrub nurses' WD during a neurosurgical intervention (ACDF) and their relationships with expertise and surgeon–scrub nurse familiarity. To our knowledge, this is the first study focusing on the relationship between these factors in the surgical context.

Overall, WD represented 9.91% of the coded surgical time and was essentially due to interruptions by colleagues and distraction. Interruptions by colleagues were in line with previous findings [14]. Cohen, in 2016 [22] evaluated the number of WD in a cardiac surgery OR population excluding surgeons. Interruptions accounted for the highest proportion of WD involved (48.6%). The frequency of WD in our study was lower than that in Cohen's (25%), but similar to another study conducted in a different context. For example, Allers et al. [8] showed that WD in prostate surgery assisted by robotics accounted for 9% of the operative time.

Interestingly, a major cause of interruption, not clearly reported in previous studies [2, 10], was related to problems of concentration among SN specifically. Firstly, a possible explanation relates to the routine nature of the surgery recorded, which is low risk and frequent in hospital context, thus leading to a loss of situational awareness among SN. Widmer et al. [23] described case-irrelevant communication (CIC) as another source of distraction. They categorized CIC into work-related CIC or social CIC. Their frequencies varied according to the phases and difficulty of the surgery. Teaching moments between surgeons and their fellow assistants could be a source of communication failure and WD. However, despite the fact that the role of simulation in surgery is not questionable, it is not sufficient for the learning of surgery. Protected time for learning in a real environment, i.e., in the OR, must be accepted in academic hospitals. Contrary to previous studies [2, 5, 24], some common types of WD related to coordination problems, communication failures or equipment dysfunction did not appear in the present study. Lastly, duration of the surgery was shorter in the afternoon possibly because of stronger time constraints due to the presence of OR end time.

Another important result of this study is the relationship between expertise, surgeon–scrub nurse familiarity and surgical WD. Actually, in our study specifically concentrating on surgeon–SN crews, the number of WD decreased as the level of expertise among neurosurgeons increased and the number of WD decreased while familiarity between surgeons and SN increased. Even if this relationship between WD and surgeons–scrub familiarity is a small-size effect, this result confirms some of those observed in previous studies [8, 17, 24–26]. For example, Parker et al. [24] have shown that miscommunications occurred more frequently in teams where a new staff surgeon was present. Moreover, Elbardissi et al. [25] showed that collaboration between a fellow and an attending surgeon who were more familiar allowed reduction of times of clamping in cardiac surgery. A number of studies [13, 27] suggest the importance of coordination and anticipation between surgeons and SN in workflow and team performance. According to the theory of transactive memory [28, 29], team familiarity permits development of a shared mental model allowing coordination, credibility and specialization and therefore increasing team performance. The ability of the SN to understand subtle differences among neurosurgeons allows them to get ready for probable challenges and reduce the influence of WD that could hinder team performance [30].

Sieweke et al. [31] in the sports field established a U-shaped relationship between the coordination errors in the team and the familiarity among the team with a moderating effect of the team leader on this relationship. In our study, we also observed this relationship between the expertise of neurosurgeon and WD. Crew familiarity effect is less influential when a SN assists an expert surgeon. The influence of familiarity seems to be stronger for the non-expert surgeons.

Despite the interest of the present findings, some limitations should be highlighted. This pilot study contains a limited number of interventions, focused only on a university hospital, in a neurosurgery department. Future studies with a larger sample are needed with the examination of team familiarity in the OR. Some variables are not mastered: variation of technical skills according to the degree of expertise for example. Neither have we carried out a specific analysis as in other studies on expert leadership versus novice leadership and workload [14, 16].

The identification and categorization of surgical WD could also suggest some practical means to improve the OR environment, such as simulation-based teamwork training in order to limit interruptions by colleagues. Interventions to reduce WD in the OR should consider the specific needs of participants. Finally, this study confirms the relationship between WD and familiarity between surgeons and nurses. OR staff need to be more vigilant with regard to the introduction of new team members in order to limit WD numbers which could impair patient safety.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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