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Making surgery better: The effect of individual, social and situational factors

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by

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Making surgery better : The effect of individual, social and situational factors

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UNIVERSITÉ DE NEUCHÂTEL

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Abstract

This dissertation is comprised of four empirical papers all of which examine effects of individual, social or situational factors in surgery.

The first paper (*Reasons for the persistence of adverse events in the era of safer surgery – a qualitative approach*) examined reasons for the persistence of adverse events despite the use of surgical safety checklists. Clinic directors in operative medicine were asked to provide arguments for the persistence of adverse events as well as advantages and disadvantages regarding the introduction and implementation of checklists. Results revealed that reasons for the persistence of adverse events are mainly considered as being related to individual aspects (e.g. strain, lack of discipline) and less to organizational or contextual causes. Advantages of introducing and implementing checklists were mainly seen on the organizational level (e.g. financial aspects). The unwillingness to implement such lists (e.g. acceptance, commitment), which was again related to individual aspects, was the disadvantage most frequently named.

The second paper (*Impact of communication within the surgical team on surgical site infections*) investigated the impact of intraoperative communication during open abdominal surgeries on surgical site infections (SSI). Based on behavioral observations, case-relevant and case-irrelevant communication were coded directly in the operating room (OR) during 103 surgeries. Results indicate that case-relevant communication during the whole surgery lowers space/organ SSI-rates, whereas case-irrelevant communication during the last 20 minutes of the surgery raises incisional SSI-rates. Case-relevant communication is therefore considered as a protective factor against and case-irrelevant communication as a risk factor for SSI.

A third paper (*Assessing distractors and teamwork during surgeries: Development of an event-based method for observation*) describes the development of the observational system used in the paper investigating the impact of intraoperative communication during open abdominal surgeries on SSI. The event-based coding system contains 18 codes and enables the assessment of teamwork, communication and distractors directly in the OR. Inter-observer agreement was assessed at different points of time (e.g. after three hours of surgery between a tired and a non-tired observer) because fatigue influences reliability, particularly when observing long surgeries. Cohen's kappa and Intraclass Correlation Coefficient (ICC) indicated very good to good inter-observer agreement assessed during 29 surgeries. The observational system is thus suitable even for surgeries longer than three hours.

In the fourth paper (*The surgeons' perspective: Promoting and discouraging factors to choose a career in surgery as perceived by surgeons*), current surgeons were asked to take the perspective of graduates considering a career in surgery and to provide factors making surgery (not) attractive as a career choice. Arguments were content analyzed and it was examined whether surgeons' perspectives differ according to their hierarchical levels. Overall, surgeons provided more discouraging than promoting aspects for choosing surgery. Concerning aspects promoting a career choice in surgery, vocation to surgery was mainly seen as an important factor for all surgeons. Concerning aspects discouraging a career choice in surgery, contextual characteristics (e.g. training) and work characteristics (e.g. workload) were mentioned the most among all surgeons.

These four papers are all related to surgery and yield valuable results that may improve patient safety in several ways. First, a unique dataset was collected in the OR, which considerably contributes to the understanding of teamwork processes during surgeries, thus indicating ways to reduce postoperative infections. Second, the results further suggest starting points to decrease the occurrence of adverse events and encourage the use of surgical safety checklists. Third, identified factors for career choice may help to attract graduates to surgical careers and therefore ensure the maintenance and function of healthcare in the future.

Key words: surgical teams, teamwork, communication, surgical site infections, behavioral observation, career choice in surgery, adverse events, surgical checklist, work characteristics

Mots-clés: équipes chirurgicales, travail d'équipe, communication, infection du site opératoire, observations comportementales, choix d'une carrière en chirurgie, événements indésirables, check-list en chirurgie, caractéristiques du travail

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1. Introduction

Surgery is a specialty in medicine and refers to the operative treatment of diseases or injuries. Surgeries take place in a complex, highly technologized and specialized environment (e.g.Stone & McCloy, 2004). Surgeons are very well trained physicians and for becoming a specialist, they have to complete residency during several years including the acquirement of anatomical and technical knowledge as well as execution of a large number of surgeries (e.g.Collins, 2011; Traynor, 2011). Nevertheless, surgeries are not performed by a single surgeon. Surgical teams usually consist of surgeons, anesthetists and at least two nurses assisting the surgeons and providing the needed instruments. Surgery requires close collaboration of different team members during many hours and often under very stressful conditions.

Despite progressive technology as well as highly specialized and trained professionals, humans are not infallible and errors or complications may occur during surgeries and harm patients. This dissertation therefore investigates teamwork in surgical teams and aims at contributing to the growing literature on patient safety and human factors in healthcare to further improve surgery.

The dissertation covers themes of human factors in healthcare, intraoperative behavior of surgical teams as well as methodological developments required for data collection. Moreover, factors making surgery attractive as a career choice are examined.

1.1 Projects related to this dissertation

This dissertation is the result of two collaborations. Given the interdisciplinary of the two projects, all papers presented in this dissertation are co-authored with several members of the different projects. On the one hand, I wrote my dissertation as a doctoral student in an interdisciplinary project of the University of Neuchâtel (Prof. Dr. F. Tschan), the University Hospital of Bern (Prof. Dr. G. Beldi), and the University of Bern (Prof. Dr. N. Semmer). The dissertation is part of the project “Relating Human Factor Aspects during Surgery to Surgical Site Infections” which was funded by a grant of the Swiss National Science Foundation (SNSF). As the title implies, the overall goal of this project was to relate human factors (e.g. teamwork, communication, distractors) during open abdominal surgeries to postoperative complications, namely surgical site infections (SSI). The decisive factor for this project was a study of Beldi, Bisch-Knaden, Banz, Muhlemann, and Candinas (2009) suggesting a possible link between intraoperative behavior of the surgical team and SSI. However, their results did not allow establishing a reliable link between intraoperative communication and SSI because they were based on questionnaires which were filled in after surgeries. We therefore developed and tested an

observational system with different behavior and communication codes allowing the assessment of teamwork, communication, and distractors during surgeries. Information on the development and testing of this observational system as well as a discussion regarding its reliability are provided in the paper "*Assessing distractors and teamwork during surgeries: Development of an event-based method for observation"*. For the sake of simplicity, I will from now on mainly refer to this paper as the "*methodological paper*". The paper is submitted and it is inserted after chapter 4 of this dissertation. Based on the observations during surgeries, we related intraoperative communication within the surgical team to SSI-rates which is illustrated in the paper *"Impact of communication within the surgical team on surgical site infections"*. This paper is also submitted and it is inserted after chapter 3 of this dissertation. In the following chapters, I will frequently name it the "*paper on intraoperative communication*". Within the context of human factors in the operating room (OR), I am also co-author of a third paper entitled *"Human factors in the operating room – The surgeon's view"* which is published but not included in this dissertation.

On the other hand, I also conducted research with two surgeons from different hospitals (Dr. A. Businger, Dr. R. Kaderli) on surgical safety checklists and more precisely on the relationship between the use of surgical safety checklists and adverse events. Qualitative and quantitative analyses were conducted and results are described in the paper *"Reasons for the persistence of adverse events in the era of safer surgery – a qualitative approach"* which is published. It is inserted after chapter 2 and I will refer to this paper as the *"paper on checklists"* in the following chapters. This collaboration further included one paper on career choice in surgery. Surgeons provided factors making surgery (not) attractive as a career choice for graduates. Methods, results and discussion are described in the paper *"The surgeons' perspective: Promoting and discouraging factors to choose a career in surgery as perceived by surgeons"*. This paper is ready to be submitted and it is inserted after chapter 5. Moreover, I will frequently refer to this paper as the *"paper on career choice"*.

Within this collaboration, I am also a co-author to a paper entitled *"Is the motivation to pursue a surgical subspecialty training gender-neutral? A national survey in Switzerland" determining factors in the decision-making process to pursue surgical training and gender differences"* which is submitted but not included in this dissertation.

1.2 Structure of this dissertation

This dissertation consists of four main parts that correspond to the four empirical papers presented. Each of the four main chapters of the dissertation relates to one of the four papers and contains additional in-depth information and background aspects. However, there might be few redundancies or overlapping parts between the chapters and the papers. The papers are inserted after the corresponding chapter. Pages of the dissertation are continuously numbered but interrupted because of the inserted papers. This was the only possibility to ensure that citations remain where they were inserted.

The dissertation is structured as follows: In *chapter 2*, themes of human factors in healthcare are described including errors and adverse events as well as the use of checklists. This chapter constitutes the background for the *paper on checklists*. In addition, non-technical skills are shortly presented and an overview on SSI is provided. These topics are also related to the other papers.

Chapter 3 is on intraoperative behavior and provides the background for the *paper on intraoperative communication*. It contains general information on teamwork in healthcare and surgery before it addresses specific aspects of teamwork in surgical teams.

In *chapter 4*, methods for data collection used in this dissertation are presented and methodological requirements for each of these methods are discussed. This chapter also comprises the *methodological paper*.

Chapter 5 refers to work characteristics and, in particularly, content of work, contextual work conditions, and vocation to a job are described. This chapter constitutes the background for the *paper on career choice*.

Finally, *chapter 6* contains the *discussion* and summarizes the main findings of this dissertation. Future perspectives and main limitations are discussed and a final conclusion is provided.

2. Human factors in healthcare

This first chapter covers a wide range of different themes related to human factors in healthcare. Factors contributing to errors and adverse events as well as their incidence rates are briefly described before checklists are discussed. This first part also serves as a background for the study investigating reasons for the persistence of adverse events (paper on checklists, chapter 2.5). Following this, non-technical skills are shortly described, and the chapter concludes with an overview on SSI.

2.1 Errors and adverse events

Errors can occur in all specialties and domains of healthcare as well as in different fields of care. For instance, studies examined and reported diagnostic errors, errors in anesthesia, in the OR during surgeries, in emergency departments and in postoperative care in the intensive care unit (e.g.Cooper, Newbower, Long, & McPeek, 2002; Gawande, Zinner, Studdert, & Brennan, 2003; Kopp, Erstad, Allen, Theodorou, & Priestley, 2006; Sonderegger-Iseli, Burger, Muntwyler, & Salomon, 2000). Moreover, errors can result in adverse events referring to “an injury that was caused by medical management (rather than the underlying disease) and that prolonged the hospitalization, produced a disability at the time of discharge, or both” (Brennan et al., 2004, p. 145). Hence, errors in healthcare can cause physical and psychological damage to patients, extend hospital stays and increase healthcare costs (e.g.Kohn, Corrigan, & Donaldson, 2000).

Several factors contributing to errors and adverse events in healthcare have been identified. Based on surgical malpractice claims, Greenberg et al. (2007) analyzed communication breakdowns resulting in patient harm. In total, they identified 60 cases that included communication breakdowns with one third occurring during surgery. These breakdowns were often related to unclear responsibilities among the team, to residents that failed to inform attending surgeons about important events, and to poor handoffs. In another study, surgical errors reported by surgeons were analyzed, and the authors identified inexperience with a surgical task, fatigue, workload as well as communication breakdowns as factors that contributed to the occurrence of errors (Gawande et al., 2003). In addition, stressful events like technical, patient and equipment problems occur frequently during surgeries, and it has been suggested that these events impair surgical performance and may thus contribute to errors (Arora et al., 2010). Some researchers also conducted direct observations in the OR and found communication breakdowns, information loss, workload and concurrent tasks to endanger patient safety and to contribute to adverse events (Christian et al., 2006). The relationship

between communication failures in the OR and procedural errors has also been shown (Lingard et al., 2004). Several studies have investigated distractors during surgeries and reported high densities (e.g.Healey, Sevdalis, & Vincent, 2006). Moreover, distractors have been shown to impair surgical performance in a laparoscopic surgical simulation (Goodell, Cao, & Schwaitzberg, 2006), and it has been found that less experienced surgeons are more diverted in case of distractors (e.g.Park et al., 2011). It is assumed that distractors divert the attention of the surgical team and thus have the potential to increase the risk for errors.

Some studies reported considerable rates of adverse events and errors in healthcare. By reviewing 1,040 patient records of two British hospitals, Vincent, Neale, and Woloshynowych (2001) found that the rate of adverse events was 11.7% with almost half of these adverse events being preventable. Moreover, Brennan et al. (1991) analyzed 30,121 patient records from hospitals in the State of New York, and found that 3.7% of patients suffered adverse events, with 2.6% of them resulting in permanent disability and 13.6% in death. Thomas et al. (2000) analyzed 15,000 discharge reports from hospitals in Utah and Colorado in order to identify incidence rates of adverse events. They reported adverse events in 2.9% of all cases, of which 6.6% resulted in death. Additionally, 44.9% of the identified adverse events were related to surgeries, and 16.6% of these adverse events caused permanent disability. The authors concluded that adverse events were attributed to surgeons and internists mostly. Similar to Thomas et al. (2000), Gawande, Thomas, Zinner, and Brennan (1999) analyzed the same sample of 15,000 discharge reports in their study, but focused on the incidence of surgical adverse events. The authors reported that 66% of all identified adverse events were surgical, with 54% of them being judged as preventable. 5.6% of identified surgical adverse events resulted in death. In addition, Gawande et al. (2003) conducted confidential interviews with 38 surgeons to obtain information on the occurrence of surgical errors. The surgeons reported 145 incidents with 60% occurring during surgeries. Moreover, 33% of surgical errors resulted in disability and 13% in death.

Several factors contributing to errors and adverse events have been identified − communication failures and breakdowns, workload, distractors and fatigue. Errors can result in adverse events and harm patients, and it is therefore important to investigate in methods to reduce and prevent the occurrence of errors and adverse events. One of the methods for reducing errors and adverse events is the introduction of checklists. Checklists are described in the following chapter.

2.2 The use of checklists to reduce errors and adverse events

Checklists are an important tool in error management and the “principal purpose of their implementation is commonly error reduction or best practice adherence” (Hales & Pronovost, 2006, p. 231). Checklists are frequently used in many industries such as aviation or in nuclear power plants in order to reduce human error (Hales & Pronovost, 2006; WHO, 2008). They help users to assess whether the listed items are all considered and completed, provide guidance for preparing a task and/or serve as means of verification after a task is completed (Hales & Pronovost, 2006).

In order to prevent and reduce adverse events and errors in medicine, the WHO launched the Safe Surgery Saves Life campaign in 2008 and introduced guidelines for surgical safety checklists on a voluntary basis (WHO, 2008). A surgical checklist consists of different parts that have to be completed in three phases of the surgery: The first phase refers to the period before induction of anesthesia. The anesthetist and patient are involved in confirming the patient’s identity and the procedure and in marking the operative site. Moreover, the anesthetist has to review the risk of blood loss, possible difficulties related to the airways and the patient’s allergies. For this part of the checklist, the presence of a surgeon is not required. The second part of the checklist has to be completed in the OR after the induction of anesthesia but before skin incision. It includes the introduction of each team member by name and role, and ensures that all people present in the OR and participating in surgery know each other. Team members confirm patient identity and the correctness of the planned procedure, and review complications that might occur during surgery. The administration of prophylactic antibiotics and the display of important imaging (e.g. computed tomography, X-ray) are also checked. At least one surgeon is present during the completion of this part of the checklist. The third and last part of the checklist is completed after surgery, before the patient is taken out of the OR. It includes the review of the performed surgery, sponge and instrument counts, labelling resected items as well as discussing postoperative management and recovery. Surgeons are present during this part of the checklist (WHO, 2008).

Several studies have examined the effectiveness of surgical checklists. For instance, Haynes et al. (2009) have shown the benefit of checklists in a study including eight hospitals all over the world (Jordan, India, USA, Tanzania, Philippines, Canada, England and New Zealand). After the implementation of the checklist, all hospitals had a decrease in the rate of death (from 1.5% to 0.8%) and postoperative complications (from 11% to 7%). However, significant decreases of postoperative complications were achieved in only three hospitals. One of them was in a newly industrializing country and had not administered prophylactic antibiotics regularly before the checklists were introduced. In sum, the results of this study suggest that surgical checklists improve patient

outcomes and patient safety. By introducing surgical checklists, Hurlbert and Garrett (2009) found in another study several improvements related to the team, patient, procedure and equipment. For instance, the number of times the circulating nurses had to leave the OR to get appropriate instruments declined. Moreover, the number of questions on information about the patient that should have been known before the surgery decreased as well as miscommunication resulting in delays or adverse events. Adverse events that harmed patients could also be reduced. In total, the introduction of surgical checklists improved teamwork in general, communication was perceived as more open and OR staff felt safer in communicating safety issues. Lingard et al. (2008) observed surgical teams before and after the introduction of surgical checklists. Results showed that surgical checklists reduced the number of communication failures per surgery (from 3.95 to 1.31) as well as communication failures leading to a visible consequence. The authors suggested that surgical checklists reduce poor communication and promote effective communication within the team.

Checklists serve as reminders, they support concentration and focus attention. Moreover, previous research has shown their positive effects on intraoperative communication within surgical teams (e.g.Lingard et al., 2008). We assume that checklists encourage surgical teams to talk about the patient or the current procedure during surgeries. This case-relevant communication, in turn, may foster the development of a shared mental model and thus enhance performance[1].

Checklists were also introduced in several hospitals in Switzerland, where in 2011, about 73.8% of surgical departments used surgical checklists (Kaderli, Hertig, Laffer, & Businger, 2012). To further improve patient safety, it is crucial to elicit reasons for the persistence of adverse events despite the use of checklists. Clinic directors in operative medicine were therefore asked to name potential reasons for the consistency of adverse events (paper on checklists, chapter 2.5).

2.3 Non-technical skills

Another topic that is frequently discussed in human factor literature and that relates to errors refers to non-technical skills. Research in high-risk domains such as aviation and nuclear power plants as well as investigations in accidents like the *Challenger disaster*, *Three Miles Island* or *Chernobyl* have shown that errors and accidents are frequently related to cognitive and social skills rather than technical problems. These cognitive and social skills are called non-technical skills (Fletcher,

[1] I will return to intraoperative behavior including communication and cognitive aspects such as shared mental models in chapter 3.

McGeorge, Flin, Glavin, & Maran, 2002; Flin & Maran, 2004; McCulloch, 2009; Mishra, Catchpole, & McCulloch, 2009; Pierre, Hofinger, Buerschaper, & Simon, 2011; Reason, 2000; Salas & Maurino, 2010; Wiener & Nagel, 1988; Yule, Flin, Paterson-Brown, & Maran, 2006).

Healthcare and surgery have primarily focused on the formation of technical skills and technical expertise for providing safe care (Yule et al., 2006). However, investigations in adverse events and errors revealed that their causes are frequently related to non-technical problems (Catchpole, Mishra, Handa, & McCulloch, 2008; Edmondson, 2003; Gawande et al., 2003; Leonard, Graham, & Bonacum, 2004). It became apparent that performance and safety in healthcare can only be maintained if attention is also paid to non-technical skills (Yule et al., 2006).

Non-technical skills in healthcare can be grouped into two broad categories: cognitive skills, which include decision-making, planning and situation awareness, and social skills, which involve communication and leadership (e.g.Fletcher et al., 2002; McCulloch, 2009; Mishra et al., 2009; Yule et al., 2006). Today, these skills are seen as being crucial for providing safe care in healthcare (Yule et al., 2006). For instance, it has been found that non-technical skills are important for patient safety and efficient collaboration in the OR (Catchpole et al., 2008; Leonard et al., 2004; Sexton, Thomas, & Helmreich, 2000).

The knowledge about non-technical skills also influenced the content of chapter 3 on intraoperative behavior.

2.4 SSI

The following section provides a background on SSI, which are, contrary to errors, complications. SSI are multifactorial, and human factors possibly contribute to their occurrence. I decided to include the discussion about SSI here because from the next chapter on (chapter 3 on intraoperative behavior), I will frequently refer to SSI, and it might therefore be useful to have additional information about them.

SSI are infections occurring in the part of the body where the surgery took place (Mangram, Horan, Pearson, Silver, & Jarvis, 1999; SwissNOSO, 2011). They are the most frequent complication after surgeries (Mangram et al., 1999). Incidence rates can be of up to 30% with the highest rate after abdominal surgeries (Hubner et al., 2011; SwissNOSO, 2011). SSI may have severe consequences for patients (Tang et al., 2001), extend hospital stays and increase healthcare costs (Leaper et al., 2004; Plowman et al., 2001).

Several risk factors have been identified for SSI. Patient-related risk factors include for example obesity (Malone, Genuit, Tracy, Gannon, & Napolitano, 2002), age, smoking, steroid use, alcoholism, diabetes, an ASA-Score (American Society of Anesthesiologists Score) higher than two (Neumayer et al., 2007), malignant condition and comorbidities (Sax et al., 2011). Risk factors related to the surgery include for example preoperative stays (Mangram et al., 1999), hair removal technique (Tanner, Woodings, & Moncaster, 2006), administering antibiotics (Leaper et al., 2010), the type (Neumayer et al., 2007) and duration of the surgery (Leong, Wilson, & Charlett, 2006), blood loss during surgery (Mangram et al., 1999), an intestinal anastomosis (Beldi et al., 2009) and postoperative care (Mangram et al., 1999).

Regarding the development of SSI, risk factors related to the patient are less important compared to influences related to the surgery (Beldi et al., 2009). It is thus crucial to investigate on intraoperative aspects related to SSI. Hospitals emphasize antiseptic measures to prevent SSI, and research has mainly focused on compliance to antiseptic measures to reduce SSI (Hugonnet, Harbarth, Sax, Duncan, & Pittet, 2004; Mangram et al., 1999). However, the effectiveness of antiseptic measures to reduce SSI seems to be limited as Beldi et al. (2009) showed. Beldi et al. (2009) examined the effect of extensive antiseptic measures versus standard antiseptic measures during abdominal surgeries on SSI-rates. Results showed that additional antiseptic measures did not reduce SSI. Instead, the authors found that intraoperative team behavior like changes within the sterile team, hectic movements, loud noise and external visitors in the OR were significantly related to SSI. The behavior was assessed using a postoperative questionnaire with questions related to the intraoperative team behavior, which was filled in by a scrub nurse.

The same research group conducted a follow-up study and assessed noise during surgeries (Kurmann et al., 2011). Again, after having controlled for patient-related risk factors, the authors showed that more noise during surgeries was related to SSI. Results of these two studies suggest that human factors and intraoperative behavior of the surgical team contribute to the development of SSI. However, how intraoperative behavior prevents or fosters the development of SSI remains unclear, and research on intraoperative behavior and SSI is very rare.

Based on the studies of Beldi et al. (2009) and Kurmann et al. (2011), we therefore investigated intraoperative behavior and its relationship to SSI (paper on intraoperative communication, chapter 3.7).

2.5 Paper on checklists

This chapter contains the paper on checklists entitled "Reasons for the persistence of adverse events in the era of safer surgery – a qualitative approach" which is published.

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Reasons for the persistence of adverse events in the era of safer surgery – a qualitative approach

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Summary

OBJECTIVE: We sought to evaluate potential reasons given by board-certified doctors for the persistence of adverse events despite efforts to improve patient safety in Switzerland.
SUMMARY BACKGROUND DATA: In recent years, substantial efforts have been made to improve patient safety by introducing surgical safety checklists to standardise surgeries and team procedures. Still, a high number of adverse events remain.
METHODS: Clinic directors in operative medicine in Switzerland were asked to answer two questions concerning the reasons for persistence of adverse events, and the advantages and disadvantages of introducing and implementing surgical safety checklists. Of 799 clinic directors, the arguments of 237 (29.7%) were content-analysed using Mayring's content analysis method, resulting in 12 different categories.
RESULTS: Potential reasons for the persistence of adverse events were mainly seen as being related to the "individual" (126/237, 53.2%), but directors of high-volume clinics identified factors related to the "group and interactions" significantly more often as a reason (60.2% vs 40.2%; p = 0.003). Surgical safety checklists were thought to have positive effects on the "organisational level" (47/237, 19.8%), the "team level" (37/237, 15.6%) and the "patient level" (40/237, 16.9%), with a "lack of willingness to implement checklists" as the main disadvantage (34/237, 14.3%).
CONCLUSION: This qualitative study revealed the individual as the main player in the persistence of adverse events. Working conditions should be optimised to minimise interface problems in the case of cross-covering of patients, to assure support for students, residents and interns, and to reduce strain. Checklists are helpful on an "organisational level" (e.g., financial benefits, quality assurance) and to clarify responsibilities.

