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An integrated OSH risk management approach to surgical flow disruptions in operating rooms

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ABSTRACT

Surgical flow disruptions (SFDs) are the deviations from the natural progression of an operation in the operating rooms (ORs). Some tools and methodologies have been proposed in the literature for the systematic assessment of the SFDs especially for the cardiac surgeries. However, they lack a clear connection with the Occupational Safety and Health (OSH) risks for the surgical team and the risks for the patient safety. In this paper, an integrated OSH risk management methodology adapted from International Labor Office (ILO) approach is proposed to account for the SFDs, surgical flow disruption effects (SFDEs), and the OSH risks by using the fuzzy cognitive mapping (FCM) as a tool for the risk prioritization. To the best of our knowledge, this is the first paper which proposes an integrated OSH risk management methodology in the surgical environments by using the FCM that incorporates the SFDs and other factors such that the critical SFDs and the critical OSH risks can be identified. Then, the respective preventive and protective measures (PPMs) can be put into effect for eliminating, controlling or minimizing the OSH risks for a safe OR environment for both the surgical team and the patient. The methodology is not limited to the surgical environments or the healthcare industry; rather, it can be adapted to different work environments for an integrated OSH risk management. The methodology has been illustrated by using the hypothetical data, the limitations and the improvement potentials of the methodology have also been discussed in detail for further research.

1. Introduction

Surgical flow disruptions can be defined as the "deviations from the natural progression of an operation that potentially compromise the safety of the operation" (Wiegmann et al., 2007; Wiegmann et al., 2012). OSH can be generally defined as "the science of anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment" (Alli, 2008). An OSH hazard is basically "a physical situation with a potential for human injury, damage to property, damage to the environment or some combination of these" (Alli, 2008), while an OSH risk is "the likelihood of an undesired event with specified consequences occurring within a specified period or in specified circumstances" (Alli, 2008). Some typical examples of the OSH risks in the ORs would be slips/trips/falls, sharp injuries, and infections due to exposure to blood. Since the SFDs are the deviations from the natural progression, they may have high potentials for causing various OSH hazards and OSH risks. However, only a few papers raised the concern for the connection of the SFDs with the OSH, while most papers merely focused on "patient safety" rather than the OSH (Sevdalis et al., 2014; Catchpole et al., 2007). Silver et al. (2017) stressed that the SFDs can increase the mental workload of the OR personnel and the likelihood of the surgical errors, and identified by means of a questionnaire conducted on 111 OR personnel that the patient safety and "staff burnout" are the most likely consequences of the SFDs. Al-Hakim (2011) highlighted that the SFDs expose surgical teams to stress and musculoskeletal disorders, and identified that "although lighting and monitors had a relatively small impact on operative time, these factors could create inconvenience and stress within the surgical teams" as one of the results of his research. The Systems Engineering Initiative to Patient Safety (SEIPS) model developed by Carayon et al. (2006) incorporates the "work system" with the core elements person, technology and tools, tasks, organization and environment; "processes" including care processes and other processes; and "outcomes" for the patient, for the employees, and the organization. Although the SEIPS model is mainly intended for patient safety, and no connection between the SFDs and the OSH is explicitly made, its main structure can be adapted as the connection between the SFDs and the OSH outcomes for the surgical team.

Wiegmann et al. (2007) highlight the importance of the effect of a single SFD on the other SFDs, and the risk of their accumulation for

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leading to the surgical errors. Lingard et al. (2008) emphasize that the accumulation of the minor events may decrease the ability of the surgical team to cope with the major problems. Thus, the SFDs are of critical importance for the performance and safety in the OR environments. With this regard, some tools and methodologies have been developed for the classification and analysis of the SFDs (as an example see Duff, 2013; for the literature review, please refer to Section 2.1). Some interventions have also been proposed in the literature for the resolution of the SFDs (as an example, see Shouhed et al., 2012; for the literature review, please refer to Section 2.1). However, these approaches are mainly limited to the identification and interpretation of a list of the SFDs and the interventions based on the observational studies, and no connection of the SFDs with other concerns such as the patient safety or the OSH of the surgical team has been made with these approaches.

In this paper, following the OSH risk management methodology of ILO, an integrated and systematic OSH risk management methodology is proposed for the ORs by considering the SFDs as the variables and the FCM as the technique. Downs and Stea (2017) defined cognitive mapping as "a process composed of a series of psychological transformations by which an individual acquires, stores, recalls, and decodes information about the relative locations and attributes of the phenomena in his everyday spatial environment". In the methodology proposed in this paper, an FCM approach is used for delineating the interdependencies among several factors including the SFDs, SFDEs, and the OSH risks. Moreover, although very limited, human reliability analysis (HRA) is also considered in this approach. HRA is a "systematic framework to assess the human contribution to system risk which includes the process of evaluation of human performance and associated impacts on structures, system, and components for a complex facility" (Su et al., 2014). It is performed to "systematically identify causes and consequences of human errors, and to predict the probability of error occurrences" (Kim et al., 2017), and involves the use of the qualitative and quantitative methods such as "Technique for Human Error Rate Prediction" (THERP), and "Cognitive Reliability and Error Analysis Method" (CREAM) (Bell and Holroyd, 2009). As a result of the analysis of the fuzzy cognitive map, the measures to be taken can be developed by using the hierarchy of PPMs approach proposed by ILO. The hierarchy of PPMs includes the measures in the order of priority for eliminating, controlling, and minimizing the OSH risks (Alli, 2008). The methodology is systematic, and the Plan-Do-Check-Act (PDCA) cycle inherent in the methodology fosters the continuous improvement of the OSH risk management process for the ORs.

The main contribution of the paper is to consider the problem of the SFDs with a systems thinking approach by means of the FCM technique so that the interrelations among the SFDs, SFDEs, OSH risks, and PPMs can be identified for an effective OSH risk management of the surgical team and for the patient safety. As in other work environments, a systems thinking approach is also inevitable for the OSH risk management in healthcare industry, and cognitive mapping is a tool capable of illustrating the interdependencies among several factors in a complex OR environment, and capable of identifying the critical SFDs and the critical OSH risks so that the PPMs can be allocated accordingly. Although the FCM was widely applied in very different areas and some applications were also proposed in healthcare industry as outlined in Section 2.3, to the best of our knowledge, no application of the FCM has been proposed for the OR environments in the literature. FCM has the main strength of integrating the human mental models with the cognitive mapping, providing the decision maker the flexibility to assign any value in the interval $[-1,1]$ or to assign the linguistic variables for the cause-and-effect relationships between the factors of the map (Gray et al., 2014; Groumpos, 2010). In this paper, an FCM approach is proposed