Key words: *adverse event; patient safety; surgical checklist; qualitative analysis; individual; working conditions; organisational level*

Introduction

Worldwide, between 45,000 and 100,000 patients die because of medical errors each year [1]. A systematic review suggested that the median overall incidence of in-hospital adverse events in industrialised countries amounts to 9.2%, of which, 43.5% were regarded as preventable [2]. Preventable adverse events lead to transient impairment in 30% to 50% of patients, to permanent impairment in 9% and even death in 3%, respectively [3].
Almost two-thirds of adverse events are associated with surgical care, with more than half of these events being operation-related or drug-related (i.e., administering the wrong type of medication, under-/over-dosing, adverse drug reactions) [2, 4]. A recent Dutch study showed that infection, bleeding, and injury due to a mechanical, physical, or chemical cause formed the largest group of injuries, as a result of surgical adverse events [4]. Almost half of the surgery-related adverse events were judged to be preventable.
In October 2004, the World Health Organisation (WHO) launched a patient safety programme to coordinate, disseminate, and accelerate improvements in patient safety worldwide [5]. The WHO World Alliance for Patient Safety has recognised the importance of creating an international language for patient safety, which led to the development of a conceptual framework for an International Classification for Patient Safety (ICPS) [6, 7]. Their goal was to enable the categorisation of patient safety information into a standardised set of concepts [7].
Important strategies to reduce medical errors include guidelines, clinical pathways, and other standardisation of procedures and improvement of communication; whereas the most important might be the implementation of checklists [8–10]. Checklists are well established in high-risk industries, such as aviation, aeronautics, and nuclear power plants. A perioperative checklist was published by the WHO in 2008 with the aim of decreasing the risk of human error and communication failures [11, 12]. At this time, about three quarters of clinics in operative medicine in Switzerland use checklists [13].

In comparison to the United States, measures related to patient safety are less developed in Switzerland, less widespread, and are subject to more resistance than in the US [14]. For Switzerland, the high number and type of adverse events and near misses reported in the Swiss Critical Incidence Reporting System (CIRS) is compelling evidence for the need to improve patient safety in Switzerland [15, 16].
The present study evaluated the potential reasons for the persistence of adverse events despite efforts to improve patient safety in Switzerland by analysing the advantages and disadvantages of introducing and implementing surgical safety checklists using free-reply arguments from directors of clinics in operative medicine.

Methods

Study design

For this qualitative study, an anonymous electronic survey was sent to all directors of clinics in operative medicine in Switzerland (classified according to the Swiss Medical Association [FMH]) during spring 2011 [17]. Eligible clinics were identified from the database of the Swiss college of surgeons (fmCh), the umbrella organisation of all surgical disciplines in medicine in Switzerland [18]. As the survey addressed healthy people on a voluntary basis, this study did not require further ethical considerations. The data were collected, stored, analysed, and shared in strict adherence with the ethics committee standards of our institution.

Assessment of responses

The electronic questionnaire consisted of multiple-choice and free-response items. The free-response items were embedded in the multiple-choice questions addressing the issues of what might be the reasons for the persistence of adverse events and what was the role of surgical safety checklists. The free-response items of the questionnaire read as follows: (1.) “Where do you see potential reasons for the persistence of adverse events in operative medicine in Switzerland? Please mention three arguments for each of the subsequent levels: The level of implementation (at the patient’s bedside), the superordinate level (politics, authorities, administration) and on other levels.” (2.) “Where do you personally see disadvantages or advantages of introducing and implementing surgical safety checklists in a clinic in operative medicine?”
The multiple-choice questions addressed information on the use of surgical safety checklists, acceptance problems during their introduction and acceptance problems of their use at the time of the survey. On the question regarding the degree of acceptance problems, the respondents were asked to reply based on a five-point Likert scale (1 = “no problems” to 5 = “very serious problems”). Furthermore, the questionnaire included information on hospital category, specialty, and size of the participating clinic (number of surgeries per year) (see supplementary material). Clinics with more than the median number of 2,200 surgeries/year were defined as high-volume clinics.

Data analysis

The focus of the present study was the analysis of the qualitative answers of the clinic directors. Analyses were done by two independent psychologists well-trained in qualitative statistics using Mayring’s content analysis [19]: First, by defining the level of abstraction for the inductive formation of categories, and, second, by stepwise inductive formulating of content categories and generating of a code manual. Inter-rater reliability was calculated with Cohen’s Kappa. Correlation analysis was performed using two-sided Spearman’s rank correlation test. Categorical variables were dichotomised and analysed with chi-square tests. A p-value of 0.05 was considered as statistically significant; tests were two-tailed. All statistical analyses were calculated with SPSS statistical software Version 20 (SPSS Inc.; Chicago, USA).
Statements given by the participants were grouped in different categories.
Categories and subcategories were assigned “1” if they were mentioned and “0” if they were missing. Summarising of mentioned subcategories into the main category resulted in value “1”, regardless of how often the subcategories were named. The number of respondents per (sub)category were summarised, and frequencies were calculated.

Results

Of 799 surveys mailed, there were 237 responses (response rate of 29.7%). Overall, 172/233 (73.8%) participants used surgical checklists with a median time since introduction of 24 (range 12–264) months (4 missing values). Of the respondents using checklists, acceptance problems during the introduction of surgical checklists were reported by 99/168 (58.9%; 4 missing values), acceptance problems at the time of the survey by 53/165 (32.1%; 7 missing values). The specialties of the participating clinic directors are shown in table 1.
Regarding the subsequent qualitative analysis, Cohen’s Kappa was calculated on 27% of the statements and revealed good inter-rater reliability (0.79).

Reasons for the potential persistence of adverse events

The 237 participants gave a total of 377 arguments for the potential persistence of adverse events grouped in four different categories. The four categories were: “context” (48/237, 20.3%), “organisation” (89/237, 37.6%), “group/interaction” (114/237, 48.1%), and “individual” (126/237, 53.2%). All categories including subcategories and representative examples are shown in table 2.
Clinic directors of general surgery units significantly more often indicated arguments in the combined subcategories “labour turnover/shift change” and “interfaces/unclear lines of responsibility” compared with directors of more specialised clinics (16/66 (24.2%) vs 23/170 (13.5%); p= 0.012). Regarding the hospital category, directors of university hospitals named significantly more arguments in the summarised subcategories “unclear procedures”, “routine” and “emergencies” (5/22 (22.7%) vs 18/212 (8.5%); p = 0.033). For high-volume clinics, significantly more mentions were found in the category “group/interac-

tion" (65/108 (60.2%) vs 45/112 (40.2%); p = 0.003), the combined subcategories "labour turnover/shift change", and "interfaces/unclear lines of responsibility" (25/108 (23.1%) vs 14/112 (12.5%); p = 0.039), and the subcategory "lack of discipline/motivation" (25/108 (23.1%) vs 9/112 (8.0%); p = 0.002). The correlation between hospital category and number of surgeries was small and nonsignificant (r= –0.052; p = 0.440).

Advantages and disadvantages of introducing and implementing surgical safety checklists

The participants (n = 237) gave a total of 149 advantages and 103 disadvantages with regard to introducing and implementing surgical safety checklists; they were grouped in four main categories each.

The advantages were categorised in: "nonspecific advantages" (25/237, 10.5%), "organisational level" (47/237, 19.8%), "team level" (37/237, 15.6%), and "patient level" (40/237, 16.9%); the disadvantages in the categories "implementation difficulties" (12/237, 5.1%), "application" (26/237, 11.0%), "willingness to implement" (34/237, 14.3%), and "effort" (31/237, 13.1%). All categories including subcategories and representative examples of advantages and disadvantages are shown in tables 3 and 4, respectively.

Clinic directors of general surgery indicated significantly more often disadvantages of introducing and implementing surgical safety checklists compared with other specialties (32/66 (48.5%%) vs 57/179 (33.5%); p = 0.033). They also mentioned significantly more often the category "implementation difficulties" (7/66 (10.6%) vs 5/170 (2.9%); p= 0.016) as well as the subcategories "dependence on hospital size" (4/66 (6.1%) vs 2/170 (1.2%); p = 0.032) and "acceptance" (12/66 (18.2%) vs 12/170 (7.1%); p = 0.011) as disadvantages.

Regarding the hospital category, clinic directors of university hospitals gave significantly more arguments in the subcategory "commitment" (3/22 (13.6%) vs 7/212 (3.3%); p = 0.023) as disadvantage. As disadvantages, directors of high-volume clinics gave significantly fewer arguments in the subcategory "paperwork" (1/108 (0.9%) vs 8/112 (7.1%); p = 0.020) and significantly more in the subcategories "control" (6/108 (5.6%) vs 0/112 (0.0%); p = 0.011) and "commitment" (9/108 (8.3%) vs 1/112 (0.9%); p = 0.008) as well as in the categories "implementation difficulties" (5/108 (4.6%) vs 0/112 (0.0%); p = 0.021) and "willingness to implement" (24/108 (22.2%) vs 10/112 (8.9%); p = 0.006).

Discussion

In recent years, substantial efforts have been made to improve patient safety by introducing surgical safety checklists to standardise surgeries and team procedures [11, 12]. To examine the potential reasons for the persistence of adverse events in surgery and the role of surgical safety checklists, the present qualitative study analyses the arguments of clinic directors in operative medicine in Switzerland.

It shows that the reasons for adverse events were mainly seen as being related to the "individual" (e.g., violation of rules, lack of experience, mistakes, and strain). Compared with participants of other operative disciplines, general surgeons named "labour turnover and shift changes" significantly more often as a reason for potential adverse events. Participants of high-volume clinics identified the "group and interactions" significantly more often as a potential reason. Checklists were thought to have potentially positive effects on the "organisational level", the "team level", and the "patient level"; with a "lack of willingness to implement" checklists in general as the potential main disadvantage.

The participants see the most important reason for adverse events in surgery in the "individual" itself, mentioning "lack of personal experience", problems with "dealing with rules and regulations", "motivational factors", "strain" and "overfatigue" as interfering factors. The actual health care system relies heavily on the work of inexperienced novices (e.g., students, interns, and residents), which might increase the rate of adverse events [20]. Several studies also suggest an association between sleep deprivation, extended work shifts, chronic staff shortage, and stress with more errors and adverse events [21–23]. Interestingly, studies on restrictions of work-hours, however, did not show an improvement in patient safety, whereas the reasons remained widely elusive [24, 25].

Problems related to "organisation" and "communication" are also seen to contribute to adverse events. Compared with participants of other operative disciplines, general surgeons saw twice as many reasons for the persistence of

Table 1: Specialties of the participating clinic directors (one missing value).

Specialty	n (%)
General Surgery	66 (27.8)
Anaesthesia	59 (24.9)
Plastic and reconstruction surgery	24 (10.1)
Gynaecology	22 (9.3)
Orthopaedics	20 (8.4)
Otolaryngology	9 (3.8)
Hand surgery	6 (2.5)
Cardiac surgery	4 (1.7)
Neurosurgery	4 (1.7)
Ophthalmology	3 (1.3)
Paediatric surgery	3 (1.3)
Urology	1 (0.4)
Others	15 (6.3)

Table 2: Examples of reasons for the persistence of potential adverse events despite the efforts to improve patient safety in Switzerland and the number of respondents per main category and combined subcategory (n = 237).

Category	Subcategory	Number of respondents (%)	Content	Examples of arguments
Context		48 (20.3)		"Provisions of labour law" "Restrictive medical data protection prevents reasonable solutions" "Lack of support" "Incomprehension of the directors" "Incomprehension of the medical necessity" "Too great administrative burden at the expense of medical care" "Increase of bureaucracy"
	Politics	33 (13.9)	Political interventions in the health care system	
	Lack of understanding		Lack of awareness of the problem, lack of support by policy makers	
	Administration	21 (8.9)	Administration, data flood	
Organisation		89 (37.6)		"Safety culture" "Lack of quality assurance" "Lack of concepts" "Lack of infrastructure and funding to implement safety valves" "Staff savings" "Pressure on savings" "Wrong savings approaches" "Lack of safety precautions" "Inadequate techniques" "Lack of checklists" "Lack of measurements"
	Culture	13 (5.5)	Business and organisational culture	
	Scarcity of resources – Personnel – Financial	74 (31.2)	Resources in general Staff shortage Cost pressure	
	Lack of safety systems	14 (5.9)	Organisational safety systems	
Group/interaction		114 (48.1)		"Due to planning optimisation surgeries are performed in another operation room" "Short-term changes of operation rooms or surgeons" "Processes and procedures are often not enough efficient in hospitals" "Lack of automation of work processes" "Lack of an accurate methodology" "Disappearance in daily routine" "Increasing problems in emergency cases" "Imprudence in emergency cases" "Frequent changes of treating physicians and nursing personnel" "Too many shift changes of physicians and anesthetist" "Responsibility of too many people for a single treatment" "Uncertainty about responsibilities" "Interface problems" "Insufficiently documented co-morbidities" "Poor indication" "Inadequate workup of patients" "Insufficient information" "Ignorance of allergies" "Lack of recognition of the patient by the surgeon" "The physician who provides the indication is not the operating surgeon" "Scheduling of the surgery is not performed by the surgeon" "Inappropriate communication" "Errors in communication" "Discussion with the patient" "Lack of language skills of staff or patient"
	Programme changes	5 (2.1)	Short-term changes in the operation programme	
	Unclear procedures	24 (10.1)	Suboptimal implementation of instruments, lack of standardisation and automatisms	
	– Routine – Emergencies		Everyday routine Unclear procedures in emergency cases	
	Labour turnover/shift change	41 (17.3)	Work force	
	Interfaces/unclear lines of responsibility		Collaboration/responsibility of several people on patients	
	Information deficits	36 (15.2)	Lack of/defective information	
	Lack of knowledge of the patient		Knowledge and recognition of the patient by the physician	
	Lack of communication	45 (19)	Problems, deficits and deficiencies in communication	
	- Communication patient - physician		Communication between patient and physician in charge	

Individual		126 (53.2)		"Lack of training" "Slowness" "Lack of schoolings for human factor trainings" "Violation of the checklist" "Readiness to take risks" "Violation of standard operating procedures" "Negligence" "Lack of consistency" "Banalisation of the procedure" "Human failure" "False documentation" "Surgical mistakes" "Same names with insufficient further differentiation" "Transposition of similar names" "Concentration errors" "Distraction" "Overload" "Overwork" "Time factor" "Lack of time" "Rationalisation of time" "Hectic everyday life" "Increasing pressure on available beds" "Pressure for rentability (DRG system)" "Fatigue" "Overfatigue"
	Lack of experience	19 (8.0)	Degree of experience	
	Violation of provisions/rules	6 (2.5)	Dealing with rules and regulations	
	Lack of discipline/motivation	36 (15.2)	Motivational realisation of measures and directives	
	Mistakes	13 (5.5)	Not meeting the requirements	
	– Confusions		Confusion of patients, medications, etc.	
	Carelessness	10 (4.2)	Attention and attentiveness	
	Strain	78 (32.9)	Workload	
	– Time pressure		Disparity between workload and timeframe	
	– Stress – Pressure to perform		Stress and hectic Concretion of work	
	Overfatigue	5 (2.1)	Level of fatigue	

adverse events in too frequent "labour turnover and shift changes" with subsequent "interface problems". The negative effect of transfers of care on complication frequencies due to cross-covering and delayed test ordering has been shown by others [26, 27].

According to Baker et al., there is a trend towards higher numbers of adverse events in teaching hospitals compared with small-to-large community hospitals [28]. Besides differences in the patient population and documentation, and the complexity of treatment in teaching hospitals, miscommunication and coordination of care between various healthcare providers were suggested as potential reasons [28]. In a study of Gawande et al., communication was found to be a causal factor in 43% of errors made in surgery [29]. This is congruent with our finding that participants of high-volume clinics identified significantly more often factors related to the "group and interactions" for the persistence of adverse events. This includes not only the frequency of "labour turnover", but also "unclear procedures", "information deficits" with regard to patients, a "lack of communication" in general and with patients in particular, and "short-term programme changes". A probable association of short-term programme changes with an increased risk of surgical errors due to inexperience and communication errors, resulting from a change in the responsible personnel for a patient's care or inadequate handoff of information, has been well documented with regard to emergencies [29, 30].

Surgical checklists are a cost-effective means to reduce complications and patient deaths, even if the underlying mechanisms are not yet well understood and are most likely multifactorial [15, 31, 32]. The participants in the present

Table 3: Examples of arguments for the advantages of introducing and implementing surgical safety checklists and the number of respondents per category (n = 237).

Category/subcategory	Number of respondents (%)	Content	Examples of arguments
Nonspecific advantages	25 (10.5)	Nonspecific advantages and absence of disadvantages/problems	"Only advantages" "No problems" "No problems - one must do it"
Organisational level – Financial aspect – Quality assurance	47 (19.8) 42 (17.7) 6 (2.5)	Positive effect on the organisation Financial advantages Quality measures and quality assurance	"The organisation's credibility is strengthened" "Liability premium is lowered" "Documentation of a quality behaviour"
Team level – Procedure – Responsibility – Security – Communication/information – Concentration	37 (15.6) 9 (3.8) 7 (3.0) 9 (3.8) 9 (3.8) 12 (5.1)	Positive effect on the team Clear, structured procedure (Clear/shared) competences Team security Improved communication and information content Enhanced concentration and attention	"Motivation of the employees" "Involvement of the whole team" "Clarification of procedures and processes" "Standardisation of procedures" "Clear list and assignment of responsibility" "Additional security for the team" "Facilitation of communication between the members of the surgical team" "It can update the short-term memory" "The pause shortly before the cut calms and lowers the rush"
Patient level – Patient safety – Mistakes	40 (16.9) 27 (11.4) 15 (6.3)	Positive effect on the patient in general Increased safety of the patient Fewer mistakes by the treating person	"Calming of the patient" "Evident improvement of patient safety with a recognised method which is simple and fast" "Avoidance of an adverse event" "Avoidance of wrong site surgery"

study mentioned positive effects of checklists for the "patient", the interaction of the involved "team", but especially on the "organisational level"; this includes "financial advantages" and "quality assurance". Whereas the implementation of a checklist-based surgical safety intervention requires financial investments at first, it will pay off by improvements in quality of care [33]. The use of checklists comprises changes in systems and behaviour of individual operating personnel [34]. It leads to a process optimisation and standardisation, respectively, and minimises information loss during transfers and between disciplines [31]. The definition of the roles and responsibilities of the team members is a prerequisite to guarantee user commitment to a checklist [33].

The main disadvantages for the use of checklists are a "lack of acceptance", "lack of role models" and "low commitment". Amalberti et al. found that historical and cultural precedents and beliefs that are linked to autonomy and performance pose the greatest threat to improved safety [20]. Surgeons and anaesthetists are accustomed to professional independence and confronted with high time pressure [35]. Although checklists only denote tasks, that have to be performed anyway, healthcare personnel are prone to refuse them, because they fear a loss of autonomy and expect an increased workload [33].

Participants of general surgery indicated significantly more disadvantages, particularly problems related to "acceptance" – mainly for the specialised disciplines. Like participants of high-volume clinics, they mentioned significantly more often a problem of a "nationwide introduction" and "realisation", among others owing to the fear that checklist were "not adapted to the specific organisation and the size of the hospital". Vats et al. found that consultant surgeons adopted checklists only after engaging local surgical experts to expound the benefits [36]. To achieve a maximum acceptance of checklists, it is important to adapt the checklist on specific needs of a clinic or a hospital. The success of a surgical checklist relies inevitably on the health care providers as end users and their motivation of using it [33]. They, thus, need to be involved in the development and introduction process using an inter-professional and cross-hierarchical approach [33, 37].

Participants of university hospitals and of high-volume clinics indicated significantly more often than did others the "repeated control" of interventions and a "lack of commitment" as main disadvantages of checklists. However, they indicated significantly less frequently additional paperwork as a disadvantage. It is evident that a long checklist has a negative effect on the task performance and that, on the other hand, if it is too short it may have no effect at all [33]. By creating redundancy in the process, safety is known to be enhanced if only a few items are concerned and the performance is not impaired [38].

The main strength of this study relies on the fact that it was conducted in all language regions of Switzerland, covering all hospital categories and specialties of the Swiss College of Surgeons (fmCh). It is the first qualitative study in Switzerland that evaluated potential reasons for the persistence of adverse events despite the efforts to improve patient safety. A limitation of this study is the methodological setting as a survey based on subjective information. Another limitation is the response rate of 29.7%. However, the response rate is comparable with that of other surveys among surgeons and has to be considered in the view of the mainly qualitative character of the survey [39, 40]. Not high enough priority in the struggle of physician's daily business and workload might be the most important reason for a low response rate [41, 42]. We lack information re-

Table 4: Examples of arguments for the disadvantages of introducing and implementing surgical safety checklists and the number of respondents per category (n = 237).

Category/subcategory	Number of respondents (%)	Content	Examples of arguments
Implementation difficulties – Dependence on hospital size	12 (5.1) 6 (2.5)	Implementation of checklists Adaptation of checklists to hospital size	"Nationwide introduction" "Realisation of a checklist" "Complete checklists are more important in large hospitals" "Adaptation of checklists to organisation and size of the hospital"
Application – Regularity/Consistency – Control – Responsibilities – Blind checking off/lack of following	26 (11.0) 8 (3.4) 6 (2.5) 5 (2.1) 8 (3.4)	 Regularity of application Control of interventions Unclear responsibilities Checklists limit thoughtfulness	"Checklists must be consistently implemented" "Repeated checks of the accuracy of information by different partners" "Who makes the documentation?" "Who takes the lead?" "With checklists automatisms are triggered. If situations occur which are not covered by the checklist, mistakes will occur. Blind checking might be dangerous as well."
Willingness to implement – Acceptance – Lack of role models – Commitment	34 (14.3) 24 (10.1) 3 (1.3) 10 (4.2)	 Agreement to an intervention Behaviour of role models Will and engagement for an application	"Frequent lack of acceptance by surgeons, especially of specialised disciplines" "Without pressure, many won't participate due to convenience" "Practice of role models" "General lack of will by surgeons and anesthetists" "Missing compliance of surgeons at all hierarchical levels"
Effort – Paperwork – Expenditure of time	31 (13.1) 9 (3.8) 14 (5.9)	Amount of the effort Material quantity Temporal component of the effort	"Additional expenses" "Considerable effort" "Additional expenditure of time which is not recorded" "Additional paperwork in an already large stack of forms" "Time-consuming"

garding the missing participants, and a selection bias in the subjects cannot be excluded.

In conclusion, the persistence of adverse events depends on individual factors, such as "lack of discipline", "experience", and "strain" and, mainly in high-volume clinics, on "group-related and interactional" factors. Labour conditions can be optimised to minimise interface problems in case of cross-coverings of patients, guarantee support for students, residents and interns and reduce strain. The occurrence of "information deficits" should not only be recalled regarding cross-coverings, but also with respect to the frequency of "labour turnover" and "short-term programme changes" in high-volume clinics.

Advantages of introducing and implementing surgical safety checklists outweigh disadvantages. Checklists are helpful on an "organisational level" and to clearly assign responsibilities. However, it is crucial to consider disadvantages: especially compliance (including "acceptance", "commitment") and "effort". To improve the willingness to implement checklists, an adaptation to the organisation and size of the hospital by a consensus among all members of the team is a prerequisite. Role models might be helpful, especially in general surgery and specialised disciplines.

Further research in operative medicine on a prospective basis will prove the validity of the clinic directors' arguments.

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Authors' contribution: Study conception and design: Businger, Kaderli. Acquisition of data: Kaderli, Businger. Analysis and interpretation of data: Kaderli, Seelandt, Umer, Tschan, Businger. Drafting of manuscript: Kaderli, Seelandt. Critical revision of manuscript: Kaderli, Seelandt, Umer, Tschan, Businger. Statistical analysis: Seelandt, Tschan. Authors Kaderli and Seelandt contributed equally to this work. Dr. Businger had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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3. Intraoperative behavior

The main focus of this dissertation is on surgical teams. The first part of this chapter therefore provides a general background about teamwork in healthcare and especially in surgery.

The second part of this chapter is more specific and gives a theoretical background on aspects of teamwork in surgical teams. More precisely, shared mental models, situation awareness, coordination, communication and leadership behavior are discussed with regards to surgical teams. The chapter also constitutes the theoretical background for the paper on intraoperative communication that investigates the impact of case-relevant and case-irrelevant communication within the surgical team on SSI (chapter 3.7).

3.1 Teamwork in surgical teams

A team generally consists of two or more individuals interacting in order to achieve a shared, common goal. Team members often have different roles and more or less interdependent tasks (Salas, Dickinson, Converse, & Tannenbaum, 1992).

In healthcare, teams are usually interdisciplinary and consist of highly trained professionals with different status, power, and professional background (Nemeth, 2008; Pearce, Watts, Watkin, Walshe, & Boaden, 2006). Interdisciplinary teamwork is particularly difficult, and influences processes and team functioning (Fortune, Davis, Hanson, & Phillips, 2012; Pierre et al., 2011) because each profession may have its own rules and different attitudes towards teamwork. Since healthcare has to be provided 24 hours, seven days a week, composition of healthcare teams is frequently changing. Team members may not necessarily be familiar with each other and they are seldom trained to work together. Healthcare teams deal with complex, often stressful tasks, and may have to make risky and fast decisions in an environment where even small decisions may have large effects (Fortune et al., 2012; King et al., 2008; Nemeth, 2008). Additionally, they have to adapt quickly to changing conditions and function in routine and non-routine situations.

Surgical teams, as part of healthcare teams, are also characterized as being interdisciplinary. During surgery, for instance, surgical teams composed of surgeons, anesthetists and nurses have to collaborate closely for many hours, despite different perspectives and roles (Nemeth, 2008). A surgical teams' composition can change frequently, especially in hospitals with large surgical wards and therefore many employees. Besides handling complex tasks and high workload, an additional challenge is the risk of non-routine situations occurring during surgeries.

Several studies have shown the importance of teamwork skills and teamwork behavior for surgical success and patient safety (e.g.Christian et al., 2006; Edmondson, 2003; Manser, Howard, & Gaba, 2009; Pierre et al., 2011); especially non-technical skills, such as situation awareness, communication, coordination and leadership have been found to be central for team functioning in surgical teams (e.g.Yule et al., 2009).

Therefore shared mental models, situation awareness, coordination, communication and leadership behavior are discussed in the next part of the chapter. Theoretical background and empirical findings are presented for each of these five aspects and they are discussed with regards to surgical teams. I will first describe cognitive aspects of teamwork including shared mental models and situation awareness. As a next step, I will discuss aspects of coordination and communication before considering leadership behavior during surgeries. All of these five aspects are highly linked to each other and due to their close interrelationship, the following parts of this chapter contain repetitions and several cross-references.

3.2 Shared mental model

The importance of shared mental models (SMM) for teamwork and coordination has been emphasized in numerous theoretical and empirical papers. A SMM refers to a common understanding and representation of the task and processes among team members (Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994; Salas, Sims, & Burke, 2005; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). It allows “team members to draw on their own well-structured knowledge as a basis for selecting actions that are consistent and coordinated with their teammates” (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000, p. 274). A SMM leads to common expectations of the tasks, and provides an understanding of what team members are supposed to do. Thus, a SMM enables team members to adapt their activities and strategies by predicting and anticipating needs and actions of their teammates based on a common understanding of the task (e.g.Cannon-Bowers et al., 1993; Mathieu et al., 2000; Salas, Rosen, Burke, & Goodwin, 2009). Cannon-Bowers et al. (1993) suggested that SMMs are especially important for teams in non-routine situations or when communication is difficult (e.g. due to high workload or time pressure), and teams therefore do not have time to plan their strategy. In such situations, team members have to rely on their SMMs to make accurate predictions on the task, their teammates’ behavior, and to initiate appropriate actions (Cannon-Bowers et al., 1993).

Different behaviors have been identified to promote the development and maintenance of SMMs. Examples of these behaviors include pre-briefings, planning, updates, talking to the room, talking about unexpected events, and clarifying situations of ambiguity or uncertainty (Badke-Schaub, Hofinger, & Lauche, 2012; Gurtner, Tschan, Semmer, & Nägele, 2007; Stout et al., 1999; Waller & Utitdewilligen, 2008). It has also been found that SMMs develop when teams frequently work together on similar tasks or from sharing team experience (Klimoski & Mohammed, 1994; Mathieu et al., 2000; Rentsch & Klimoski, 2001).

Research has shown that SMMs facilitate coordination and also has established a positive relationship between SMMs and performance (Marks, Sabella, Burke, & Zaccaro, 2002; Mathieu et al., 2000; Smith-Jentsch, Mathieu, & Kraiger, 2005; Waller, Gupta, & Giambatista, 2004). For instance, Stout et al. (1999) demonstrated in a helicopter simulation task that planning increased the SMMs of team members and facilitated coordination. In a similar vein, Waller and Utitdewilligen (2008) analyzed audio recordings of air traffic employees during 9/11 terror attacks, and found that talking to the room made better SMMs and thus facilitated coordination. Both studies reported that better SMMs led to better coordination and this was especially important during situations of high workload. In contrast, without a SMM, team members are not able to make predictions on the task or to anticipate their teammates' behavior, which may result in inappropriate actions and thus to grievous consequences (Salas et al., 2005).

Taken together, research suggests the development of SMMs by behaviors like planning and talking to the room which in turn facilitates coordination and thus results in better team performance.

Surgical teams have to adapt quickly to changing conditions while dealing with complex tasks, high workload and time pressure. According to Cannon-Bowers et al. (1993) description of SMMs, surgical teams have to rely on SMMs in order to meet task requirements and to carry out surgeries successfully. However, the team composition of surgical teams changes frequently, and establishing a SMM based on team experience is barely possible. Therefore surgical teams have to establish and maintain a SMM by applying behaviors like planning, talking to the room, briefings, updates, talking about unexpected or ambiguous events. Based on these considerations, we hypothesized that case-relevant communication (including talking to the room, planning next steps, loud thinking and explaining own actions) facilitates coordination within the surgical team and thus results in lower rates of SSI (see also the paper on intraoperative communication, chapter 3.7).

3.3 Situation awareness

Situation awareness (SA) is an internalized mental model and defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the future time" (Endsley, 2012, p. 554). Beside individual SA, it is also important to have situation awareness on the team-level (team SA), which is defined as "the degree to which each team member possesses the SA required for his or her responsibilities" (Endsley, 1999, p. 270).

Endsely distinguishes three levels of SA (Endsley, 1995, 1996, 2012): The first level involves the perception of crucial factors in the environment – knowing what happens and which factors are present in the current situation (e.g. a surgical team is aware of patient's vital signs during the resection of a tumor). The second level goes beyond perception and refers to the understanding of the perceived factors – attaching a meaning to the factors and understanding what they signify in relation to a goal (e.g. while surgeons are resecting a tumor on the aorta, anesthetic alarm rings indicating that patient's blood pressure decreases; surgeons have to check whether blood pressure falls because the artery has been clamped or whether other blood vessels are damaged). The third and highest level denotes the projection of the future status – imagining how the situation could evolve and what could happen in the future (e.g. blood pressure during surgery decreases because other blood vessels are damaged; surgeons have to intervene immediately to prevent patient harm).

Hence, SA includes the perception and understanding of a situation and its expected state in the future (Wright & Endsley, 2008). Therefore different information and data of the environment as well as past experience have to be brought together to obtain a complete picture of the current situation. This picture then serves as a mental model and can be used for predictions about what may occur in the future and from which actions take place (Endsley, 2012; Wright & Endsley, 2008). SA requires cognitive mechanisms and involves short-term sensory memory, attention, perception, the working memory and the long-term memory (Endsley, 1995, 2012).

SA is important in dynamic and complex situations to perform effectively, for decision-making and to recognize error-prone situations (Endsley, 1995, 1996; Salas et al., 2005). However, SA is demanding and failures in developing and maintaining SA can occur easily due to fatigue, anxiety, workload, poor communication, distractions, lack of experience and training (Badke-Schaub et al., 2012; Endsley, 2012; Fortune et al., 2012). For instance, Mishra, Catchpole, Dale, and McCulloch (2008) assessed situation awareness during laparoscopic cholecystectomy, and their results showed a strong negative correlation between situation awareness and surgical errors.

SMMs and SA are similar but distinct concepts. Both are mental models helping individuals "to describe, explain, and predict events in their environment" (Mathieu et al., 2000, p. 271), and it has been argued that a SMM is beneficial for establishing SA (Endsley, 1999). SMMs refer to common representations and knowledge of tasks and related processes across team members. These representations are rather general and more static. SA, on the other hand, includes contextual knowledge in terms of a specific task at a certain point of time and its expected state in the future. SA requires a deeper understanding of the environment, it is more dynamic and has to be updated continuously (Endsley, 1999; Uitdewilligen, Waller, & Zijlstra, 2010).

3.4 Coordination

Coordination of team activities is another important issue of teamwork and refers to "orchestrating the sequence and the timing of interdependent actions" (Marks, Mathieu, & Zaccaro, 2001, p. 363).

In the next section, two frameworks of coordination are presented. Both consider coordination as a special process and stress the distinction between planning and execution phases. These phases are described rather abstractly, and it is important to bear in mind that they are less structured in practice because other factors may also have an influence on coordination (e.g. team composition). Therefore both frameworks have to be adapted to the healthcare environment, and more precisely to coordination in surgical teams.

The first framework suggests that teams have to coordinate their behaviors and actions on different levels accompanied by different supporting mechanisms (e.g. leadership) (Fernandez, Kozlowski, Shapiro, & Salas, 2008; Marks et al., 2001; McGrath & Tschan, 2004). McGrath and Tschan (2004) distinguish three levels of coordination: a purpose level, where teams define their goal(s) and allocate their resources; a planning level, where teams elaborate their strategy and work process; and a performance level, where teams coordinate the execution of their task(s). Regarding the second framework, Marks et al. (2001) add the notion of recurrent performance episodes and differentiate in action and transition phases. Action phases refer to "periods of time when teams are engaged in acts that contribute directly to goal accomplishment (i.e., taskwork)" (p.360). Transition phases, on the other hand, refer to "periods of time when teams focus primarily on evaluation and/or planning activities to guide their accomplishment of a team goal or objective" (Marks et al., 2001, p. 360).

Engaging in actions on the planning level allows team members to establish a SMM which refers to a common understanding of the task and its related processes (e.g.Cannon-Bowers et al., 1993) (see

also chapter 3.2 on SMM). Planning activities are one example of explicit coordination, which is "the exchange of information between two or more team members through formal or informal and oral or written transactions in order to integrate their respective contributions" (Rico, Sánchez-Manzanares, Gil, & Gibson, 2008, p. 163). Explicit coordination requires the exchange of information, and communication is an important coordination mechanism. Other examples of explicit coordination include leadership, closed-loop communication, feedback, loud information sharing and talking to the room (Grote, Kolbe, Zala-Mezo, Bienefeld-Seall, & Künzle, 2010; Kolbe, Burtscher, Manser, Künzle, & Grote, 2011; Salas et al., 2005; Tschan et al., 2006; Waller & Utitdewilligen, 2008) (see also chapter 3.5 on communication).

Team coordination can also be implicit. Implicit coordination "takes place when team members anticipate the actions and needs of their colleagues and task demands and dynamically adjust their own behavior accordingly, without having to communicate directly with each other or plan the activity" (Rico et al., 2008, p. 164).[2] For effective implicit coordination, team members must have a SMM of the task and situation which enables them to anticipate actions and to adapt their behavior (e.g.Cannon-Bowers et al., 1993) (see also chapter 3.2 on SMM). Implicit coordination saves resources because less communication and time are needed, and it is most appropriate in routine situations or when teams are well trained to work together and share team experience (e.g. Rentsch & Klimoski, 2001; Smith-Jentsch et al., 2005). Unfamiliar or unexpected conditions, however, increase the demands on team members and force them to modify their behavior: Due to changing requirements, teams have to redefine the problem, plan the next steps and allocate tasks (Rico et al., 2008). If teams rely too heavily on implicit coordination during non-routine situations, mistakes and misunderstanding can occur (e.g.Grote, Zala-Mezö, & Grommes, 2004; Riethmüller, 2012). Therefore explicit coordination is more appropriate in non-routine situations (Smith-Jentsch et al., 2005). This is in line with Edmondson (2003) arguing that task changes increase the need for communication in order to coordinate actions that had previously been sufficiently known to enable effective coordination without communicating. Contrary to that, it has also been argued that explicit coordination requires too many resources (communication, time), which could be problematic especially in stressful, non-routine situations (Marques-Quinteiro, Curral, Passos, & Lewis, 2013). MacMillan, Entin, and Serfaty (2004) suggest reducing explicit coordination during non-routine situations in order to decrease workload, which in turn results in better team performance.

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2 Other researchers have slightly different definitions regarding explicit and implicit coordination (e.g.Kolbe, Künzle, Zala-Mezo, Wacker, & Grote, 2009).

Some research suggests implicit coordination during non-routine situations. This might only be recommendable for teams that share common experience as they frequently work together or in resuscitation teams using algorithms for task execution (e.g.Tschan et al., 2006). Varying team composition, however, hinders many surgical teams from gaining common team experience, which would facilitate the establishment of a SMM and thus enable implicit coordination. Additionally, surgical teams have to deal with complex tasks and unexpected events which require in-process planning (e.g. bleeding, high blood loss, widely spread tumors/metastases).

Taken all considerations together, surgical teams should use explicit coordination via communication for performing safe and successful surgery because it helps team members to update their SMMs, to plan actions and to allocate tasks. This assumption was tested in the paper on intraoperative communication using event-codes that are examples of explicit coordination with our observational system (chapter 3.7). Codes include case-relevant verbalizations which refer to talking to the room, planning, loud thinking as well as problem solving, the latter involving a concentrated discussion of a current problem (see also chapter 4.1 and the methodological paper, chapter 4.6).

3.5 Communication

Communication is important for establishing and maintaining a SMM, for team processes and coordination (see also chapter 3.2 on SMM and 3.4 on coordination).

Effective communication implies the accurate transfer and sharing of information between several team members (Fuchshuber & Greif, 2012; Schuster & Nykolyn, 2010). Knowing and understanding the current task and situation help team members to plan actions, make decisions and monitor for problems (Fletcher et al., 2004). This in turn enables the establishment of a SMM and facilitates coordination and team processes (Mathieu et al., 2000; Schuster & Nykolyn, 2010; Waller et al., 2004).

Types of effective communication include closed-loop communication and talking to the room, both also being examples of explicit coordination (see also chapter 3.4 on coordination). Closed-loop communication refers to a double checked information transfer ensuring that a message sent was received and understood as intended. It involves three steps: First, a sender initiates a message; second, the receiver confirms the reception of the message, and third, the sender ensures that the message was received and understood as intended. For example, a surgeon asks the anesthetist to administer 20mg Buscopan during surgery, “Please administer 20mg Buscopan”. Anesthetist answers “20mg Buscopan was given”, and the surgeon repeats “Ok, 20mg Buscopan was given, we can now

continue resecting”. Closed-loop communication was introduced by military crews to avoid breakdowns in communication, and it has been shown to facilitate problem-solving (Bowers, Jentsch, Salas, & Braun, 1998; Burke, Salas, Wilson-Donnelly, & Priest, 2004; Salas et al., 2005). According to Burke et al. (2004), closed-loop communication seems to be an important communication strategy in surgical teams to avoid miscommunication that may occur due to the interdisciplinary of the team (surgeons, nurses, anesthetists). Another effective communication type is talking to the room. When team members use talking to the room, they speak louder about the assessment of the situation without addressing a specific team member but the whole team. Loud information sharing increases the probability of getting the attention of all team members and invites them to participate in problem solving, which in turn increases the chance to establish a SMM or to detect misunderstandings and differences in mental models (Artman & Wærn, 1999; Tschan et al., 2009; Tschan, Semmer, Hunziker, & Marsch, 2011; Waller & Utitdewilligen, 2008). Talking to the room has been examined in emergency teams, and it has been shown to facilitate accurate diagnosis in medical emergency driven teams (Artman & Wærn, 1999; Tschan et al., 2009; Waller & Utitdewilligen, 2008).

In contrast, breakdowns in communication have repeatedly been shown to impair performance (Barrett, Gifford, Morey, Risser, & Salisbury, 2001; Pearce et al., 2006; Pierre et al., 2011; Schuster & Nykolyn, 2010; Wright & Endsley, 2008). If important information is missing, not shared or misinterpreted, teams are not able to establish a SMM, and decisions are based on incomplete data. This can in turn result in inappropriate actions and treatments and may harm patients (Pierre et al., 2011; Schuster & Nykolyn, 2010). Previous studies on communication in the OR have shown that communication fails when its purpose is unclear or inappropriate, when communication occurs at the wrong time or is directed at the wrong person, and when information is missing or inaccurate (Fuchshuber & Greif, 2012; Lingard et al., 2004). Gillespie, Chaboyer, and Fairweather (2012) also observed communication in the OR and found that about 30% of the information related to the current procedure may be lost due to communication failures.

Literature has emphasized the importance of communication in surgical teams (e.g.Leonard et al., 2004), but only a few studies have observed and examined communication during surgeries. Previous studies have primarily considered communication failures and their potential impact on performance during surgery (e.g.Christian et al., 2006; Lingard et al., 2004). None of the existing studies have distinguished between different communication behaviors and related them to patient outcomes. By differentiating between case-relevant communication (e.g. talking to the room) and case-irrelevant communication (e.g. laughter, joking) during surgeries and relating them to SSI, we could show how

important it is to have a closer look at communication and its influence on surgical and patients outcomes (paper on intraoperative communication, chapter 3.7).

3.6 Leadership

Leadership is considered as leadership behavior in situations, and especially during surgery, in this chapter. Based on Zaccaro, Rittman, and Marks (2002), I narrow leadership behavior down to structuring and coordinating team actions during surgery. From this follows that leadership in general including aspects of management (e.g.Yukl, 2002) or different leadership styles (e.g. transactional/transformational (Burns, 1978)) are not part of the chapter.

In their review, Künzle, Kolbe, and Grote (2010) mention two essential functions of effective leadership behavior in healthcare teams: First, leaders have to support their teams in completing a task. This involves defining clear goals, assigning tasks required for achieving the goals as well as decision-making and problem-solving. Moreover, leaders have to monitor task execution, coordinate and adapt processes, if necessary, and make sure that resources needed for goal attainment are available (e.g.Flin, Yule, Paterson-Brown, Rowley, & Maran, 2006; Pierre et al., 2011; Salas et al., 2005; Vincent, 2011; Zaccaro et al., 2002). Second, leaders have to maintain team functioning by establishing a positive climate (Northouse, 2012). This involves creating a psychological safe environment where team members feel safe for interpersonal risk taking and voicing their concerns without fear of consequences (Edmondson, 1999). Psychological safety allows team members to actively participate, to express themselves and to speak up when they have safety issues (Leonard et al., 2004; Pierre et al., 2011). Hierarchy in surgical teams could hinder team members from speaking up, but effective leaders flatten hierarchies and reduce power distance (Edmondson, 2003; Leonard et al., 2004; Pierre et al., 2011) by being accessible for ideas and questions (Edmondson, 2003; Vincent, 2011), inviting team members to share their opinions (Pierre et al., 2011) and by providing feedback (Zaccaro et al., 2002).

Ensuring the exchange of information, thoughts and safety concerns is important in surgical teams: It is essential for establishing and maintaining a SMM, facilitates coordination and therefore dealing with complex tasks and non-routine situations (see also chapter 3.2 on SMM and 3.4 on coordination).

3.7 Paper on intraoperative communication

This chapter contains the paper on intraoperative communication entitled „The impact of communication within surgical teams on surgical site infections" which is submitted.

DRAFT – PLEASE DO NOT CITE

Impact of communication within the surgical team on surgical site infections

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Communication and Surgical Site Infections

Abstract

Background

Surgery is a classical team effort, but the impact of case-relevant and case-irrelevant communication within surgical teams on morbidity rates remains widely unknown. This study assesses the impact of intraoperative communication and distractors on surgical site infections (SSI), one of the most frequent surgical complications.

Methods

A prospective observational study was performed in 103 patients undergoing major elective open abdominal procedures. Case-relevant and case-irrelevant communication and distractors between incision and closure were observed by trained work psychologists. Primary outcome parameter was SSI 30 days postoperative.

Results

A total of 21 (20.4%) SSI were diagnosed. During 459.4 hours of observation, 8,780 case-relevant and 2,584 case-irrelevant communications and 24,410 distractors were identified. Multinomial logistic regression analysis revealed that case-relevant communication during the entire procedure was associated with a significant reduction in organ/space SSI (relative odds 0.856, 95% confidence interval [CI] 0.741-0.988; P=0.033). Case-irrelevant communication during the closing phase (last 20 minutes) of the procedure was associated with a significant increase of incisional SSI (relative odds 1.170, 95% CI 1.039-1.1.317; P=0.009). Incidence and type of distractors had no effect on SSI.

Conclusions

This study reveals a significant association between intraoperative behavior and SSI as a clinically relevant outcome parameter. Case-relevant communication is a preventive factor to protect from organ/space SSI whereas unusually high case-irrelevant communication during the last 20 minutes of the procedure is a risk factor for incisional SSI.

Keywords:

Patient safety; communication; distractors: teamwork; human factors; surgical wound

Infection/prevention

Introduction

Surgical site infections (SSI) are the most common complications in surgery, with highest incidence rates in open abdominal procedures [1]. Known risk factors for SSI are related to patient characteristics and to the procedure [2]. Despite attempts to reduce SSI by evidence-based practices, their incidence remains high [3]. Interestingly, few studies have explored the influence of human factor aspects such as intraoperative communication and distractions on SSI [4-6]. Previous studies focussed mainly on compliance to hygiene-related protocols and antiseptic procedures [3,7], and on the introduction of checklists [8].

Aspects of teamwork and communication influence the quality of healthcare in general [9], including surgeries [5,10-16]. Prospective observational studies during routine surgeries not only found that communication failures occur in almost every procedure [10,17], but also established a link between low teamwork quality and procedural problems [14]. However, the endpoints of these studies were not clinical outcomes, but parameters of team performance that at best may be a surrogate of clinical outcomes.

In this study, case-relevant and case-irrelevant communication and the presence of distractors during the procedure were assessed as potential influences on SSI. Case-relevant communication may facilitate the development of a common understanding of the task [18] and may help the team members to coordinate their actions [12], thus fostering performance. In contrast, case-irrelevant communication may divert the attention of the surgical team from its main task [19] and thus impair performance [20]. However, the influence of case-relevant and case-irrelevant communication may be different for different phases of a surgery. Case-relevant communication is likely to be beneficial throughout the surgery; in contrast, case-irrelevant communication may be more detrimental during the last, closing phase, which contains

more routine activities. During routine activities, case-irrelevant communication is likely to increase [21], and may be particularly distracting for the surgeon.

The main goal of this prospective observational study was to test the hypothesis that aspects of communication during surgery have an impact on SSI. We tested the effect of case-relevant and case-irrelevant communication during the whole surgical procedure and of case-irrelevant communication during the closing phase (last 20 minutes) on the occurrence of SSI in major elective open abdominal surgeries.

Based on previous studies that found higher noise levels [22] or "lapses in discipline" (operationalized as traffic, noise, and visitors) [3] to be related to a higher incidence of SSI, the second goal of the study was to test the impact of distractors in the operating room [23] (operationalized as traffic, noise events and side-conversations outside the sterile surgical team) on the occurrence of SSI.

Methods

Sample

A total of 103 major elective open abdominal surgeries were observed between June 2010 and November 2011 in the Department of Visceral Surgery and Medicine, Inselspital (University Hospital Bern), Switzerland. Inclusion criteria were elective open abdominal surgery and availability of the observers. Exclusion criteria were laparascopic and emergency procedures and pre-existing SSI. The surgeries took place in one of three equally spaced and identically equipped operating rooms (OR); all of them equipped with a high-efficiency particulate air (HEPA) filtered vertical laminar air flow ventilation system. The surgical teams were composed of one senior surgeon, at least one resident and one student; one scrub nurse, one or two circulating nurses, and at least one anesthesiologist and one nurse anesthesist. The study was approved by the Internal Review Board of the Hospital.

Patient and surgery data

Demographic and clinical patient data were collected prospectively. Preoperative bowel preparation, hair clipping and skin disinfection using povidon-iodine based solution, administration of antibiotics between 60 to 30 minutes before the incision and repetition of the dosage after 6 hours of surgery, drain placements including stomach tubes, and postoperative care followed a standardized protocol.

Primary study endpoint – SSI

SSI was assessed according to the standards defined by the Center of Disease Control and Prevention [2] including a follow-up by phone calls 30 days post-surgery for all patients. If SSI was suspected, consultants or general practitioners were asked to confirm and to classify the SSI. SSI were grouped as superficial incisional, deep incisional, or organ/space SSI. In line with other authors [3,24], superficial and deep incisional SSI were combined into one category.

Behavioral observations

Behavioral observations included case-relevant and case-irrelevant communications and distractions. Each surgery was observed by trained work psychologists, using a validated event-coding observational system [25]. Observers were located in the OR, in about 1.5m distance of the surgical team, facing the main surgeon. The observation started when the patient was wheeled into the OR and ended with the last suture; data were analyzed between incision and closure.

Each exchange of communication within the sterile team (surgeons and scrub nurses) and between the sterile team and the anesthesiology was time-stamped and coded as either case-relevant or case-irrelevant. An exchange of communication was defined as one or several related sentences not interrupted by pauses.

Case-relevant communication was defined as communication about medical or procedural aspects related to the patient receiving surgery. Observational codes included (1) communication about current or future actions and explanations related to the case and the procedure (e.g. talk about the next steps of the procedure), (2) leadership statements (e.g. the surgeon demands insertion of a stomach tube), and (3) teaching related to the case. Case-relevant communication is expressed as mean per hour throughout the procedure.

Case-irrelevant communication was coded if members of the sterile team (surgeons or scrub nurses) (1) talked about other topics than the actual patient or procedure or (2) joked or laughed. Case-irrelevant communication is expressed as mean per hour throughout the procedure, and as mean per hour for the closing phase (i.e., the last 20 minutes).

Distractions were coded using an adapted version of an existing observational system [26]; it included (1) noise events (e.g. loud noises when opening packages) produced by a member of the non-sterile team, (2) traffic in the OR (operationalized by counting doors that were opened) and (3) Side-conversations (coded if non-sterile personnel in the OR (anesthesiologist, scrub nurses, technicians, visitors) engaged in conversations among each other, except if those conversations were held very quietly). Noise events, door openings, and side-conversations are expressed as mean per hour throughout the surgery.

To assess inter-observer agreement, 18 of the surgeries (17.5%) were simultaneously observed by two trained observers. Cohen's weighted kappa was assessed based on all five minute intervals of observation. All kappas were higher than .70, which is considered substantial agreement [27] .

Statistical analyses

Using the SPSS V20.0 software [28], univariate logistic regression analyses, Chi-square, or Fisher's exact tests were conducted. We used multinomial logistic regression to test models with multiple predictors. Time-effects were assessed using repeated measures analysis of variance. Weighted Kappa statistics were used to estimate inter-observer agreement. $P \leq 0.05$, two-sided, was set as significance level.

Results

Patient characteristics and operative details are given in Table 1. SSI was diagnosed in 21 (20.4%) patients; 11 (10.7%) were incisional SSI and 10 (9.7%) deep/organ space SSI. More case-relevant than case-irrelevant communication was observed (Table 2).

Univariate analyses assessing each risk factor separately for incisional or deep SSI against no SSI showed that none of the patient characteristics was significantly related to SSI in this study. Among the surgical risk factors, intestinal anastomosis was a significant univariate risk for organ/space SSI (Table 1).

Case-relevant and case-irrelevant communication and SSI

Separate univariate analyses showed that case-relevant communication was a significant preventive factor against space/organ SSI (P=0.050). Case-irrelevant communication during the closing phase was a significant risk factor for incisional SSI (P<.001), but not for organ/space SSI (Table 1, Figure 1).

Table 3 shows the results of a multinomial logistic regression analysis that includes the strongest known risk factors for SSI (BMI [> 30]; ASA class [> 2], intestinal anastomosis performed [yes/no]), and includes case-relevant and case-irrelevant communication per hour during the whole surgical procedure, as well as case-irrelevant communication during the closing phase. The likelihood ratio Chi-square indicated a significantly better fit for the model with all predictors than for the empty model without predictors (Chi^2 (DF=12) = 33.958; P<0.001). The multinomial model showed that more case-relevant communication during surgery was associated with a decreased incidence of organ/space SSI (relative odds 0.856; Confidence Interval [CI] 0.741-0.988; P=0.033) (Table 3). Case-irrelevant communication during closure was associated with a significantly increased risk of incisional SSI (relative odds 1.170; CI 1.039-1.317; P=0.009); (Table 3). A repeated measures analysis of variance

revealed that case-irrelevant communication was significantly higher during the closing phase than before (significant within-surgery time effect; $F(1)=26.569$; $P<0.001$). The increase of case-irrelevant communication during the closing phase differs between SSI categories (significant interaction effect; $F(2)=8.676$; $P<0.001$)). Post-hoc tests with Bonferroni-correction yielded a significant difference between incisional SSI and no SSI ($P<0.001$); and between incisional SSI and space/organ SSI ($P=0.001$), indicating that the increase of case-irrelevant communication in the closing phase was significantly higher for operations associated with incisional SSI (Figure 2).

Perioperative distractors and SSI

None of the observed distractors (noise events, door openings and side conversations, all per hour) was significantly related to either incisional or organ/space SSI in both univariate (Table 1) and multinomial (Table 4) logistic regression analyses.

Discussion

This study established a link between intraoperative case-relevant and case-irrelevant communication and SSI in patients undergoing major elective open abdominal surgery. Whereas more case-relevant communication throughout the surgery diminished the risk of organ/space SSI, more case-irrelevant communication during the closing phase increased the risk of incisional SSI. Distractors such as noise events, traffic in the OR, and side-conversations by non-sterile team members did not impact the incidence of SSI.

Case-relevant communication assures the exchange of information [29] and may foster the development of a shared understanding of the task within the team. Studies from medicine and other fields show that task-relevant communication helps team members to cooperate more smoothly [13,30,31]; this could be particularly important during difficult phases of the surgery. Case-relevant communication also facilitates the immediate correction of misunderstandings and errors [32]. Persistent misunderstandings and loss of information, which are the most frequently observed problems [10,33]; may be prevented by more case-relevant communication.

Things are more complex for case-irrelevant communication. Case-irrelevant communication could positively influence team climate. Relaxed communication and the use of humor are seen as an important part of team-building processes in the OR [14]. However, case-irrelevant communication is also seen as a distractor, and is expected to be associated with impaired performance [23]. Our results support the interpretation that case-irrelevant communication may be distracting, but only under specific circumstances. First, case-irrelevant communication did not influence the occurrence of organ/space SSI, but incisional SSI. Second, only case-irrelevant communication during the last 20 minutes, thus, during closing of the abdominal wall, was responsible for this effect. In the final phase

of the surgery, the most difficult part of the surgery is finished, and what is left resembles routine activities (e.g., closing the abdomen, clearing and removing equipment). People are more likely to engage in case-irrelevant talk during routine phases of surgeries [21]. Engaging in case-irrelevant communication may increase the probability of minor errors for several reasons. First, performing a manual task while engaging in an unrelated communication can be seen as multitasking, which has been shown to increase accidents in studies on driving[34]. Second, it is well established that effects of demanding tasks may manifest themselves particularly after the period of high workload is over [35]. Such effects are often tied to diminished attention after the main task, if a routine situation follows. For example, residents working long hours have an increased risk of a car accident on their way home [36]. Third, although supervised by an experienced surgeon, closing the patient's abdominal wall is often performed by a junior surgeon, for whom suturing may require high concentration. In contrast to experienced surgeons, who are able to shield themselves from distractors [37,38], junior surgeons perform worse in distracting environments [19,20,39]. Finally, fatigue may play a role, because it enhances the risk of performance impairments if distractors are present [40]. Impaired concentration may lead to micro-contaminations that are not captured by the surgical team and thus lead to a higher SSI rate.

The results of this study refine findings from an earlier study showing that reduced concentration enhances the risk of SSIs [3], as we now were able to identify the most sensitive phase (the last 20 minutes) for this effect. However, if our interpretation is correct, the question remains why only case-irrelevant communication was able to distract surgeons in the final phase but other distractors were not. We suspect that this effect is related to the fact that communication conveys meaning to a greater extent than other noises. Meaningful noise is difficult to ignore [41] and thus more likely to impair concentration.

Our results do not imply that surgical teams should abstain from all case-irrelevant communication. Case-irrelevant communication has been found to foster a positive team climate [14]. It is understandable that after a long and difficult procedure, the surgical team relaxes and releases the tension it had to maintain [21]. Prohibiting case-irrelevant communication may produce tension and frustration, which may have detrimental effects. It seems more plausible that teams should adapt their behavior to the situational requirements by allowing for a short period of tension release or a short break [42]before the closing phase, but then calling for renewed focusing on the task.

A strength of this study is the observation method used, because it allows for observing instances of case-relevant and case-irrelevant communication and of distractions simultaneously, which is an advantage over a general assessment of communication quality for the whole procedure. Most importantly, this methodology allows for assessing different phases of a surgical procedure separately. Given that long, open, abdominal surgery bears the highest risk of SSI, the focus on this type of surgery also constitutes a strength, as most observational studies investigated relatively short procedures [26]. A further strength of this study is its focus on everyday behaviors in the OR, rather than on gross communication failures [15,43]. Our findings show that general, and rather unspectacular, aspects of communication may have a measurable effect on SSI, thus supporting previous findings that intraoperative behaviors that are not dramatic yet lack optimal discipline may lead to minor contaminations that often go unnoticed [3].

This study has limitations. First, a random controlled design was not possible; rather we observed naturally occurring behavior, adopting a prospective design. However, reverse causation is not a plausible explanation, because SSI were assessed 30 days after the surgery. In the multinomial regression analysis, we controlled for the most important risk factors for SSI, and the univariate analyses did not suggest other risk factors except intestinal anastomosis being related to SSI in the

present study. However, we cannot exclude the presence of other, unmeasured variables that may have influenced the occurrence of SSI and that may be associated with communication behavior. A second limitation concerns the generalization of the results, as it is a single-site study in a teaching hospital and only elective, open, abdominal surgeries were included. Finally, sample size was limited; a power analysis showed that with an alpha error probability of 0.05, power of 0.85 could be achieved, thus allowing for the detection of medium size effects.

This study related intraoperative communication to a measurable patient outcome; specifically, to SSI as the most frequent complication in general surgery. It highlights the importance of specific types of intraoperative communication in specific phases of the procedure. Thus, although the study awaits replication, it adds a novel and important aspect to the large literature on SSI.

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Tables and Figures.

Table 1. Patient and surgery characteristics, communication and distractors. Descriptive statistics and univariate relationship to incisional or organ/space SSI

	no./ total no.	Mean(SD) or %	No SSI	Incisional SSI	Organ/space SSI	P-value incis. SSI [a]	P-value org/sp. SSI [b]
Patient characteristics							
Age (years)		60.8(14.54)	60.35(14.65)	65.45(13.8)	59.20(14.8)	0.274	0.813
Male gender	55/103	53.4%	44/82	6/11	5/10	0.956	0.827
Smoking last 30 days	24/103	23.3%	22/82	2/11	1/10	0.542	0.27
Excessive alcohol use	14/103	13.6%	9/82	3/11	2/10	0.145	0.414
BMI (kg/m^2)		25.9(4.86)	26.1(5.0)	24.1(4.23)	26.6(4.0)	0.179	0.799
Diabetes mellitus	16/103	15.5%	14/82	1/11	1/10	0.507	0.573
Medication: Oral steroid use	13/103	12.6%	9/82	3/11	1/10	0.145	0.925
Malignant disease	73/103	70.9%	59/82	7/11	9/10	0.570	0.246
ASA class >2	61/103	59.2%	49/80	6/11	4/10	0.671	0.208
Days prehospital stay		2.18(5.68)	2.46(6.31)	0.90(.83)	1.30(1.1)	0.451	0.588
Surgery characteristics							
Upper GI-tract	15/103	14.6%	14/82	0/11	1/10	0.152	0.684
Liver	34/103	33.0%	29/82	2/11	3/10	0.287	0.866
Pancreas	20/103	19.4%	14/82	3/11	3/10	0.463	0.354
Lower GI-tract	26/103	25.2%	19/82	5/11	2/10	0.093	0.714
Operative time (hours)		4.46 (1.83)	4.40(1.78)	4.61(2.16)	4.86(1.86)	0.727	0.451
Intestinal anastomosis	59/103	57.3%	41/82	9/11	9/10	0.064	***0.0401****
Blood loss > 500mL	59/102	57.8%	49/82	4/11	6/10	0.152	0.688
Perioperative communication							
Case-relevant communication (p.h)		18.87(7.37)	18.86(7.52)	23.41(6.32)	14.03(3.34)	0.059	***0.050****
Case-irrelevant communication during closure (p.h)		8.27(9.04)	6.951(7.163)	19.1(13.36)	7.2(10.31)	***0.001****	0.918
Distractors during procedure							
Noise events (p.h)		9.8(4.6)	10.04(4.73)	9.67(4.46)	8.33(3.5)	0.800	0.270
Traffic (door openings) (p.h)		32.9(6.0)	33.34(6.13)	30.50(6.20)	32.31(4.06)	0.143	0.602
Side conversations (p.h)		11.1(5.7)	11.19(5.91)	11.53(5.49)	9.65(3.85)	0.849	0.417

Mean and Standard Deviations are reported for continuous variables; counts and % for categorical variables

SSI: surgical site infection; BMI: Body Mass Index; ASA class: American Society of Anesthesiologist physical status classification system, GI: Gastrointestinal tract; p.h: mean per hour

[a] P-value of comparison between no SSI and incisional SSI; [b] P-value of comparison between no SSI and deep/organ SSI

Table 2. Communication and distractors observed between incision and closure for N=103 operations

Observation categories	Total events observed (N=103)	Events observed per hour (SD)	Inter-observer agreement Cohen's kappa
Case-relevant communication overall	**8,780 (100%)**	**18.9(7.4)**	**0.80**
Communication related to procedure	6,834 (77.8%)	14.5 (6.4)	0.77
Leadership	1,061(12.1%)	2.3 (1.6)	0.83
Teaching, explaining	885 (10.1%)	2.1 (2.2)	0.84
Case-irrelevant communication overall	**2,584 (100%)**	**5.9 (4.7)**	**0.82**
Not patient-relevant talk	1120 (43.3%)	2.7 (2.6)	0.82
Laughter, joking	1464 (56.7%)	3.2 (2.5)	0.79
Distractors overall	**24,410 (100%)**		
Noise events	4,310 (17.7%)	9.8 (4.6)	0.73
Door openings	15,191 (62.2%)	32.9 (6.0)	0.82
Side-conversations	4,909 (20.1%)	11.1 (5.7)	0.82

Case-relevant and case-irrelevant communication refer to communication within the sterile surgical team or between sterile surgical team and anesthesiologist

Inter-observer agreement based on 18/103 surgeries coded by two observers, SD = Standard Deviation

Table 3. Multinomial logistic regression models predicting incisional and organ/space SSI by case-relevant and case-irrelevant communication

Endpoint		B	SE	Wald	P-value	Odds ratio	Confidence Interval lower	higher
SSI incisional	Diabetes mellitus	-1.604	1.772	0.820	0.365	0.201	0.006	6.479
	BMI>30 (kg/m^2)	-0.334	1.237	0.073	0.787	0.716	0.063	8.089
	ASA >2	0.338	0.836	0.164	0.686	1.403	0.273	7.218
	Intestinal anastomosis	1.669	0.935	3.183	0.074	5.307	0.848	33.193
	Case-relevant communication (p.h)	0.098	0.061	2.599	0.107	1.103	0.979	1.243
	Case-irrelevant communication overall (p.h)	-0.114	0.116	0.974	0.324	0.892	0.711	1.119
	Case-irrelevant communication during closure (p.h)	0.157	0.060	6.727	***0.009****	1.170	1.039	1.317
SSI organ/space	Diabetes mellitus	-0.630	1.166	0.292	0.589	0.532	0.054	5.237
	BMI>30 (kg/m^2)	0.040	1.214	0.001	0.974	1.040	0.096	11.228
	ASA >2	-0.899	0.768	1.369	0.242	0.407	0.090	1.835
	Intestinal anastomosis	2.206	1.114	3.921	***0.048****	9.082	1.023	80.633
	Case-relevant communication ph	-0.156	0.073	4.526	***0.033****	0.856	0.741	0.988
	Case-irrelevant communicaition overall	0.069	0.139	0.246	0.620	1.071	0.816	1.406
	Case-irrelevant communication ph during closure	0.014	0.078	0.032	0.859	1.014	0.870	1.181

- 2 log likelihood for null model = 132.32, for model with all predictors = 98.367 chi2(12)=33.958; P(Δ)=0.001**

SSI: surgical site infection; BMI: Body Mass Index; ASA class: American Society of Anesthesiologists physical status classification system; p.h: per hour

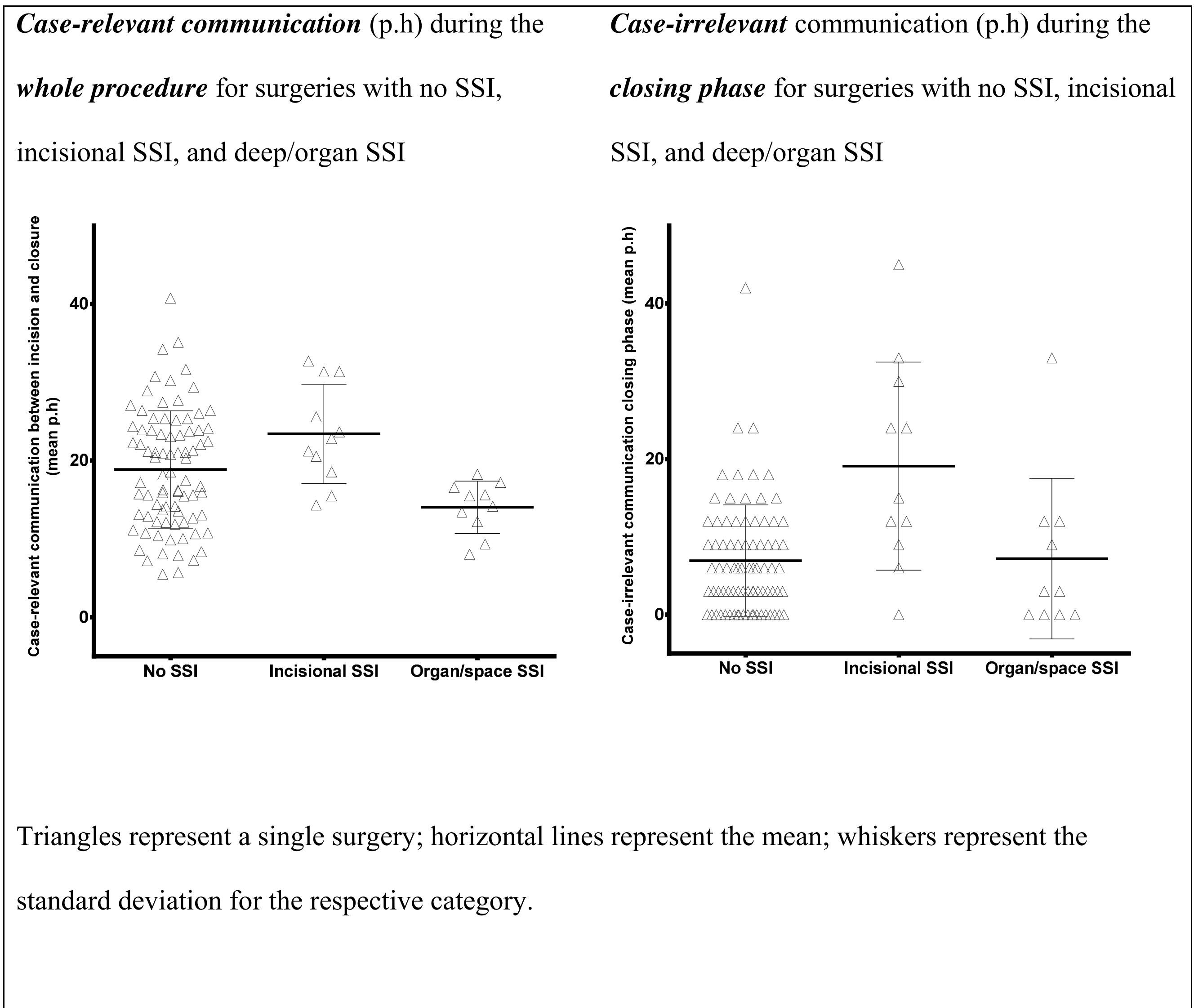
Table 4. Multinomial logistic regression models predicting incisional and organ/space SSI by noise events, door openings and side-conversations

Endpoint		B	SE	Wald	P	Relative odds	Confidence Interval lower	higher
SSI incisional	Diabetes mellitus	-0.801	1.145	0.490	0.484	0.449	0.048	4.232
	BMI>30 (kg/m^2)	-0.346	1.164	0.088	0.766	0.708	0.072	6.926
	ASA >2	0.059	0.695	0.007	0.932	1.061	0.272	4.139
	Intestinal anastomosis	1.371	0.832	2.716	0.099	3.939	0.771	20.110
	Noise events (p.h)	-0.030	0.092	0.106	0.745	0.970	0.810	1.162
	Door openings (p.h)	-0.093	0.068	1.882	0.170	0.911	0.797	1.041
	Side-conversations (p.h)	0.050	0.069	0.525	0.469	1.051	0.919	1.202
SSI organ/space	Diabetes mellitus	-0.686	1.142	0.361	0.548	0.503	0.054	4.720
	BMI>30 (kg/m^2)	-0.143	1.206	0.014	0.906	0.867	0.082	9.211
	ASA >2	-0.709	0.738	0.924	0.336	0.492	0.116	2.089
	Intestinal anastomosis	2.070	1.097	3.561	0.059	7.922	0.923	67.982
	Noise events (p.h)	-0.064	0.103	0.387	0.534	0.938	0.766	1.148
	Door openings (p.h)	0.012	0.074	0.024	0.876	1.012	0.875	1.170
	Side-conversations (p.h)	-0.012	0.087	0.018	0.892	0.988	0.834	1.172

2 log likelihood for null model = 132.325, for model with all predictors = 117.358 chi2(14)=14.967; P(Δ)=.380

SSI: surgical site infection; BMI: Body Mass Index; ASA class: American Society of Anesthesiologists physical status classification system; p.h: per hour

Figure 1 Case-relevant communication during the whole procedure (per hour) and case irrelevant communication during the closure phase (per hour) for surgeries without SSI, superficial SSI or organ/space SSI

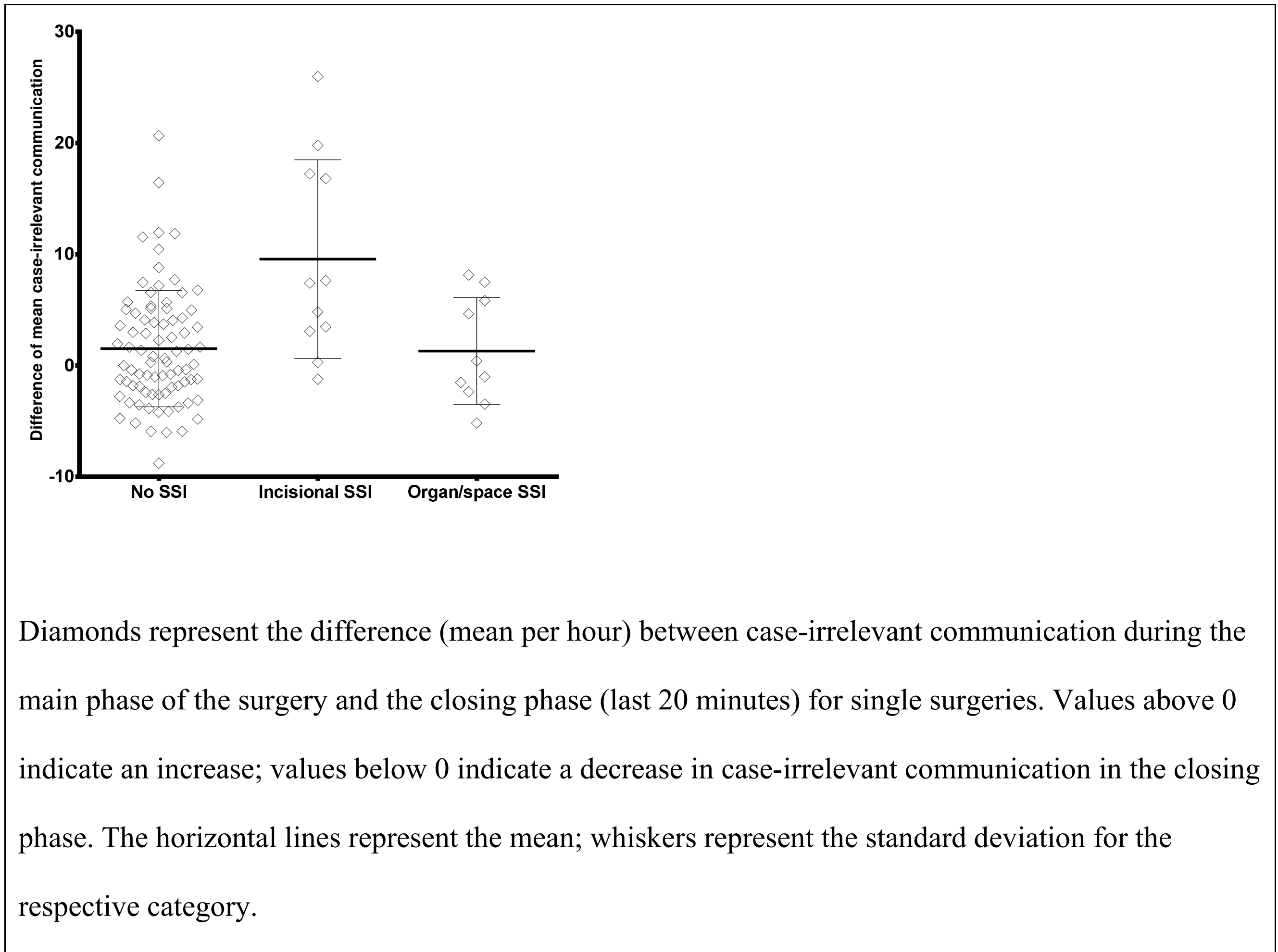


Case-relevant communication (p.h) during the ***whole procedure*** for surgeries with no SSI, incisional SSI, and deep/organ SSI

Case-irrelevant communication (p.h) during the ***closing phase*** for surgeries with no SSI, incisional SSI, and deep/organ SSI

Triangles represent a single surgery; horizontal lines represent the mean; whiskers represent the standard deviation for the respective category.

Figure 2 – Difference in case-irrelevant communication (mean per hour) between the main and the closing for surgeries with no SSI, incisional SSI, and deep/organ SSI



Diamonds represent the difference (mean per hour) between case-irrelevant communication during the main phase of the surgery and the closing phase (last 20 minutes) for single surgeries. Values above 0 indicate an increase; values below 0 indicate a decrease in case-irrelevant communication in the closing phase. The horizontal lines represent the mean; whiskers represent the standard deviation for the respective category.

4. Data collection methods

Different methods for data collection have been used in this dissertation, specifically behavioral observations (methodological paper, chapter 4.6; paper on intraoperative communication, chapter 3.7), assessment of SSI-rates according to a standard protocol (paper on intraoperative communication), information taken from patient records (paper on intraoperative communication) and surveys involving qualitative content analyses (paper on checklists, chapter 2.5; paper on career choice, chapter 5.4). Each of these methods has to meet the methodological requirements of validity (method measures what is supposed to measure) and reliability (method provides similar results under different conditions). In the following chapter, the different methods of data collection are described and methodological considerations are discussed.

Methods related to observing surgeries

4.1 Behavioral observations

Goal of the paper on intraoperative communication was to empirically establish a link between intraoperative behavior and the development of SSI. We therefore assessed intraoperative behavior by using a detailed behavioral observation system specifically developed for this purpose. The observational system is described in the methodological paper: In the first part of the paper, advantages and disadvantages of different observational methods are shortly presented. In addition, an overview of existing observational tools for the assessment of teamwork and distractors during surgeries is given. In the second part of the paper, the observational system is introduced including detailed information about the development and descriptions of the observational categories. Methodological requirements concerning reliability and validity are also discussed and data about its reliability is presented. Since the paper on the observational system is a methodological paper, discussing its aspects here would be repetitive. I therefore refer directly to that paper (chapter 4.6).

4.2 Assessment of SSI

Main dependent variable in the paper on intraoperative communication are SSI. In order to assess SSI, the standardized and validated method suggested by the SwissNoso[3] surgical site infection module was used (SwissNOSO, 2011). This method is mainly based on the recommendations of the American National Nosocomial Infections Surveillance (NNIS), and the classification of SSI is based on international criteria of the American Centers for Disease Control and Prevention (CDC). These criteria have been identified "as the best-established definition for monitoring and identifying SSI" (Henriksen et al., 2010, p. 176). Moreover, SwissNoso surgical site infection module for the assessment of SSI is considered a very reliable and valid method for measuring infections (Thomas & Petersen, 2003; Vincent & Moorthy, 2010).

A particular strength of the method are telephone interviews conducted 30 days after surgeries as suggested by Mangram et al. (1999). This is important because SSI can occur within 30 days after surgery (Horan, Gaynes, Martone, Jarvis, & Emori, 1992). As the length of hospital stays generally decrease, contacting the patient directly is necessary to have full data. For the telephone interviews, a standardized protocol with questions referring to the healing process and the condition of the wound is used. If the telephone interview provides evidence of a SSI, the physician in charge is also contacted for additional information (SwissNOSO, 2011). As it has been shown in a study of Manniën, Wille, and Snoeren (2006), assessing SSI within 30 days after patients discharge therefore helps to obtain more correct and more complete SSI-rates.

The SwissNoso surgical site infection module classifies postoperative infections as defined by CDC into superficial infections (skin and subcutaneous tissues affected), deep incisional infections (fascia and muscle are infected) and organ/space infections (organ/space that was opened or manipulated during surgery is affected) (Horan et al., 1992). For each infection, information is gathered on criteria for diagnosing SSI, type of SSI (superficial, deep, organ/space) and information on follow-up care due to SSI.

[3] SwissNoso is a group of physicians in management/executive positions working in university hospitals, in cantonal hospital societies and at the federal agency of health in Switzerland. SwissNoso monitors SSI-rates in Switzerland, publishes recommendations to reduce nosocomial infections and antibiotic resistance in healthcare, formulates guidelines and informs about current developments regarding the prevention of infections (http://www.swissnoso.ch/de/swissnoso).

Besides the occurrence and type of infection, SSI-assessments include collecting patient data like age, sex, weight, height, ASA-score, type and duration of main/secondary/tertiary surgery, wound contamination scores, etc. (complete list see table 1). These data can be used as control variables.

For our study, data on infections was collected by specifically trained study nurses. These study nurses also collect infection data within the SwissNoso surgical site infection module for the same hospital.

From the data collected within SwissNoso surgical site infection module, information on age, gender, Body-Mass-Index (BMI, calculated using information of height and weight), ASA-Score and duration of surgery were used for analyses in the paper on intraoperative communication. Type of SSI was also included but superficial and deep incisional infections were regrouped into one category.

Table 1 *Demographic and clinic data of patients collected within SwissNoso surgical site infection module*

Demographic and clinic data of patients within SwissNoso surgical site infection module	**Format of answers**
Date of birth	Day/month/year
Sex	Female/male
Height	In cm
Weight	In kg
BMI	Calculated using information of height and weight
ASA-score	Ranging from 1 to 5 depending of patients' health
Date of hospital entry	Day/month/year
Date of surgery	Day/month/year
Type of main surgery/secondary surgery/third surgery	Name of surgical procedures
Elective/emergency surgery	Elective/emergency
Duration of surgery from incision to closure	Calculated using information of incision and closure time
Endoscopy	Yes/no/started as an endoscopy
Implant (mesh)	Yes/no
Antibiotic administration	Notion of time, dose and type
Contamination degree of wound during surgery	Clean wound, clean-contaminated wound, contaminated wound, infected wound
Destination after hospital discharge	Home/other hospital/rehab hospital/exitus
Further surgery, not due to an infection	Yes/no
Date of follow-up by telephone interview	Day/month/year
Type of infection	No infection, superficial, deep incisional infection, organ/space infections
Date of diagnosis	Day/month/year
Criteria for diagnosis	Three different criteria for diagnosing each infection type and whether the infection was diagnosed by a physician
Clinical microbiology and germs	Name of identified germs
Re-admission to hospital due to an infection	Yes/no
Date of exitus	Day/month/year

4.3 Review of patient records

For the paper on intraoperative communication (chapter 3.7), demographic and clinic data of patients were supplemented with information collected from patient records. The additional information was on patient and surgery characteristics that are considered as risk factors for SSI. The choice for these risk factors was based on the list of risk factors reported by Mangram et al. (1999), and the recommendations of two senior surgeons who adapted the list to particularities of the hospital and the study population. For example, risk factors for SSI like hair clipping and the preparation of the patient using povidone-iodine, administering antibiotics, suture technique and postoperative care were not measured for each patient because they are standard protocol.

Table 2 shows the information collected from the patient records. A senior surgeon and a medical student therefore reviewed patient records (containing anesthesia protocols, surgery reports, consultations reports and discharge reports) to collect the information.

Reviews of patient records are an often used method to collect data about patients and procedures. For instance, patient records have been used in several studies to assess adverse events and to get information on their potential causes (e.g.Brennan et al., 1991; Vincent et al., 2001). In these studies, nurses screened patient records for defined criteria, and those records meeting the defined criteria were then further analyzed by physicians to decide whether an adverse event exists or not (Vincent & Moorthy, 2010). Reviewing patient records is a commonly used method that is rather inexpensive because data is readily available.

However, there might be questions about reliability and validity. A literature search revealed only few studies that assessed the validity of patient records (e.g.Hassey, Gerrett, & Wilson, 2001), and reliability was particularly examined with regard to the identification of adverse events (e.g.Zegers et al., 2009). In addition, many patient records are incomplete (Thomas & Petersen, 2003; Vincent & Moorthy, 2010), and it is unclear whether patient records contain accurate information, particularly about sensitive topics such as substance use. Patient records probably comprise several biases because they also contain information given by patients and the data appear to be more objective as they actually are. In sum, validity and reliability of patient records remain unclear but we included data from patient records in our analyses because these were the data we had access to.

For the purpose of the paper on intraoperative communication, patient records were reviewed to obtain more information on patient and surgery characteristics that are considered risk factors for SSI. Patient-related risk factors included in the analyses of that paper were nicotine/smoking during the last 30 days, excessive alcohol use, diabetes, use of steroids and malignant condition. Surgery-

related risk factors taken from records included the name of the surgical procedure, anastomosis and the amount of blood loss during surgery.

Table 2 *Patient- and surgery-related risk factors for SSI coded by a senior surgeon and a medical student based on patient records*

Patient- and surgery-related risk factors for SSI from patient records	**Format of answers**
Diabetes	Yes/no
Excessive alcohol use	Yes/no
Nicotine/smoking during last 30 days	Yes/no
Chronic kidney disease	Yes/no
Pneumopathy	Yes/no
Cardiovascular disease	Yes/no
Malignant disease overall	Yes/no
Malignant disease, reason for the surgery	Yes/no
Previous abdominal surgery	Yes/no
Use of immunosuppression/steroids	Yes/no
History of chemotherapy/radiation	Yes/no
History of anticoagulation use	Yes/no
Diagnosis	Name of specific diagnosis
Type of surgery	Name of surgical procedure
Experience of consultant surgeon	Chief surgeon; consultant surgeon; resident
Bowel preparation	Yes/no
Anastomosis	Yes/no
Blood loss	In milliliter
Blood transfusion during surgery (erythrocytes, fresh frozen plasma)	Number of blood transfusion
Use of drainage	Yes/no
Further surgery required during hospitalization	Yes/no
Reason for further surgery	Name of specific reason
Length of hospital stay	In days

4.4 Coding of surgery type

In addition, two senior surgeons coded each surgery into the categories a) upper gastrointestinal tract, b) liver, c) pancreas, d) lower gastrointestinal tract and e) hernia. Another categorization regrouped liver and pancreas into one category called hepatobiliary. Surgeries that did not fit in those categories were coded as “other”.

Methods related to survey analysis

Two papers of this dissertation contain qualitative data (paper on checklists, chapter 2.5; paper on career choice, chapter 5.4) deriving from open questions. These open questions, in turn, were part of two different surveys conceptualized by consultant surgeons working in Swiss hospitals.

The next section therefore contains a short introduction to survey methodology, its advantages and disadvantages as well as considerations on open and closed questions.

Regarding advantages, surveys can be distributed per mail to numerous potential participants and thus allow to obtain large sample sizes. As compared to interviews, surveys put less pressure on the participants because they do not require an immediate answer (Judd, Smith, & Kidder, 1991). Participants can think about their responses and fill in the survey at any point of time appropriate for them. The use of surveys moreover avoids interview biases which may influence the answers of participants through the interviewers' way of asking questions or due to their presence (Judd et al., 1991). In addition, surveys convey the feeling of greater anonymity and may therefore encourage participants to answer even sensitive or delicate questions (Judd et al., 1991). On the other hand, a disadvantage related to surveys is the risk of low response rates (Judd et al., 1991). Surveys can be distributed simply by mail, but participants may not be motivated to fill in the survey especially when it consists of many questions and answering therefore takes much time. In addition, the use of surveys does not allow intervening if questions are misunderstood or misinterpreted, and participants may consequently answer incorrectly or not at all (Judd et al., 1991). Another disadvantage refers to the context of answering the survey which is not controllable. Other people could be presented when answering the survey and cause biases by commenting on answers (Judd et al., 1991).

A survey can contain open or closed questions. Closed questions are very specific and respondents have to select from answers provided by the researchers who developed the survey. But the choice of provided answers could be incomplete, and important information of the participants may be lost (Reis & Judd, 2000). In addition, provided answers have to be comprehensive, which requires pretesting the questions in an open formulation (Reis & Judd, 2000). Open questions, on the other hand, allow participants to answer in their own words, and they provide higher reliabilities and validities compared to closed questions (Reis & Judd, 2000). However, answers to open questions have to be coded and grouped into categories. This is costly and time-consuming because it involves the transcription of answers, development of coding-schemes for each question and calculating inter-rater reliabilities (Reis & Judd, 2000).

4.5 Qualitative content analysis of open survey questions

Analysis of open survey questions can be done using qualitative data analyses methods, specifically content analysis that is intended for systematic textual or documentary analysis (e.g.Hsieh & Shannon, 2005; Mayring, 2002). The aim of content analyses is to reduce the unstructured material while preserving the essential and crucial contents of the basic material. Therefore, the material is analyzed in several steps using a theory-driven coding scheme based on the research question and the material at hand (Mayring, 2002).

Data from the first survey referred to the use of surgical safety checklists (paper on checklists, chapter 2.5). Clinic directors in operative medicine in Switzerland were asked to answer two open questions about reasons for the persistence of adverse events despite the use of surgical safety checklists and about potential advantages and disadvantages of the introduction and implementation of surgical safety checklists. The questions read as follows: 1. "Where do you see potential reasons for the persistence of adverse events in operative medicine in Switzerland? Please mention three arguments for each of the subsequent levels: the level of implementation (at the patient's bedside), the superordinate level (politics, authorities, administration) and on other levels." 2. "Where do you personally see disadvantages or advantages of introducing and implementing surgical safety checklists in a clinic in operative medicine?"

The second survey topic was the attractiveness of choosing surgery as a career (paper on career choice, chapter 5.4). Board-certified surgeons and general surgery residents were asked to provide reasons that influence to choose a career in surgery: 1. "In your opinion, which factors make surgery attractive for today's graduates?" 2. "In your opinion, which factors could discourage todays' graduates to choose surgery as a career option?"

Answers to the open questions of both surveys were in note forms and stored separately in two different Excel files. The Excel files were converted into rich text format documents and entered into a software program for qualitative data analysis (MAXQDA, 2010). This program was then used to organize and categorize the open answers.

Formation of categories was done using an inductive approach (Mayring, 2002). The selection criterion and level of abstraction for category formation had to be determined as a first step. Regarding the selection criterion, we decided to use all answers given to open questions. Categories were formed gradually out of the data with regard to the research questions of the surveys and the previously determined levels of abstraction. Answers were sorted step by step into the categories, and if they did not fit into existing categories, new categories were developed inductively. After

having processed a portion of the data, the chosen categories were reviewed. It was examined whether redundant or overlapping categories exist, and whether the levels of abstraction fit the research questions. After reviewing the coding schemes, final versions were established and coding manuals were written before all answers were sorted into the final categories.

Regarding the methodological requirements, validity results in part from the questions of the survey (e.g. survey on use of surgical safety checklists inviting participants to give answers for different levels). Validity of the choice of categories was assured in that the coding schemes and the coding manuals were discussed with two subject matter experts: Two consultant surgeons commented on the chosen categories. Based on this discussion, small changes in the coding schemes and coding manuals were made. Inter-rater reliability for the surgical safety checklist data was assessed between two coders that independently coded 27% of the material. Cohen's Kappa was .79 indicating good inter-rater reliability (Landis & Koch, 1977). Concerning the attractiveness of choosing surgery as a career, Cohen's Kappa was calculated on 12.8% of the answers assessed between two independent coders and showed high inter-rater reliability (.88) (Landis & Koch, 1977).

4.6 Methodological paper

This chapter contains the methodological paper entitled "Assessing distractors and teamwork during surgery: Development of an event-based method for direct observation" which is submitted.

TITLE PAGE

Assessing distractors and teamwork during surgery: Development of an event-based method for direct observation

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ABSTRACT

Objective

Aim was to develop a behavioral observation method to simultaneously assess distractors and communication/teamwork during surgical procedures in direct, on-site observations and to establish its reliability even for long (> 3h) procedures.

Methods

Observational categories for an event-based coding system were developed based on expert interviews, observations and a literature review. Inter-observer agreement based on 29 procedures was established for the entire surgery, the first hour, after three hours of surgery between two tired observers and after three hours of surgery between a tired and a non-tired observer using Cohen's kappa and Intraclass Correlation Coefficient (ICC).

Results

The observational system contains five codes for distractors (door openings, noise distractors, technical distractors, side conversations and interruptions), eight codes for communication/teamwork (case-relevant communication, teaching, leadership, problem solving, case-irrelevant communication, laughter, tension, and communication with external visitors) as well as five contextual codes (incision, last stich, personnel changes in the sterile team, location changes around the table and incidents). Cohen's kappa based on five minute intervals were good to excellent for distractors (.74 to .98) and for communication/teamwork (.70 to 1). ICC based on frequency counts was excellent for distractors (.86 to .99) and good to excellent for communication/teamwork (.45 to .99).

Discussion

The observational method presented allows to assess distractors and communication/teamwork simultaneously by a single observer. High inter-observer agreement for even long procedures can be achieved.

INTRODUCTION

It is increasingly accepted that human factors play an important role for surgical performance[1-4]; distractions during surgical procedures as well as intra-surgical teamwork are among the aspects most frequently discussed[5-9]. Although distractions and teamwork are both important during surgeries, previous research has rarely assessed them simultaneously. To our knowledge, currently no method exists that allows observing distractors and teamwork in surgeries at the same time. Most of the existing observational systems have been used to assess rather short surgeries. As long surgeries bear a particular risk for patients, it is important to include long procedures in human factor research. To fill these gaps, we developed SO-DIC-OR (Simultaneous Observation of DIstractions and Communication in the OR), a behavioral observation method to be used directly in the operating room (OR), that simultaneously captures distractors and teamwork, and that can be also used for the observation of long procedures. We first provide a short introduction into advantages and disadvantages of different observational methodologies, followed by an overview of existing methods for assessing distractors or teamwork in surgeries. We present the development of our observational system and provide information about its reliability.

Distractors and teamwork in the OR.

Surgical procedures take place in an environment with frequent distractors, such as noise from machines and manipulations; traffic in the OR; incoming phone calls; conversations outside the sterile team, etc. Previous research has shown high densities of distractors (every 1 to 3 minutes), even for short procedures[10-13]. Distractions have been found to negatively influence surgical performance[14-16], albeit not under

all circumstances, with surgeon experience emerging as an especially important factor [16-18].

Furthermore, teamwork and communication in the OR influence surgical quality[19-23]. Surgeons, nurses, and anesthetists have to collaborate closely and effectively, which requires complex teamwork[24]. Adapted teamwork and communication in the OR increase surgical quality, whereas poor or ineffective communication in the OR can jeopardize patient outcomes[24-27].

From a research point of view, the gold standard for investigating the relationship between distractions, teamwork, and surgical outcomes is behavioral observation, because it assesses behaviors as they occur. Behavior observation is particularly useful for prospective studies, because it does not rely on retrospective assessments based on memory processes that may be biased[1]. Although behavioral observation methods have been developed to assess both teamwork and distractors in the OR[5, 6, 25, 28-30], none of the existing methods combines both aspects, and none has been tested in very long (< 3h) procedures.

Methods for observing behavior in the OR

Behavior during surgical procedures can be observed directly in the OR or by using filmed material. Video-taping has advantages, most importantly the possibility to rewind, which allows coding many different behaviors, even if they occur simultaneously. In addition, videos allow going back to the material, if post-hoc questions arise[31-33]. However, legal and ethical issues and technological constraints make video-based observations in the OR often not suitable. Thus, much research in this field involves direct observation. Direct observation requires that behavior is observed when it occurs[31], and its most important constraint is that only

a limited number of behaviors can be assessed by an observer. In addition, observers have to take fast and immutable decisions during an ongoing process, which makes it especially challenging to achieve high inter-observer agreement.

The most often used methodologies for direct observations in the OR are field notes, behavioral marker systems and event coding systems, their advantages and limitations are discussed below (see Table 1).

Field notes are common in ethnographic research[34]. Observers take extensive notes as free text[35-37]. An advantage of field notes is that they can be used in most every situation and are very flexible, because there are few restrictions on what should be observed. Field notes allow a wide angle on a situation; they are also adapted for non-routine situations. However, field notes require the note-taker to be familiar with the situation in order to avoid the risk of overlooking potentially important events. A good understanding of the situation is particularly important if high specialized groups are observed. Although field notes are often used for qualitative research or case studies. it is possible to code and categorize field note contents, which allows obtain quantitative data[25], although to a limited degree.

When using a *behavioral marker system* methodology, observers assess behavior classes: Their definition is clear and they are coded based on examples and descriptions of the class as well as on anchor examples of qualitative aspects of behaviors within a class[7, 38]. An example is the behavior class “exchanging information”, of the observational system NOTSS (Non-Technical Skills for Surgeons)[30]. Optimal information exchange is described as “talks about the

progress of the operation" whereas "fails to communicate concerns with others" illustrates poor behavior[39, p.17]. Behavior classes defined in behavioral marker systems are context-specific; they are based on analyses of nontechnical skills relevant for good performance.

Behavior marker based observational systems exist for assessing behavior of surgeons [30], anesthetists[40], scrub nurses[41] and whole teams[42]. The advantage of behavioral marker systems is that they directly focus on desired and undesired behavior in a specific situation, and thus allow for an immediate assessment of the quality of the process. Nevertheless, they are standardized enough to be used for research. Behavioral marker based observations are assessed once for a predefined time period (often for the whole procedure); they do not capture individual events but provide an overall assessment. Thus, observers are required to (a) continuously assess the quality of behaviors, (b) relate these behaviors to the predefined classes, and (c) mentally integrate their observations into an overall qualitative judgment for each class over time. These processes are complex and cognitively demanding, which limits the number of different behaviors that can be observed and renders it challenging to achieve high inter-observer agreement[29, 42]. Furthermore, retrospective analyses of incidents showed that often, a single communication failure contributes to adverse events[1]; such significant single behaviors may not be well captured by behavioral marker systems; conversely, single events may well bias the judgment of observers and thus be given too much weight.

Event coding is the continuous real-time coding of one or more specific, well predefined events or behaviors. Examples of events are "communicates about the patient" or "door opens". For an event-coding system, researchers define the

behaviors to be observed based on theoretical considerations. A coding manual contains specific and unambiguous descriptions of the events to be observed[43]; these predefined behaviors are then coded each time they occur. For example, Healey and colleagues[10] coded “case irrelevant communication” each time the team engaged in communication not related to the patient or the procedure.

Event coding requires extensive observer training[43, 44]. Compared to behavioral marker systems, the advantage of event-coding systems is that they rely on well-defined observational categories that require less integrative judgment. Event coding allows to assess frequency, timing, and sequences of behaviors; it is thus well suited to detect behavioral patterns, and it also allows to analyze and compare different phases of a surgery[45]. The disadvantage of event coding systems is that they only assess predefined behaviors, and they are of limited use for immediate feedback to the team. Table 1 compares the three methods.

Table 1: Comparison of field notes, behavioral markers and event-based observations

	Field notes	Behavioral markers	Event-based observations
Suited for direct observations	Yes	Yes	Yes
Theoretical bases needed of observational system	Not necessary, but may be useful	Necessary	Necessary
Subject matter experts needed	Partially	Yes, to a high degree	Yes, but to a limited degree
Capture unusual events	Yes	Possible	Possible
Quality of behavior assessed	Possible	Yes	Possible
Immediate assessment of process possible (e.g. for feedback)	Partially	Yes	To a limited degree
Timing of events possible	Limited	Partially	Yes
Observer training needed?	Yes	Yes, extensive	Yes, extensive

There is no a priori advantage for a specific observation method; such a choice has to be made in accordance with the specific research question. Interestingly however,

research groups observing communication in ORs have most often used field notes [25, 32, 46, 47]; research groups assessing the quality of teamwork and non-technical skills have often relied on behavioral markers[7, 9, 41, 48, 49]; and research on distractions in the OR has most often used event-coding[10, 11]. These methodological traditions may also explain why teamwork and distractions have not yet been observed simultaneously.

Existing observational systems for assessing distractors or teamwork

We provide an overview of existing observational systems that assess distractors (Table 2) or teamwork and communication (Table 3). We included papers focusing on the description of an observational method as well as papers focusing on specific results but providing information about the observational system in the method section. We excluded methods focusing solely on adverse events (e.g.[50]), and papers based on subsamples of earlier published research. The tables contain information on what was observed, how it was observed, who observed (i.e. medical professionals, psychologists); the number, type, and duration of the procedures, the observational method, and information about inter-observer reliability, if provided. Our main interest is on the intraoperative phase; therefore, observational systems focusing on anaesthesia (i.e. ANTS [40]), or on handovers from the OR to postoperative care (i.e. [51]) are not included.

Table 2. Overview on existing methods to observe distractors during surgeries.

Authors	Observers	Number and type of procedures; duration (minutes)	Roles observed	Observational method	Behaviors observed	Inter-observer reliability
Gillespie et al. 2012 [52]	Registered nurses	160 mixed surgical procedures, 10 specialties, elective and emergencies *Duration:* M=85.1, SE=111.8; Range 15-990	Surgeons Anesthetists Nurses	Direct observation Combined field notes with event-coding	• Procedural interruptions • Conversational interruptions	None reported
Healey et al. 2007 [11]	Medical student	30 Urology day-case procedures *Duration:* M=52.35, SE=10.70; Range 7.4-312.7	Surgeons Anesthetists Nurses	Direct observation Event-coding Intensity rating	Same categories as Healey et al. (2006); not observed categories: radio, external staff, communication difficulties	None reported
Healey et al. 2008 [12]	Not specified	22 Laparoscopic cholecystectomies *Duration:* M=31.37, SE = 3.05; Range 10-65	Surgeons Anesthetists Nurses	Direct observation Event-coding Intensity rating	Same categories as Healey et al. (2006)	None reported
Healey et al., 2006 [10]	Psychologists	50 mixed general surgical procedures from anterior resection to cholecystectomy, open and laparoscopic *Duration:* M=55.62, SE=5.44 ; Range 13-217	Surgeons Anesthetists Nurses	Direct observation Event-coding Intensity rating	• Telephone calls • Bleeper • Radio • External staff • Equipment • Work environment • Procedural • Movement in front/ behind monitors • Case irrelevant communication • Communication difficulties	ICC: 0.85; 0.65 for specific events
Parikh et al. 2010 [53]	Medical Student	26 Pediatric orthopedic surgical procedures *Duration:* Not reported	Surgeons Anesthetists Nurses	Direct observation Event-coding	• Number of door swings • Changes of OR personnel during procedure	None reported
Persoon et al. 2011 [13]	Intern; researcher (not specified)	78 Endourological procedures, not conventional or laparoscopic *Duration:* M=35, SE not reported; Range 8-107	Surgeons	Direct observation Event-coding Intensity rating	• Telephone calls • Bleeper • Radio • Patient-irrelevant communication • Medically irrelevant communication • Procedure • Equipment • Door movement	Percentage of agreement [a] 80% for first 17 procedures

NOTE: ICC= Intraclass Correlation Coefficient; [a]Number of agreements divided by the sum of agreements and disagreements multiplied by 100%.

Table 3. Overview on existing methods to observe teamwork/communication during surgical procedures.

Authors	Observers	Sample: number, type of surgeries observed; duration in minutes	Roles observed	Observational method	Behaviors observed	Inter-observer reliability
Parker et al. 2012 [54]	Psychologists	29 general, orthopedic and vascular surgical procedures *Duration:* M=136, SE=92; Range 20-305	Surgeons Anesthetists Nurses	Direct observation Field notes Field note coding	Leadership • Guiding and supporting • Communicating and coordinating • Managing tasks • Directing and enabling • Maintaining standards • Making decisions • Managing resources	Kappa .61, not further specified
Frankel et al. 2007 [55]	Not specified	17 mixed surgical procedures (gastric bypass, interdisciplinary surgeries, cesarean Sections) and 6 videotaped simulations (emergency cesarean section) *Duration:* Not reported	Not specified	Direct observation/ Based on videos[b] Behavioral markers	• Communication • Cooperation • Coordination • Situational awareness	None reported
Gillespie et al. 2012 [52]	Registered Nurses	160 mixed surgical procedures, 10 Specialties, elective and emergencies *Duration:* M=85.1, SE=111.8; Range 15-990	Surgeons Anesthetists Nurses	Direct observation Combined event-coding/field notes	Miscommunication categories: • Audience (recipients absent) • Purpose (goals of exchange not met) • Occasion (inappropriate timing) • Content (incomplete, inaccurate) • Experience (comprehension)	None reported
Guerlain et al. 2005, 2009 [33, 56],	Not specified	10 laparoscopic cholecystectomies *Duration:* Not reported	Surgeons Anesthetists Nurses	Based on videos Event-coding	Communication, (no categories reported)	None reported
Healey et al. 2008 [12]	Not specified	22 laparoscopic cholecystectomies *Duration:* M=31.37, SE=3.05 ; Range 10-65	Surgeons Anesthetists Nurses	Direct observation Behavioral markers Quality assessment	OTAS Same categories as Undre et al. (2006)	None reported
Lingard et al. 2002 [47]	Researcher (not specified)	35 mixed surgical procedures (general, urology, otolaryngology, cardiac surgery) *Duration:* M=219.42; SE, Range not reported	Surgeons Anesthetists Nurses	Direct observation Field notes Field note coding Intensity rating (level of tension)	• Time • Safety and sterility • Resources • Roles • Situation control	Consensus through discussion
Lingard et al. 2004 [57]	Field Researcher (Not specified)	32 General surgical procedures (not Specified) *Duration:* Not reported	Surgeons Anesthetists Nurses	Direct observation Field notes Field note coding Intensity rating	• Content • Non-verbal cues • Tone of voice • Use of repetition and emphasis	Consensus through discussion

				(level of tension)	• Outcome of exchange	
Mazocco et al. 2009 [58] Thomas et al. 2009 [59]	Registered nurses	300 mixed general surgical procedures; from biopsy to aortic aneurysm repair, open/ laparoscopic *Duration:* Not reported	Surgeons Anesthetists Nurses Others	Direct observation Behavioral markers Quality assessment	• Briefing • Information sharing • Inquiry • Assertion • Vigilance and awareness • Contingency management	RWG for observer calibration between .85 and .90
Mishra et al. 2009 [60]	Surgeons Human factor experts	36 laparoscopic cholecystectomies and carotid endarterectomies *Duration:* Not reported	Surgeons Anesthetists Nurses	Direct observation Behavioral markers Quality assessment	NOTECHS • Teamwork and cooperation • Leadership and management • Situation awareness • Problem-solving; decision-making	RWG between .68 and .98
Russ et al. 2012 [61]	Surgeons Psychologists	14 general surgical procedures from hernia repairs to cholecystectomies, open/laparoscopic *Duration:* M=94, SE=36; Range 30-150	Surgeons Anesthetists Nurses	Direct observation Behavioral markers Quality assessment	OTAS Same categories as Undre et al. (2006)	ICC: .68 and >.70
Santos et al. 2012 [62]	Human factor expert	10 pediatric cardiac surgeries *Duration:* M=136.15, SE=19.52; Range not reported	Surgeons Anesthetists Nurses Perfusionists	Based on videos Combined event-coding / field notes	Case-relevant communication • Requests • Questions • Answers • Statements • Informations • Explanations	None reported
Schraagen et al. 2010 [63]	Human factor experts	19 pediatric cardiac surgeries *Duration:* Not reported	Surgeons Anesthetists Nurses Perfusionists	Direct observation Behavioral markers Quality assessment	• Non-routine events • Teamwork classification • Teamwork and cooperation • Leadership • Situation awareness • Decision-making	Kappa based on 1-2 hours video excerpts: .50 - .77
Sevdalis et al. 2009 [42]	Psychologist Human factor experts	12 elective urological procedures *Duration:* Not reported	Surgeons Anesthetists Nurses	Direct observation Behavioral markers Quality assessment	OTAS Same categories as Undre et al. (2006)	Pearson r correlation coefficients between .72 and .76
Undre et al. 2006 [6]	Surgeons Psychologists	50 mixed general surgical procedures from hernia repairs to ileostomy reversals, open and laparoscopic, elective and emergency *Duration:*	Surgeons Anesthetists Nurses	Direct observation Behavioral markers Quality assessment	OTAS • Communication • Co-operation • Co-ordination	None reported

		M=136, SE=not reported; Range 61-240			• Leadership • Monitoring	
Wallin et al. 2009 [64]	Not reported	Type of surgical procedures not reported *Duration:* Not reported	Not specified	Direct observation/ Based on videos[b] Behavioral markers	• Gathers information and communication • Coordinates and executes tasks • Takes a team member role • Contributes to shared understanding • Makes collaborative decisions	None reported
Yule et al. 2008, 2009 [65] [66]	Surgeons	6 videotaped simulated scenarios (general and orthopedic surgery) *Duration:* M/SE not reported; Range 2.3-5.4	Surgeons Anesthetists Nurses	Based on videos[a] Behavioral markers Quality assessment	NOTSS • Communication and Teamwork • Leadership • Situation awareness • Decision-making	RWG between .51 and .72

NOTE: OTAS=Observational Teamwork Assessment for Surgery; NOTECHS=Non-technical skills, NOTSS=Non-Technical Skills for Surgeons; Kappa = Cohen's Kappa; ICC= Intraclass Correlation Coefficient; RWG=Within group inter-rater agreement; [a] videotaped simulated scenarios used to test reliability, tool developed for direct observations; [b] introduction of a behavior-based tool that can be used for direct observations and videotaped simulations.

As the overview shows, there are methods for observing distractors and aspects of teamwork during surgery, but no method includes both aspects. The aim of this study is to address this gap by developing and testing an observational method that combines the assessment of distractions and aspects of teamwork.

We address the following research questions:

Q1: Is it possible to reliably assess distractions as well as aspects of teamwork simultaneously during surgery?

Q2: Is the observational method suitable for the observation of long procedures (3 hours or longer) as demonstrated by maintaining acceptable inter-observer reliability over time?

METHODS

Sample

The sample consisted of 29 elective open abdominal procedures related to the digestive tract, intestines, rectum, liver, pancreas and esophagus. Specifically, we observed major liver resections including extended hemihepatectomy and hemihepatectomy (left/right), minor liver resection including resection of less than three liver segments; surgeries of the duodenum/pancreas including duodenopancreatectomy and segmental duodenectomy; procedures related to the upper gastrointestinal tract including gastrectomy (total or partial), esophagectomy (incl. transhiatal) and hiatoplasty; endocrine procedures including adrenalectomy; procedures related to the lower gastrointestinal tract including hemicolectomy (right or left) and resection of enterocuteneous fistula; and spleen surgeries including splenectomy. Observations took place at a University Hospital in Western Europe

over a period of 12 months. Ten trained observers holding at least a bachelor's degree in industrial psychology participated. We observed in two identically spaced and equipped OR's. The study was approved by the local institutional review board.

Procedure

Development of the observational system

Main goal was to develop and test an observational system to assess distractors and aspects of teamwork during surgery (SO-DIC-OR; Simultaneous Observation of DIstractions and Communication in the OR). Each observational method has to satisfy the criteria of validity (the method measures what it is supposed to measure, thus, the observational categories have to be meaningful and adapted to the situation) and of reliability (the observations have to be consistent across observers and over time, thus, inter-observer agreement has to be established).

To satisfy the criterion *of validity*, we established the list of behaviors to be observed based on expert interviews, on observations of five surgical procedures, and a literature review (Figure 1). First, we performed seven in-depth expert interviews with senior and junior surgeons, anesthetists, scrub nurses, and circulating nurses about their perception of potential sources of distractions during the intraoperative phase, as well as their assessment of helpful and problematic communication and teamwork in the OR. Second, using a guided field-note method (instructing observers to concentrate on teamwork, communication, and distractors), we observed five open abdominal procedures. The field notes were reviewed in order to extract observational categories. Third, we conducted an extensive literature search on observational systems already used in the OR (see Tables 2 and 3). Unsurprisingly, the behaviors

mentioned in the expert interviews, extracted from field notes and described in the literature were largely overlapping. A first version of the observational system was tested by two observers during eight surgical procedures; they were advised to write comments for the events coded. After each surgery, the observers compared their observations event by event, and divergences were discussed. Code definitions and descriptions were revised, and the final system was developed (Table 4).

We chose *timed event-sampling* as the observational method for several reasons. First, it does not require the observers to make integrative judgments and is cognitively less demanding than using behavioral marker methodology. This in turn allows including more behavioral categories without overcharging observers. Second, distractors are often single events, which makes event-sampling particularly appropriate. Third, adding a time-stamp to each observation coded (hence the term: timed event-sampling) allows analyzing data over time and for different phases of the surgery; it is thus particularly suited for the observation of long procedures.

The observational system contains five *distraction-related event-codes*: door openings, noise distractors, technical distractors, side conversations, and interruptions; largely based on the system developed by Healey and colleagues [10]. The system contains eight *teamwork-related codes* that focus on a) communication within the sterile team, and b) between members of the sterile team and anesthetists: case relevant communication, teaching, leadership, problem solving; case irrelevant communication, laughter, and tensions; the same categories were applied for communication with external visitors, where appropriate. Note that patient-irrelevant communication within the sterile team is a teamwork code in this system, not a

distractor, as in other systems. Also note that talking among anesthetists or among circulating nurses/visitors is coded as side-conversations, which are categorized as a potential distractor for the sterile team. The observational system contains several *contextual codes*, such as time of incision, last stitch, personnel changes within the sterile team, and location changes of personnel around the operating table. Unusual incidents (e.g. an x-ray after an inconclusive sponge count) are described using an open text option, and a code "other" allows observers to insert open text describing any observation they judge important or interesting, but that is not covered by the predefined event-codes. Table 4 presents the codes and a short description of each code (A full codebook is available on request). Codes are entered into a laptop using a spreadsheet (Microsoft excel); a macro automatically time-stamps each event-code the moment it is chosen by the observer. Open text comments can be included for each code. Observations started at incision and ended with the last stich.

Observers were seated behind a small moveable tray close to the wall, about two meters away from the sterile field at the left side of the patient, thus facing the primary surgeon for most of the procedures. This position allows a good view of the room, the sterile team and the anesthetic team including the patient monitor; all doors are in sight of the observers. The observers were sufficiently close to the sterile team to overhear communication, but sufficiently far away in order not to be an obstacle for the OR personnel.

Observer training

Observers underwent a four-step training procedure with an overall duration between 25 and 35 hours. The training started with (1) an informal visit to the OR that included instruction about dress codes, hygiene procedures, and behavioral guidelines

in the OR, as well as an unstructured observation of one procedure. The second step was (2) a 4 hour off-site training session where trainees received general information about setting (including roles and functions of the OR team members, formal working procedures, and spatial arrangements in the OR), followed by a structured introduction into the observational system (explanations about each code, and short video clips as behavioral examples). Trainees were then handed an information package and asked to familiarize themselves with the coding system. (3) The third training step consisted of the observation of two procedures under direct guidance of an expert observer. (4) The trainees then observed two to four surgical procedures independently, but parallel to an expert coder. After each of the surgeries, disagreements between expert and trainee were discussed. Training was considered complete if agreement between trainees and expert coders (Cohen's kappa) was ≥.75 for all codes; this was normally the case after three or four independent observations.

Inter-observer reliability

Many studies based on observational data refer to relatively short procedures (see table 2 and 3). SO-DIC-OR was developed to allow observing long procedures with a scheduled duration of three to five hours. Long continued observation bears a high risk of potential quality loss due to observer fatigue. We therefore tested inter-observer reliability for different time periods, and we assessed fatigue effects. Reliabilities were calculated a) for the whole procedure b) for the early (first hour) and the late phase (three hours after incision until the end of the procedure). To test for fatigue effects, we assessed inter-observer reliability between an observer present from the beginning of the procedure (tired) and an observer that joined after three hours ("non-tired").

Statistical Analyses

Inter-observer reliability was assessed estimating Cohen's kappa and Intraclass Correlation Coefficients (ICC). Cohen's kappa is well suited for nominal scales and expresses the proportion of agreement in terms of a given category being coded or not, controlling for the expected proportion; it ranges from -1.00 to +1.00, with zero indicating no agreement [67]. Values between .41 and .59 are seen as fair, between .60 and .80 as substantial, and values above .81 indicate very good agreement [68]. We calculated Cohen's kappa for the occurrence versus non-occurrence of each observational code for every five-minute segment of the observational period. To assess inter-observer reliability for frequency counts, we calculated one-way random ICC for each code between two observers for the different observational periods[69, 70]. ICC ranges from 0 to 1, but can also be negative. Values higher than .75 indicate very good inter-observer reliability[71, 72].

RESULTS

Table 4 displays the results for inter-observer agreement for the different time periods. Kappa's indicate good to excellent inter-observer agreement for the whole procedure, for the first hour, and after three hours of coding, as well as for a tired and a non-tired observer that joined after three hours of the procedure (all kappa >.74). Similarly, most ICC's are above .75. Exceptions are frequency ratings of tensions in the first hour of coding (ICC = .703) as well as after three hours of coding between two "tired" observers (ICC = .667). Frequency agreement of two tired observers were also below .75 for teaching activities (ICC = .555); and for communication with external visitors (ICC = .446).

Table 4: SO-DIC-OR event codes, short descriptions, and inter-observer reliabilities

Event-code	Description (*example*)	Whole procedure		Early (first h) [a]		Late > 3h (tired-tired) [b]		Late > 3h (tired-not tired)	
Surgeries / units included		17/908		18/216		10/295		9/206	
		κ	ICC	κ	ICC	κ	ICC	κ	ICC
Distractors									
Doors	A door to the OR opens and closes	.887	.971	.926	.914	.931	.923	.839	.991
Noise distractors [28]	Events (except communication) that are loud enough to be potential distractors originated by non-sterile team members (*noise from putting away instruments; instrument falls on the floor, etc.*)	.789	.877	.740	.864	.799	.895	.853	.953
Technical distractors [28]	A technical device requires attention (*incoming phone call; beeper; alarms from technical devices*)	.892	.976	.843	.972	.827	.947	.890	.985
Side conversations	Conversations between members outside of the sterile team that can be well overheard but that do not imply a member of the sterile team. (*anesthesiologist talks with external surgeon about the next case; two circulating nurses are talking and laughing*)	.783	.983	.746	.930	.775	.979	.833	.960
Interruptions[52]	The surgery is interrupted, surgeons are not operating (*e.g visitor to the OR asks question; surgical team waits for pathology results*)	.855	.946	.965	.976	.920	.948	.878	.859
Teamwork/Communication									
Case-relevant communication	Explicit communication of/with a member of the sterile team about the patient or the procedure : planning next steps, explanations of own actions, loud thinking, talking to the room (*primary surgeon announces which part she is dissecting next*)	.863	.958	.924	.966	.797	.965	.858	.971
Teaching	A member of the sterile team engages in a teaching-conversation (explaining, asking questions) with a "learner" concerning aspects of the procedure, anatomy, disease, surgical techniques, etc.(*resident shows student how to do sutures; surgeon explains which percentage of patients has a similar anatomical structure as the current patient and what that means for the surgery*)	.885	.954	1	.989	.947	.555	1	.984
Leadership	Explicit instructions by a surgeon on what to do or not to do; except demands to hand an instrument already on the table (*surgeon asks scrub nurse to dial a phone number; orders anesthetist to insert stomach tube now*)	.916	.936	.905	.843	.912	.972	.921	.813
Problem solving	Focused discussion about a problem of the case within the sterile team or with external experts. The surgery is interrupted during the discussion (*sterile team gathers around the CT on the screen and discusses the next steps*)	1	.923	1	.832	NO	NO	NO	NO -
Case-irrelevant communication [11]	Communication not related to the actual patient or procedure within the sterile team (*Resident talks about his children*)	.847	.954	.905	.984	.828	.956	.830	.893
Laughter	Joking or laughter within the sterile team (*the surgeon makes a joke about an overweight dog)*	.834	.979	.815	.974	.843	.937	.939	.982
Tension	Open conflict or tense conversations involving a member of the sterile team (*the scrub nurse yells at the resident to not start suturing before the sponge count is completed; two surgeons angrily disagree about the next step of the procedure*)	.696	.703	.815	.830	1	.667	1	-

Communication with visitors [11]	A member of the sterile team talks with a person temporarily in the OR and not part of the surgical team (*A surgeon from another OR asks for a consult; the primary surgeon discusses scheduling problems with the anesthesiologist, who is not involved in the ongoing surgery*)	.899	.741	.964	.949	.844	.446	.925	.896
Contextual codes									
Incision	Time of incision	NA	NA	NA	NA	NA	NA	NA	NA
Personnel changes in sterile team	A member of the sterile team leaves the table, or arrives at the table (surgeons or scrub nurse)	.938	.968	.946	.979	.930	.992	1	NA
Location changes around the table	Change of positions within the sterile team around the table (*senior surgeon and resident surgeon change places*)	.904	.930	.978	.973	.890	.890	.951	.968
Last stitch	Time of last stich	NA	NA	NA	NA	NA	NA	NA	NA
Incident	A special, unforeseen incident happens (*the sponge count is inconclusive, and an x-ray is done)*	.650	.695	NO	NO	NO	NO	1	NO
Other	Any observation or thought of coders that is not captured by a code but judged to be worthwhile to note	NA	NA	NA	NA	NA	NA	NA	NA

NOTE: κ = Cohen's Kappa; reflecting whether or not coded a given category within a predefined 5-minute interval; based on the number of units included. ICC = Intraclass Correlation, reflecting agreement concerning the frequency with which a given category is coded within the interval specified in the header, based on the number of surgeries included. NO = Not observed; NA = Reliability measures do not apply [a] 16 of the 18 procedure are the also included in the estimation of inter-observer reliability for the whole procedure. [b] 16 of the 10 procedure are the also included in the estimation of inter-observer reliability for the whole procedure.

DISCUSSION

We developed and tested SO-DIC-OR, an observational systems that allows to simultaneously observing distractors and aspects of teamwork and communication in the OR. The importance of human factor aspects in surgeries is uncontested, and research on communication and teamwork as well as of distractors in the OR becomes increasingly important. Thus far, their co-occurrence and potential mutual influence have not yet been evaluated, most likely because no observational system allowed to assess distractors and communication simultaneously. SO-DIC-OR addresses this gap.

Of the 21 studies summarized in Tables 2 and 3, only nine reported results referring to observer agreement (2 of the 6 distraction studies; 7 of the 15 communication studies). Compared with the values reported there, reliability of SO-DIC-OR is similar or higher. This is a good result, given that 17 different event types have to be observed, and given that behavioral observation is a difficult task, because it requires constant attention, and often fast decision making; this over an extended period of time. Inter-observer agreement was acceptable to excellent for all time phases tested, with the exception of two ICC values (teaching and communication with visitors), between two "tired" observers after three hours of observation. Note that both events occurred with low frequency, which implies that any discrepancy has a rather strong influence on ICC. Apart from these two codes, there were no substantial signs of fatigue effects, making the system well suited for direct observation of short as well as long procedures.

The high inter-observer agreement of SO-DIC-OR may be due to different reasons. First, we chose very well defined categories and described them as unambiguously as

possible. We defined specific, rather than combined categories, because they are easier to code. For example, we distinguished between teaching and case-relevant communication, although both are examples of a broader category “patient-relevant communication”. More specific categories require less cognitive effort from the observers, because they do not have to relate different behaviors to the same category. For later analyses, categories can be used separately but can also be combined into a larger category. Second, we chose event-coding, which requires coders to record behavior as it happens without having to judge the quality of the behavior observed. This reduces cognitive load and interpretational biases; we can therefore expect higher inter-observer agreement and fewer differences between novices and experts than for behavioral marker based systems[29, 42, 63]. Third, observers underwent an intense training that lasted between 25 and 35 hours and included theoretical aspects as well as the coding of at least five procedures in presence of an expert, post-observation discussions. This is a considerable investment in training, however not unusual for observing group interactions[73, 74] .

This study has limitations. First, SO-DIC-OR has only been tested in elective surgeries; emergency procedures have not yet been observed. Second, our results do not allow assessing observer-specific biases. To do this, multiple observers would have to observe the same procedure. Due to space limitations, it was not possible to install more than two observational stations in the OR. Assessment of rater-biases would thus require video-taping or working in more spacious OR’s.

CONCLUSIONS

Our study showed that it is possible to reliably observe both teamwork and distractors simultaneously in the OR, even for long procedures. Data collection is relatively straightforward, and based on an easily adaptable spreadsheet; no specialized observational software is needed. Data collected with SO-DIC-OR will allow assessing combined influences of distractors and communication on surgical performance and outcomes.

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Competing interests

None of the authors declares competing interests

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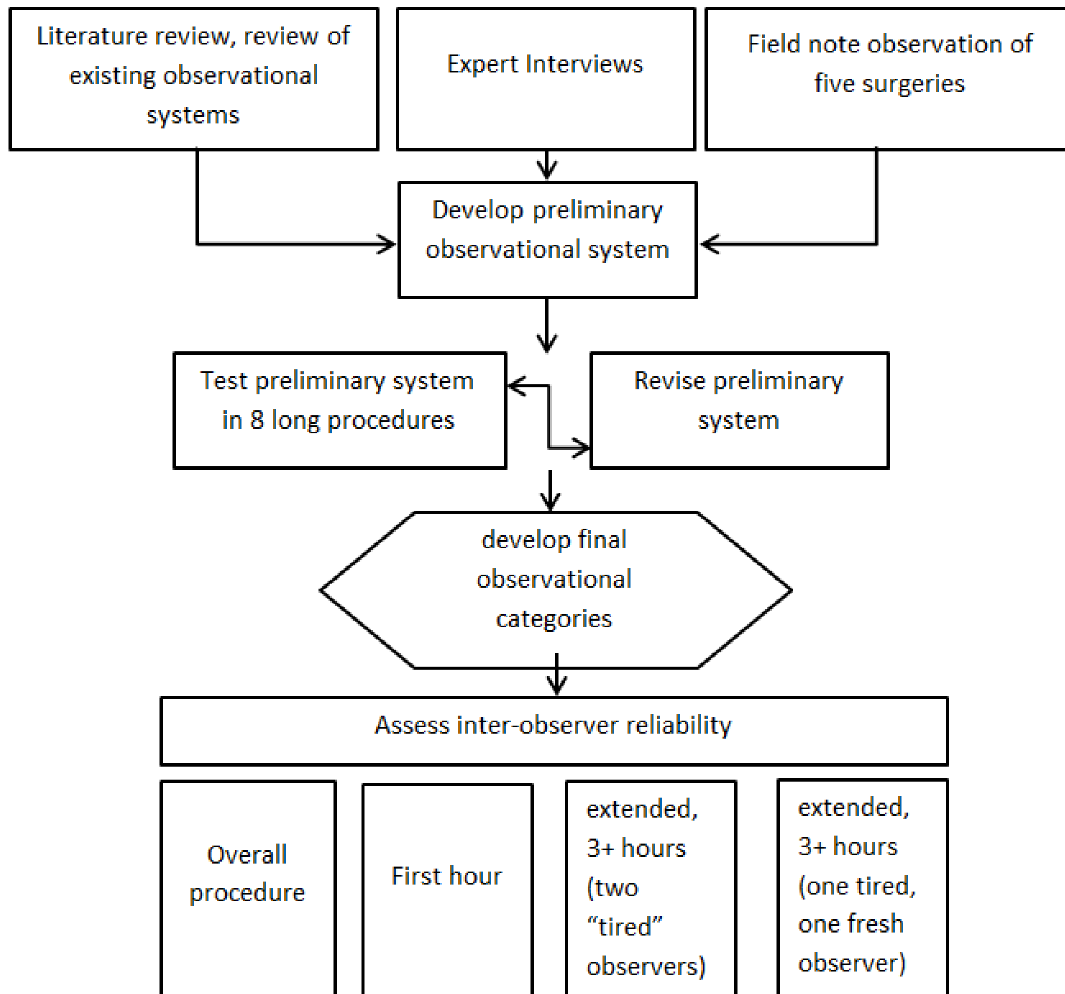
Figure 1: Development process of the observational system.



5. Work characteristics

In this chapter, factors that are perceived as important for people in their job and considered as making a job (not) attractive are discussed. More precisely, content of work, contextual work conditions and vocation to a job are described in the following section. This chapter also provides background for the study that identified factors making surgery (not) attractive as a career choice (paper on career choice, chapter 5.4).

5.1 Content-related characteristics

Hackman and Oldham proposed the job characteristics model that specifies job characteristics which influence people's motivation and satisfaction as well as performance (Hackman & Oldham, 1976). The model contains five important job characteristics: skill variety, task identity, task significance, autonomy and feedback. First, skill variety refers to the extent to which different activities and skills have to be used to perform a task. Second, task identity is the degree to which an employee can complete a whole piece of work from the beginning to the end, including a visible outcome. Third, task significance is the extent to which a job has an influence on others peoples' lives or work. Fourth, autonomy refers to the extent to which a job allows autonomy and independence in carrying out tasks and determining the procedures for carrying them out. Fifth, feedback is the degree to which tasks allow information about how well they were executed.

Although Hackman and Oldham (1976) mentioned that social factors at work are also important, their model does not consider such factors. Humphrey, Nahrgang, and Morgeson (2007) therefore extended the job characteristics model and integrated information processing (e.g. having to think and reflect on the job), problem-solving and specialization as additional work characteristics. Moreover, they emphasized social characteristics like the possibility of social interactions and interdependence, feedback from others and social support (Morgeson & Humphrey, 2006).

Hackman and Oldham (1976) and Humphrey et al. (2007) both suggest that job characteristics lead to several favorable personal and work-related outcomes. This implies that people generally react positively to favorable job characteristics, and thus contend that the model can be applied to all professions (Oldham & Hackman, 2010). Surgeons, for instance, have to deal with complex tasks requiring high technical skills and anatomical knowledge. They have to make medical indications and treatments independently and on their own responsibility. Surgery also requires teamwork and surgeons, nurses and anesthetists have to collaborate closely. Applying the job characteristics model,

surgeons should be highly motivated and satisfied with their jobs. Based on these considerations, we thus expect that surgeons report content-related job characteristics making surgery attractive as a career choice.

In contrast, in highly specialized professions – such as being a surgeon – some of the job characteristics that are generally perceived as positive may also become too demanding and may be experienced to be negative. For example, surgeons have to take very complex and sometimes risky decision, and take responsibility for patients' lives, which may result in psychological and emotional strain. In addition, surgeries can last several hours without having possibilities for breaks, which is physically demanding. We thus expect that surgeons also report content-related job characteristics which make surgery not attractive as a career choice (paper on career choice, chapter 5.4).

5.2 Context-related characteristics

There are also context-related characteristics of work which can be perceived as either positive or negative. Regarding surgery, we assume income, work-life balance and future perspectives as being typical contextual work characteristics of this discipline (Businger, Villiger, Sommer, & Furrer, 2010; Kaderli, Guller, Muff, Stefenelli, & Businger, 2010) (paper on career choice, chapter 5.4).

The first contextual work characteristic we refer to is income. The study of Cherrington, Reitz, and Scott (1971) provides evidence that rewards are linked to job satisfaction and job performance. The authors found a positive relationship between job satisfaction and job performance for participants that have been rewarded appropriately. For participants that have been rewarded inappropriately, however, this relationship was found to be negative. In addition, Oldham, Hackman, and Pearce (1976) showed that individuals react more positive to complex work conditions when they were also satisfied with contextual work factors like their income. Regarding medical careers, it has been reported that a good salary was particularly important for male medical students in terms of preferences for a specialty (van Tongeren-Alers et al., 2011). Based on these findings, we assume that rewards in terms of salary and income are also important for surgeons' job satisfaction and thus expect it as an argument for surgery as a career choice.

The second contextual work characteristic refers to work-life balance. Expectations of people regarding personal and work-related values have changed over the decades. Whereas people of former generations defined themselves by professional success and were willing to work hard to achieve this, the present generations generally emphasize the importance of work-life balance. This does not mean that people of the present generations are not willing to work hard – they are but not

at the cost of quality time with family and friends (Wey Smola & Sutton, 2002; Zemke, Raines, & Filipczak, 2000). The importance of work-life balance for people has been shown in several studies and was reported from medical students (Cochran, Melby, & Neumayer, 2005) and surgeons (Businger, Villiger, et al., 2010). We therefore assume that surgeons report arguments related to work-life balance and lifestyle.

Finally, we assume future perspectives as the third contextual work characteristic for surgery. Besides assuring the material basis for existence, being employed has several psychological and social functions. Having a job enables individuals to cooperate with other people and thus to have social contacts. Work has an influence on personality, values and attitudes and increases self-esteem. Moreover, it conveys the impression that people make a useful contribution to society and thus experience social recognition (e.g.Rosenstiel, 2001). Given the significance and importance of work, we assume that surgeons are interested in long-term employment, and therefore mention future perspectives as a contextual factor. This is in line with several studies reporting future perspectives and career opportunities as being important for a career choice in medicine and surgery (Azizzadeh et al., 2003; Erzurum et al., 2000; Glynn & Kerin, 2010).

5.3 Surgery as a vocation

Beside content- and context-related characteristics, there seems to be another aspect particularly important in medical careers, namely the vocation to a job. It refers to the passion and dedication for work and a strong identification with it (Hirschi, 2012). As it has been noted several times, working as a physician or surgeon is recognized as a calling and vocation to such jobs (Dayton, 2008; Iaria & Cardillo, 2006; Strobel, 2009). In addition, several studies have examined reasons for choosing a medical profession and results show that the vocation to the job plays a role. Hyppölä et al. (1998), for instance, asked young physicians about their reasons to enter medicine and vocation was mentioned as a factor for their career choice. In a similar vein, Andlauer et al. (2012) and Millan et al. (2005) examined reasons of medical students about their choice of the medical profession, and both studies also reported medical vocation as an important factor.
Our sample in the paper on career choice consists of surgeons working in operative medicine, and we therefore expect arguments about the vocation and calling as factors influencing a career choice in surgery. We only assume these arguments related to factors making surgery attractive as a career choice because “anti-calling” does not exist.

5.4 Paper on career choice

This chapter contains the paper on career choice entitled “The surgeons’ perspective: Promoting and discouraging factors to choose a career in surgery as perceived by surgeons” which is ready to be submitted.

The surgeons' perspective: Promoting and discouraging factors to choose a career in surgery as perceived by surgeons

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Abstract

Background

Aim of this study is to identify factors making surgery (not) attractive for today's graduates' career choice as perceived by current surgeons. In addition, it is examined if the perspective of surgeons in different professional situations converges. Content of work, contextual work conditions and vocation to this job are discussed with regard to career choice in surgery.

Methods

869 surgeons and residents were asked to answer to open questions concerning factors making surgery (not) attractive for today's graduates as a career choice. 492 surgeons participated and 1525 arguments were analyzed using Mayring's content-analyses method; Chi-square tests were used to analyze differences between hierarchical positions.

Results

Concerning promoting aspects, 40.8% of the surgeons (209/492) mentioned that surgery is a vocation, 29.1% of the surgeons (149/492) gave at least one argument related to positive task characteristics, and 12.9% of the surgeons (66/492) gave arguments related to positive contextual factors.
Concerning discouraging factors, 45.7% of the surgeons (234/492) provided at least one argument related to discouraging work characteristics, and 67.6% of the surgeons (346/492) to problematic contextual characteristics.

Conclusion

Goal of this study was to present factors given by current surgeons making surgery today (not) attractive for recent graduates and to elicit differences regarding different hierarchical positions.
The study emphasizes the importance of vocation to surgery as an important factor for career choice. However, extensive workload, training as well as a poor work family balance have been identified as discouraging factors. The identified factors could be used to attract and to maintain graduates to surgical careers in Switzerland.

Background

The general demographic development, the limited number of physicians trained in Switzerland, and changes in population characteristics of medical students raise concerns about the availability of sufficient physicians and particularly of sufficient surgeons in the near future. Several studies found a declining interest of medical students to choose surgery as a career [1-3], especially in first world countries [4, 5].

Previous studies have mainly focused on the perspectives of medical students when investigating aspects influencing the choice of surgery as a career [4-9]. However, students' decisions about their career choice are based on little information and this information may be biased because they do not really know the discipline yet [10].

One of the main influences on career choice towards surgery, and particularly in early stages of medical training, is the positive impact of role models and mentors [e.g.11, 12-15]. Surgeons therefore have to promote their discipline and it is important that they understand the concerns of potential candidates that influence career choices. It seems thus crucial to know more about the perspective of surgeons on how they perceive promoting or discouraging aspects of becoming and being a surgeon for today's graduates. Primary goal of this paper is to identify the factors rendering surgery (not) attractive for today's graduates as perceived by surgeons.

Promoting and discouraging factors in career choices

Becoming and being a physician or a surgeon is often associated with a vocation to the field and discipline [16-18]. Several studies report vocation to medicine as an important factor to choose medicine as a career [19, 20], and this particularly holds for surgery [7]. However, vocation and fascination with surgery is not the only factor influencing career choice. Work psychologist have identified general work and contextual characteristics that are related to work satisfaction, motivation and job performance across many professions and thus influence career choices [21-23]. Work characteristics such as meaningful and challenging tasks, being able to use different skills and having positive social interactions are promoting aspects; too high demands in terms of workload and a difficult, non-supportive social environment, on the other hand, are discouraging factors [24]. In

addition, contextual characteristics, and particularly threats to a satisfactory work-family balance play a major role concerning the attractiveness of a career. Many studies found that medical students, but also surgeons themselves perceive surgery as largely incompatible with a satisfactory work-family balance [5, 7, 25-28]. Indeed, extensive working hours and work-family imbalance are frequent among surgeons and are the most important contributing factor to surgeon burnout and depression [5, 7, 29, 30]; they are also the major reason for career changes among residents and attendants [31].
Depending on the surgeon's experience and the time elapsed since medical training, surgeons in different hierarchical situations may perceive different promoting and discouraging aspects for today's graduates' career choice. Secondary goal of the paper is to evaluate if the perspective of surgeons in different professional situations converges.

Method

In summer 2011, a survey was mailed to 869 board-certified surgeons and general surgery residents working in Switzerland [32]. To assess factors that could influence medical students to consider a career in surgery, two open-text questions were introduced: (1) "In your opinion, which factors make surgery attractive for today's graduates?" (2) "In your opinion, which factors could discourage todays' graduates to choose surgery as a career option?" There was no restriction regarding the length of the text entered. The survey also contained socio-demographic questions (age, gender, hierarchical position, hospital category and language region). Responses were anonymous. The data were collected, stored, analyzed, and shared in strict adherence with the ethics committee standards of our institution.

Data analysis

The 1788 written arguments provided by the participants were transcribed. 263 arguments did not fit the topic and were thus not analyzed. The remaining 1525 arguments were analyzed using a content analyses procedure [33]: first, we defined the level of abstraction for the inductive definition of categories. Second, content categories were stepwise formulated using an inductive approach; a coding manual was written. Third, each answer was sorted into a final category. Fourth, to determine whether

or not a participant had mentioned a specific category, we assigned “1” if a category was mentioned once or more, and “0” if not. We summarized subcategories into main categories in assigning “1” for the main category, if at least one, but regardless of how many of the subcategories were coded. Cohen’s kappa was used to calculate inter-rater reliability between two raters. Chi-square tests were used for analyzing differences between hierarchical positions. A *P*-value of 0.05 was considered as statistically significant, tests were 2-tailed. Codings and categorization of arguments was done using Maxqda [34]. Statistical analyses were done using SPSS V20.0 software [35].

Results

A total of 512 of the 869 surgeons returned the questionnaire (response rate 58.9%). Twenty participants did not specify their position or did not work in surgery anymore and were not included in analysis. The sample thus consisted of 492 surgeons: 22 were residents (4.5%), 109 (22.2%) attending surgeons, 94 (19.1%) consultants, 123 (25%) head of departments and 144 (29.3%) surgeons in private practice. Table 1 shows demographic data of the participants.

Table 1

Participants' demographic data (N=492)

Characteristic	Value
Hierarchical position	
Resident, No. (%)	22 (4.5)
Attending, No. (%)	109 (22.2)
Consultant, No. (%)	94 (19.1)
Head of department, No. (%)	123 (25)
Surgeons in private practice, No. (%)	144 (29.3)
Hospital category* (2 missing values)	
Type U, No. (%)	68 (13.8)
Type A, No. (%)	116 (23.6)
Type B3, No. (%)	44 (8.9)
Type B2, No. (%)	67 (13.6)
Type B1, No. (%)	41 (8.3)
Private practice, No. (%)	97 (19.7)
Others, No. (%)	57 (11.6)
Language region of workplace	
German-speaking, No. (%)	376 (76.4)
French-speaking, No. (%)	84 (17.1)
Italian-speaking, No. (%)	14 (2.8)
Romansh-speaking, No. (%)	7 (1.4)
Others, No. (%)	11 (2.2)
Women/men, No. (%)	62 (12.6)/430 (87.4)
Age (yrs: Standard deviation)	49.47 ± 9.55

* Type U: university hospitals, Type A: large referral centers, Type B3: regional or specialized hospitals, Type B2/B1: small regional surgical departments.

Coding accuracy

Inter-rater reliability of categorizing arguments was assessed between two coders that independently coded 12.8% (196/1525) of the arguments. Cohen's kappa was .88, which represents high inter-rater reliability [36].

Results of the content analyses: Promoting and discouraging surgery as a career

The content analyses resulted in three main categories for promoting and two main categories for discouraging surgery as a career. Table 2 and 3 show the descriptions of the categories, subcategories and representative examples of arguments mentioned for each subcategory.

Table 2

Promoting factors for the career choice surgery

Main category	Subcategory	Examples of arguments
Task characteristics		
	Meaningfulness & responsibility: Surgery is important, surgeons have many responsibilities	"curative" "meaningfulness of the profession" "responsibility that is very worthwhile"
	Challenge & task variety: Surgery is demanding, includes many different tasks and is highly dynamic	"challenging job" "varied" "versatile" "dynamic discipline"
	Teamwork: Surgery includes collaboration and coordination with other professionals	"teamwork" "possibility of teamwork"
Contextual factors		
	Prestige: Surgery is a profession with high prestige and is highly appreciated	"prestige" "appreciation"
	Good ***future prospects***: Surgeons have good and many different career and work opportunities	"bright future prospects " "rather good job opportunities given the anticipated lack of qualified specialists"
	Regulated working hours: Regulations limiting working hours for surgeons are in effect.	"loosen strict requirements concerning working hours"
Surgery as a vocation		
	Fascination: In general, surgery is interesting and fascinating and allows to be passionate	"passionate professional" "fascination for the subject"
	Manual skills: Surgery allows the use of manual skills	"pleasure of manual activity" "handcraft"
	Skill combination: Surgery includes a unique combination of manual, intellectual and social aspects	"handcraft and intellect and humanity" "connection hand-heart-brain
	Patient care: Surgery includes close care and contact with patients	"proximity to the patient" "contact with patients"
	Technology: Rapid technological progress allows developing new techniques and approaches	"technical progress"

Table 3

Discouraging factors for the career choice surgery

Main category	**Subcategory**	**Examples of arguments**
Work characteristics		
	Extensive workload: Surgery includes high quantitative, physical and emotional workload	"a lot of night work" "physical work load" "high stress level"
	Hierarchy: Structural aspects and interpersonal relations can be difficult	"hierarchy" "arrogance" "dealing with colleagues" "absolute dependency on mentors and University hospitals"
	Excessive responsibilities: Surgeons carry very high responsibilities	"excessively high responsibility" "high responsibility"
	High demands: Requirements for becoming and staying a surgeon are very high	"high requirements for candidates" "contractual conditions for consultants"
Contextual factors		
	Training: Lack of quality regarding training for prospective surgeons	"long training period" "Insufficiently structured apprenticeship results in inadequate operative experience" "overspecialization"
	Limited future prospects: Surgery as a career has uncertain and unclear perspectives	"uncertainty" "lack of prospects" "unclear development"
	***Poor work-life balance*: Career in surgery makes it difficult to combine family and work	"scarifying a lot of things (social, family)" "raising a family is more difficult for women" "working part time hardly possible"
	Laws and regulations: Extraneous regulations by laws and insurances can be a constraint and limit autonomy	"dependent on politics" "health policy" "health care insurer"
	Bureaucracy: Increasing administrative and bureaucratic requirements take too much time	"little surgery a lot of administration" "handcraft is substituted by administration"
	Loss of prestige: Decreasing status, appreciation and income	"decreasing income" "little reward for the effort" "less status" "it is nothing special anymore" "lack of appreciation"

Overall, surgeons wrote more arguments discouraging (945) than arguments promoting (580) surgery as a career.

With regard to promoting aspects, 40.8% of the surgeons (209/492) mentioned that surgery is a vocation; 149/492 (29.1%) gave at least one argument related to positive task characteristics, 12.9% (66/492) gave arguments related to supportive contextual factors.

Table 4

Promoting arguments, with number of participants for categories and subcategories listed by hierarchical position

Category	**Subcategory**	**Total number of participants (%)**	**Resident (N=22)**	**Attending (N=109)**	**Consultant (N=94)**	**Department Head (N=123)**	**Surgeons in private practice (N=144)**	**CHI2=(4, N=492)**	**P**
Task characteristics		149 (29.1)	6 (27.3)	37 (33.9)	30 (31.9)	39 (31.7)	33 (22.9)	4.643	0.326
	Meaningfulness & responsibility	78 (15.2)	1 (4.5)	20 (18.3)	16 (17)	18 (14.6)	22 (15.3)	2.901	0.574
	Challenge & task variety	89 (17.4)	6 (27.3)	22 (20.2)	19 (20.2)	23 (18.7)	16 (11.1)	6.678	0.154
	Teamwork	15 (2.9)	1 (4.5)	4 (3.7)	5 (5.3)	2 (1.6)	2 (1.4)	4.345	0.361
Contextual characteristics		66 (12.9)	5 (22.7)	18 (16.5)	15 (16)	11 (8.9)	16 (11.1)	5.901	0.207
	Prestige	34 (6.6)	4 (18.2)	11 (10.1)	7 (7.4)	4 (3.3)	8 (5.6)	9.072	0.059
	Future prospects	21 (4.1)	1 (4.5)	1 (0.9)	6 (6.4)	7 (5.7)	5 (3.5)	5.041	0.283
	Regulated working hours	16 (3.1)	0 (0)	7 (6.4)	3 (3.2)	3 (2.4)	3 (2.1)	5.105	0.277
Surgery as a vocation		209 (40.8)	11 (50)	48 (44)	41 (43.6)	56 (45.5)	47 (32.6)	6.695	0.159
	Fascination	82 (16)	6 (27.3)	18 (16.5)	19 (20.2)	15 (12.2)	20 (13.9)	5.174	0.270
	Manual skills	71 (13.9)	6 (27.3)	21 (19.3)	11 (11.7)	17 (13.8)	15 (10.4)	7.507	0.109
	Skill combination	44 (8.6)	2 (9.1)	5 (4.6)	11 (11.7)	16 (13)	9 (6.3)	7.323	0.120
	Patient care	22 (4.3)	0 (0)	1 (0.9)	5 (5.3)	11 (8.9)	5 (3.5)	10.505	0.033
	Technology	36 (7)	1 (4.5)	6 (5.5)	4 (4.3)	12 (9.8)	12 (8.3)	3.433	0.488

Note. Mentions in multiple subcategories were counted as one for the respective main category.

Table 4 shows which promoting factors were mentioned, separately for each hierarchical level. For all but one category, no significant differences between hierarchy levels were found. Patient care as a promoting factor was never spontaneously mentioned by residents, and only by 0.9% of attendings, whereas 8.9% of department heads mentioned it as a promoting argument (P=0.033). Furthermore, 18.2% residents mentioned "prestige" as a promoting aspect, whereas 3.3% of the department heads did (P=.059).

With regard to discouraging factors, 45.7% (234/492) of the surgeons provided at least one argument related to discouraging work characteristics, and 67.6% (346/492) to problematic contextual characteristics.

Table 5 shows which discouraging factors were mentioned, separately for each hierarchical level.

Table 5.
Discouraging arguments, with number of participants for categories and subcategories listed by hierarchical position

Category	Subcategory	Total number of participants (%)	Resident (N=22)	Attending (N=109)	Consultant (N=94)	Head of department (N=123)	Surgeons in private practice (N=144)	CHI2=(4, N=492)	p
Work characteristics		234 (45.7)	16 (72.1)	64 (58.7)	36 (38.3)	49 (39.8)	58 (40.3)	19.401	0.001
	Extensive workload	193 (37.7)	15 (68.2)	53 (48.6)	32 (34)	40 (32.5)	42 (29.2)	20.699	0.000
	Hierarchy	47 (9.2)	6 (27.3)	17 (15.6)	4 (4.3)	6 (4.9)	12 (8.3)	19.673	0.001
	Excessive responsibility	21 (4.1)	0 (0)	3 (2.8)	3 (3.2)	4 (3.3)	11 (7.6)	6.175	0.186
	High demands	12 (2.3)	1 (4.5)	2 (1.8)	1 (1.1)	2 (1.6)	4 (2.8)	1.666	0.797
Contextual characteristics		346 (67.6)	11 (50)	68 (62.4)	71 (75.5)	79 (64.2)	105 (72.9)	9.689	0.046
	Training	160 (31.3)	10 (45.5)	28 (25.7)	34 (36.2)	45 (36.6)	34 (23.6)	10.266	0.036
	Limited future prospects	72 (14.1)	1 (4.5)	19 (17.4)	16 (17)	10 (8.1)	23 (16)	7.386	0.117
	Poor work family balance	74 (14.5)	2 (9.1)	25 (22.9)	14 (14.9)	13 (10.6)	15 (10.4)	10.454	0.033
	Laws and regulations	54 (10.5)	1 (4.5)	3 (2.8)	10 (10.6)	17 (13.8)	23 (16)	13.184	0.010
	Bureaucracy	59 (11.5)	2 (9.1)	11 (10.1)	7 (7.4)	14 (11.4)	24 (16.7)	5.474	0.242
	Loss of prestige	88 (17.2)	2 (9.1)	20 (18.3)	19 (20.2)	19 (15.4)	26 (18.1)	2.003	0.735

Note. Mentions in multiple subcategories were counted as one for the respective main category.

Extensive workload and training issues were most frequently mentioned as discouraging factors. Residents mentioned "extensive workload" most often, surgeons in private practice the least (68.2% vs. 29.2%; *P*=0.000). Residents also mentioned issues related to training more often than other surgeons (45.5%, surgeons in private practice 23.6%, P=0.036). Other significant differences between surgeons on different hierarchy levels were concerns with work-life balance (attendings 22.9%, residents, 9.1%, *P*=0.033); concerns with the hierarchical organization (residents 27.3%; consultants 4.3%; *P*=0.001); laws and regulatory constraints (surgeons in private practice 16%, attendings 2.8%; *P*=0.010).

Discussion

We asked surgeons to take the perspective of today's graduates when considering a surgical career. This study provides information about promoting and discouraging factors as they are perceived by surgeons in different stages of their career.

<u>Surgeon's perception of factors promoting surgery as a career for today's graduates</u>

With more than 40% of surgeons overall, surgery as a vocation is the most often mentioned promoting factor for surgery as a career choice, with general fascination and the use of manual skills as well as skill combinations as important subcategories. Becoming and being a physician or a surgeon has often been associated with a vocation to the field [16-18]. Several studies report vocation as an important factor to choose medicine as a career [19, 20], this also holds for surgery [7]. Indeed, a recent study showed that 62% of medical students considering surgery as a specialty held this plan even before entering medical school, another 13% decided during the preclinical year [8]. Personal fit with the job was the most important influence named by students planning for a surgical career [7]. The fascination for manual and technical skills mentioned by about 14% of all surgeons in our sample reflects arguments put forward by medical students for considering surgery [37].

In our sample, there were no significant differences in all but one of the factors of the category vocation between surgeons in different hierarchy levels: The importance of patient

care as promoting factor was significantly more often mentioned by more advanced surgeons (consultants, department heads) than by residents or attendings. On the one hand, this may underscore the importance of manual and technical fascination of surgery as promoting factor; on the other hand, it may reflect a difference in attitudes particularly of department heads as compared to other hierarchy levels.

The second most often mentioned promoting aspects from the perspective of surgeons are related to task characteristics, such as meaningfulness of the work, responsibilities, challenging tasks and task variety. Having work characterized by meaningful and challenging tasks, being able to use different skills and having positive social interactions has been identified by work psychologist as related to high work satisfaction, higher motivation and better job performance across many professions [21-23]. It is important to note that many surgeons in our sample underscore these aspects as potentially promoting factors for new candidates for a surgical career.

Contextual characteristics of being a surgeon, such as prestige, future prospects, but also the recent regulations of working hours for hospital physicians in Switzerland were mentioned as positive, however less often than the other aspects. Prestige of the profession seemed to be perceived as more important by younger surgeons (18.2% of residents, 10.1% of attendings see this as a promoting factors), whereas department heads and surgeons in private practice consider prestige somewhat less important for today's graduates career choice (3.3% and 5.6%, respectively; P=.059). Prestige of the surgical profession has also been mentioned as an promoting argument in several other studies investigating perceptions of medical students, particularly for males [37, 38].

Surgeon's perception of factors discouraging surgery as a career for today's graduates

Overall, surgeons spontaneously provided more arguments describing discouraging aspects for a surgical career (580 promoting versus 945 discouraging arguments). This may be due to a phenomenon called negativity bias: We recall negative aspects more often and in more detail, and we pay more attention to negative aspects in general. However, it may also reflect

a more general, and critical attitude of surgeons towards their own profession. According to several studies, less than half of the surgeons would recommend a medical or surgical career to their own children [29, 39] and another study revealed that 18% of surgeons would not go into medicine again [25].

The most often mentioned specific discouraging aspects were extensive workload (37.7%), issues of training (31.3%) and problems with work-family balance (14.5%).
Work characteristics such as too high demands in terms of workload and a difficult, non-supportive social environment have been generally found to be stressful across professions [24]. Both, extensive working hours and poor work-family balance are among the most consistent findings and the most important arguments put forward against a career as a surgeon. Many studies found that medical students, but also surgeons themselves perceive surgery as well as the working schedule of surgeons as largely incompatible with a satisfactory work-family balance [5-7, 11, 25-28, 37, 40].
Interestingly, in this study, we found significant differences in the perception of workload and work-family compatibility as discouraging arguments between surgeons in different hierarchical positions. Whereas close to 70% of residents and close to 50% of attendants spontaneously mentioned high workload, only a third or less of consultant, department heads or surgeons in private practice saw workload as a discouraging factor ($P<.001$). Work-family incompatibility was also mentioned much more often by attendants than by other surgeons ($P=.033$). Thus, “older” surgeons (department heads, in private practice) seem to clearly underestimate the importance of workload and work-family balance issues for the career choice. This is particularly interesting because high work load persists during surgical careers and has detrimental effects: high work-load is one of the most important stress factors for surgeons and is related to lower well-being, higher depression [41] as well as to burnout [30]. The same holds for work-family issues. In one study on active surgeons, 50% of surgeons reported at least one important conflict between family and work in the last three weeks, many of those were resolved in favor of work [29]. Similarly surgeons with poorer work-

family balance suffer from higher burnout, more depression, and less career satisfaction [28, 30, 42]. In addition, work-life imbalance is one of the main arguments for residents and attendants to change their career path away from surgery [31].

One explanation for the differences between the perception of more and less experienced surgeons of the two most important discouraging factors for a surgical career may lie in the so called "code among surgeons": According to Balch and colleagues [28], the self-image of surgeons includes starting work early and finishing it late, very long working hours, night and weekend shifts, and mastering a high volume of work while never complaining. This indicates that long working hours and work-family issues may be seen as a sign of dedication and may even be a source of pride and are part of the identity as a surgeon. Another explanation, particularly for the current sample, is that in 2005, a work-hour limitation (50 hours) for residents has been introduced in Switzerland [43]. Surgeons who's residency took place when working hours were much longer, may have formed their less negative impression based on the comparison of their situation as residents with new graduates that profit from the working hour limitation.

The second most often mentioned discouraging aspect was related to training. It is interesting to see that training to become a surgeon is seen as discouraging factor for almost a third of the surgeons, albeit not similarly for surgeons of different hierarchy levels. Residents (45.5%), consultants (36.2%) and department heads (36.6%) mention training as a discouraging factor more often than attendings (25.7%) or surgeons in private practice (23.6%) (P=.036).

Other research also showed that training seems to be of great concern for the decision about a career in surgery. The most critical discussion about training is related to its duration [7, 11, 25, 37, 44, 45]. As it has been stated by JP Collins [46], "mastery of surgery can only be attained through extensive and repeated practice accompanied by appropriate feedback" (p.3) which takes several years. On the one hand, this requirement is demanding for residents because to conclude their residency, they have to perform a specific number of different surgeries, learn surgical techniques and acquire anatomical knowledge besides working at the

ward. On the other hand, training can also be a burden for senior surgeons because they have to teach residents and perform safe and successful surgery at the same time.
A further concern for training is the lack of structure of training [6] which makes it difficult for trainees to plan and to assure having sufficient cases [25]. It is important to note that lack of structure and length of training may be connected, and both may also be related to long working hours. Residency seems to be characterized by a particularly high workload and particularly low work-family balance [37]. Assuring sufficient cases may take a lot of time, depending on case availability during the residency. For this specific aspect, limitation of working hours is not an advantage: A previous study showed indeed that regulatory limitations of working hours for residents had a negative effect on training because limitations of working hours also reduced time spent in surgery [43].

Do surgeons make good role models?

Many medical students take the decision to pursue a career in surgery early on [8, 47], and one of the most important influences for entering and staying in surgical career is the availability of positive role models [7, 14, 15]. Role models are particularly important for students that are undecided, but may be attracted to surgery [27, 48, 49]. This means that the surgeons themselves have a non-negligible influence on recruiting success. Recent studies have emphasized the importance of early exposure of medical students to surgery as an influence that may spark interest, and may work against negative stereotypes of surgery [14, 47]. Because surgeons themselves may be a crucial influence to promote career choices, it is important that they know and acknowledge the perspective of graduates with regards to promoting but also to discouraging aspects. Our study suggests that all surgeons are prone to emphasize positive aspects, such as vocation, and positive task characteristics. However, surgeons higher in hierarchy may underestimate or even belittle major concerns of today’s graduates, such as extensive workload, training issues or work-family imbalance.

The main strength of this study is that we asked surgeons to take the perspective of a medical student who evaluates surgery as his or her career. This allows comparing students' perceptions (from previous research) with the perceptions of surgeons of different hierarchy levels and it allows identifying convergent, but also divergent perspectives. Another strength refers to the fact that the data of this study is derived from open questions. Participants thus noted the aspects that were most salient and important for them, and they could answer in their own words. We therefore obtained a broad and individually weighted spectrum of answers.

A limitation of the study is its geographically limited sample (Swiss surgeons) that does not allow generalization to other areas. Although generalizations to other countries are limited, it is interesting to notice the high convergence of the results with other studies. Another limitation is the limited sample size and the unequal participation of surgeons on different hierarchy levels, particularly, residents were numerically underrepresented.

Conclusions

This study examines how surgeons think about potential influences on graduates that consider a career in surgery. The emphasis on surgery as a vocation is an important aspect. Although vocation cannot just be injected to a person - one might have it or not – enthusiasm and dedication from a role model can be contagious and may help undecided students to appreciate and weight the positive aspects of surgery. On the other hand, it is also important for interested students to see that their concerns about training are seen and shared by the surgeons, particularly by those most involved in training. This may spark optimism that reflections about training issues may lead to changes. Another important conclusion of this study is that it is important that surgeons do not underestimate or belittle the most often and most consistent concerns against a career in surgery – the extensive workload and the perceived incompatibility of surgery and family. Not working in conditions of constant exhaustion and striving for both, a fulfilled work life and a family, is not a lack of dedication, but a protection against burnout, depression and health problems. It could well be that today's

graduates are not willing to accept extensive workload and work-family imbalance as an unchangeable fact in a surgical career.

Competing interests

None of the authors declared competing interests

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Authors' contributions

Study concept and design: Businger, Kaderli

Acquisition of data: Businger

Analysis and interpretation of data: Seelandt, Kaderli, Tschan, Businger

Drafting of the manuscript: Seelandt

Critical revision of the manuscript for important intellectual content: Seelandt, Kaderli, Tschan, Businger

Statistical analysis: Seelandt

Study supervision: Businger

All authors had full access to all of the data in the study. The corresponding author takes responsibility for the integrity of the data and the accuracy of the data analysis.

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6. Discussion

This final chapter first contains a summary of the main results of this dissertation. For each paper, the main findings are discussed separately. The chapter also includes propositions for further research and a discussion on limitations before a final conclusion is provided.

Summary of main results related to observing surgeries

6.1 Paper on intraoperative communication

Our primary aim was to explore intraoperative aspects (teamwork, communication, distractors) and their relationship to SSI. We therefore investigated the influence of case-relevant and case-irrelevant communication during long, open, abdominal surgeries on the incidence rate of SSI.

Regarding case-relevant communication, our hypothesis was supported. We found that case-relevant communication during the whole surgery decreases organ/space SSI. Case-relevant communication is therefore considered as a protective factor against SSI. Our hypothesis regarding case-irrelevant communication, on the other hand, was only partially supported. We expected that case-irrelevant communication during surgeries increases SSI. Results showed that only case-irrelevant communication during the last 20 minutes of surgeries increases incisional SSI. We therefore consider case-irrelevant communication at the time of wound closure as a risk factor for SSI.

Surgical teams have to handle complex tasks and high workload and according to existing research, we assume that case-relevant communication during surgeries fostered the development of a SMM. This in turn helped team members to detect misunderstandings or different expectations and to initiate appropriate actions. The SMM thus facilitated coordination and resulted in better performance, namely less SSI. Our results confirm research according to which explicit planning and talking to the room (both examples of case-relevant communication) contribute to better SMMs, facilitate coordination and result in better performance, especially during high workload situations (Stout et al., 1999; Waller & Utitdewilligen, 2008).

In addition, we extend the assumption that explicit coordination is rather suitable for non-routine situations (Smith-Jentsch et al., 2005). Based on our results, we assume that surgical teams should only rely on explicit coordination regardless of whether they are in a routine or non-routine situation. Explicit coordination via case-relevant communication allows team members in-process planning and establishing a SMM and thus fostering performance. It has been argued that explicit coordination

requires too many resources (e.g. time) (Marques-Quinteiro et al., 2013) but we suppose that it is worth doing so.

In contrast to that, case-irrelevant communication is considered as a distractor for surgical teams diverting their attention from the actual task and thus impairing performance (Feuerbacher, Funk, Spight, Diggs, & Hunter, 2012; Healey, Olsen, Davis, & Vincent, 2008; Sevdalis et al., 2012). However, case-irrelevant communication is also considered as an important medium to establish a positive climate in the OR (Catchpole et al., 2008).

With regard to our results, we suggest that engaging in case-irrelevant communication during surgeries is without any problems. However, it is crucial to not exaggerate case-irrelevant communication during the last 20 minutes of surgery because it seems to impair concentration, thus leading to an increase of SSI. For example, it might be that multitasking due to talking and closing the wound at the same time increases the chance of errors. In addition, residents frequently perform the wound closure and it has been found that they are more diverted when distractors occur (Feuerbacher et al., 2012; Goodell et al., 2006; Hsu, Man, Gizicki, Feldman, & Fried, 2008; Park et al., 2011).

Previous research has emphasized the importance of communication for quality of healthcare. However, existing studies have mainly examined communication breakdowns and failures in the OR (e.g.Christian et al., 2006; Lingard et al., 2004) and none of them related intraoperative communication to surgical/patient outcomes nor examined different types of communication. With our study, we address this gap and contribute to the existing research and literature as follows: First, by assessing communication within the surgical team during surgeries and establishing a relationship to surgical/patient outcomes. Second, our results stress the distinction between case-relevant and case-irrelevant communication by showing their different impact on SSI. Third, we identified the critical phase regarding the impact of case-irrelevant communication on SSI.

Surgical teams should be aware of these results and the effects of the two types of communication. Case-relevant communication should be encouraged during the whole surgery whereas case-irrelevant communication should be avoided during the last phase of the surgery.

Based on our results, behavioral recommendations and rules for surgical teams can be derived in order to enable efficient communication during surgeries, to prevent SSI and thus to improve patient safety. One possibility would be to introduce intraoperative breaks similar to preoperative timeouts allowing all team members to be on the same page by providing the opportunity to ask questions, share ideas and concerns or by explaining the next steps. Such short breaks could also be introduced

before the last 20 minutes of the surgery starts allowing team members to engage in case-irrelevant communication before they have to re-focus on the last part of the surgery. These breaks should be very short because duration of surgery is considered as a risk factor for SSI. Another possibility would be to form teams specifically for the purpose of finishing the surgery and closing the wound, respectively. However, this is cost-intense and challenging to plan and organize.

Our results emphasize the importance of relating intraoperative behavior to outcomes and to consider the content of communication as well as the timing of communication (when communication occurs). It is an important contribution to human factor research in healthcare and improving patient safety.

6.2 Methodological paper

A range of different methods for data collection were used in this dissertation and we developed an observational system specifically for our research purpose. To our knowledge, this is the first observational system allowing the assessment of intraoperative aspects of teamwork and communication as well as distractors simultaneously during surgeries. Based on this method, we are also the first research group that explored and established a relationship between intraoperative communication and postoperative outcomes as discussed in the previous section of this chapter.

Existing observational systems assess either aspects of teamwork or distractors and rely mainly on video-tapes. Moreover, most of them have been used to examine rather short surgeries and inter-rater reliabilities are reported only for a few of them. As opposed to this, we were able to ensure stable inter-rater reliabilities also for long surgeries which is important because observers are getting tired and this may have an influence on reliability. We used two indexes for calculating inter-rater reliabilities, namely Cohen's Kappa and Intraclass Correlation Coefficient (ICC) and results for both were good to very good.

High inter-rater reliability confirms that our observational system is applicable to examine intraoperative aspects during long surgeries. It therefore allows a new research approach of human factors in the OR because it is now possible to assess intraoperative behavior during short and long surgeries with a reliable method. Moreover, examining long surgeries is particularly important because duration of surgery increases the risk for patients and working for hours under stressful conditions is demanding for surgical teams in terms of teamwork and communication. The observational system contains 18 codes and thus provides a broad range of intraoperative aspects and behavior which can be assessed.

Although event-sampling may be exhausting for observers especially during stressful situations that require quickly choosing the appropriate codes, we assume that this method is preferable to field notes or behavioral markers and especially suitable for long surgeries. Moreover, it seems possible to identify different phases of surgeries as well as favorable and unfavorable behavior or behavioral patterns. The knowledge and insights obtained with this method can be ideally used to derive guidelines and rules to further improve patient safety.

Summary of main results related to open surveys

6.3 Paper on checklists

We investigated reasons for the persistence of adverse events as well as advantages and disadvantages of introducing and implementing these checklists.

Reasons related to the individual and in particular lack of discipline and strain were named most frequently as potential reasons for the persistence of adverse events. In addition, main disadvantage of introducing and implementing checklists was lack of willingness related to acceptance and commitment problems.

On the one hand, results demonstrate that reasons for the persistence of adverse events are mainly attributed to the individual level whereas aspects related to the system (e.g. organization, context) are considerably less mentioned. When errors occur, people usually tend to find someone who is responsible for the error and blame this person. However, errors mostly result from a number of converging factors and blaming a person does neither change these factors nor avoid the occurrence of the same errors in the future (Kohn et al., 2000). According to Kohn et al. (2000), we therefore assume considering a system approach to prevent errors instead of blaming a single person.

On the other hand, the results indicate the importance to draw on attitudes to promote acceptance and commitment for the use of checklists. It is generally assumed that checklists are an important tool for reducing errors and adverse events (e.g.Hales & Pronovost, 2006). For instance, Wolf, Way, and Stewart (2010) evaluated a medical team training (MTT) with briefings and debriefings including all items of the WHO checklist. Their results indicated several improvements, but it took almost two years until the effects were stable. Introducing and implementing new tools takes time, their benefits might not be obvious immediately, and that may be the problem: If surgeons do not see an immediate effect of the checklists, they might not accept and commit to using them in the future. Besides, surgeons are generally seen as being highly committed and dedicated to their work

(e.g.Balch, Freischlag, & Shanafelt, 2009) but their commitment does not prevent them from errors or adverse events. When errors occur, it does not imply that surgeons are not committed. It seems important to make surgeons aware of this fact that they accept checklists and commit to using them. However, it takes time to change attitudes and does not happen overnight.

Furthermore, medicine was considered as being infallible and stood off the research of human factors for a long time (Aspden, Corrigan, Wolcott, & Erickson, 2004; Pierre et al., 2011). This point of view changed when the Committee on Quality of Health Care in America, the Institute of Medicine, published their report “To Err is human” which analyzed the quality of health care in America and focused primarily on medical errors (Kohn et al., 2000). The numbers of medical errors reported were disturbing and questioned the quality of healthcare. Based on that, several initiatives worldwide were then initiated for improving healthcare and preventing medical errors (e.g.Aspden et al., 2004; Cooper et al., 2002; Flin, Fletcher, McGeorge, Sutherland, & Patey, 2003; Kohn et al., 2000; Omotosho & Portenier, 2012; Pierre et al., 2011). Although research on human factors has grown and the awareness of errors in medicine and healthcare has increased since the publication of “To Err is human”, availability of current incidence rates of errors and adverse events is still scarce. The fact that only very few articles report incidence rates of errors and adverse events may lead to the assumption that errors do not occur which may result in distorted or inadequate perceptions of their risk and occurrence. We therefore emphasize the importance to inform people working in medical professions about incidence rates of errors and adverse events to enhance the acceptance and commitment regarding the use of checklists.

With our study, we contributed to the growing literature regarding errors and adverse events but there seems to be still room for further investigations.

6.4 Paper on career choice

Current surgeons in different hierarchical positions and thus with different levels of experience were asked to give arguments that may or may not attract recent graduates to choose a career in surgery.

As expected, arguments making surgery attractive as well as arguments making surgery not attractive as a career choice were related to content and contextual characteristics of the work environment. Arguments related to vocation for surgery were only reported as making surgery attractive for career choice.

Regarding arguments making surgery not attractive as career choice, extensive workload (content-related characteristic) and training (context-related characteristic) were named most frequently among all surgeons. In contrast, challenge and variety (content-related characteristic) and fascination for surgery (related to surgery as a vocation) were mentioned most frequently among all surgeons with regard to arguments making surgery attractive as career choice.

All surgeons mentioned extensive workload very frequently and regarding hierarchical positions, residents mentioned it the most and surgeons in private practice the least. One explanation could be that surgeons in private practice are more independent and have more freedom regarding their time management. Residents working in hospitals, however, have to adhere to the shift schedule. They additionally have to perform a large number of surgeries to become a specialist in surgery and have to do a lot of paperwork. To reduce workload, work-hour limitations for residents have been introduced in 2005 in Switzerland. Aim of these limitations was to restrict working hours for residents to a maximum of 50 hours per week but contrary to expectations, a negative influence of work hour limitations on training in surgery was reported (Businger, Guller, & Oertli, 2010).

In addition, it is remarkably that training was mentioned very frequently among all surgeons of all hierarchical positions. Residents have to perform a set of surgeries and acquire knowledge during their residency. It is thus not surprising that they mention training as a factor for making surgery not attractive because they are directly affected. However, senior surgeons also named it very frequently. We therefore assume that training is also a concern for senior surgeons because they have to perform their surgeries and to teach junior surgeons at the same time.

Indeed, the sample consisted of current surgeons who were asked to take the perspective of graduates and name arguments of their work which make surgery (not) attractive as a career choice for graduates. Although the questions in our study were in relation to career choices of graduates, we cannot exclude the possibility that the reported arguments were biased by the actual situation of the surgeons. For instance, Businger, Villiger, et al. (2010) asked surgeons in a recent study to give pros and cons for a career in surgery and the reported arguments are similar compared to our findings.

Surgery seems to be less preferred and several studies report a decline in interest (Azizzadeh et al., 2003; Debas, 2002; Khan, Pillay, Veller, Panieri, & Westcptt, 2006), which is not conducive for the recruitment of future surgeons. Our results provide a basis to rethink and restructure existing working conditions in surgery to attract graduates to surgical careers.

6.5 Future perspectives

We developed our observational system to investigate the relationship between intraoperative aspects and SSI. The paper on intraoperative communication and the methodological paper are thus highly linked to each and I therefore combine the discussion of future perspectives for both papers.

Our observational system was tested and used during elective abdominal surgeries. Future research could extend our findings as follows: First, we would advise to extend the sample size in further investigations, as this allows to obtain stronger effects. With our current sample size in the paper on intraoperative communication, we already detected medium size effects.

Furthermore, we suggest using the observational system during emergencies including hectic and stressful sequences. It has to be tested whether observers are still able to code behavior reliably under these conditions. In addition, emergencies are challenging in terms of teamwork and communication and teams have to collaborate smoothly particularly when patients are in life-threatening situations where every second counts. Consequently, examining emergency situations could further shed light on the reliability of our observational system and ideally extend our findings to these situations.

Moreover, we further propose using the observational system in other disciplines (e.g. cardiac surgery) and hospitals (e.g. non-teaching hospitals). Then, we would be able to compare our findings which may also contribute to their generalization. If the findings could be generalized, they may serve as a basis to improve quality in healthcare having a lasting effect on patient safety. On the other hand, by using the observational system in other disciplines and hospitals, additional intraoperative aspects related to SSI may be identified.

As it has been already discussed in chapter 6.1, it might be worth to introduce short intraoperative breaks for encouraging case-relevant communication. Additionally, teams specifically composed for the last phase of the surgery could be introduced.

In the next section, future perspectives for the paper on checklists and the paper on career choice are provided and I will also combine the discussion for these two papers. At a first glance, this might appear disconcerting with regard to their different research questions. However, some of their results are quite similar. The results of the paper on career choice showed that extensive workload was one of the most often named arguments among all surgeons making surgery not attractive as a career choice for graduates. In a similar vein, results of the paper on checklists revealed that strain related to workload was one of the most named reasons for the persistence of adverse events. Moreover, the amount of effort required for the use of surgical safety checklists was also frequently

named as a disadvantage of introducing and implementing such checklists. High workload may have severe consequences and future research should address possibilities to optimize working conditions and to reduce workload in surgery. Reducing workload and thus stress may allow surgeons taking the time needed for using checklists which in turn contribute to patient safety. Additionally, optimized working conditions and reduced workload may probably increase the attractiveness of surgery as a career choice for graduates.

With regard to the paper on checklists, we moreover assume introducing information sessions on the occurrence of errors and adverse events for employees working in surgical wards to reduce biases in their risk perceptions.

6.6 Limitations

This dissertation has limitations. However, these limitations are at the same time suggestions for future perspectives which were discussed previously. From this follows that the discussion on limitations is relatively short.

One limitation refers to the limited sample size in the paper on intraoperative communication which allows detecting medium size effects. Moreover, we tested our observational system and thus assessed intraoperative aspects only during elective surgeries at one teaching hospital in Switzerland which limits the generalization of the results. Additionally, we cannot exclude biases related to the observer (methodological paper).

Regarding the papers containing qualitative data, both papers are geographically limited to Switzerland; the sample of the paper on checklists includes clinic directors and the sample of the paper on career choice contains surgeons working in Switzerland. Another limitation of the paper on checklists is the low response rate of 29.7%.

6.7 Conclusion

We investigated individual, social and situational factors for making surgery better, and with our results we contributed to the growing literature of patient safety and human factors. The results can serve as a basis for further studies and investigations as well as for interventions in medical settings. We invested a lot of time and effort in developing our method, observing surgeries and analyzing data. For instance, we spend 459.4 hours observing surgeries (from incision to closure), identified 8,780 case-relevant and 2,584 case-irrelevant communications as well as 24,410 distractors, and we analyzed 1,762 arguments. When considering these numbers, it becomes apparent that this dissertation was not realized overnight. It would have been easier to collect data by means of surveys solely, but with regard to the extremely valuable results, it was worth doing so and making the extra effort.

7. References

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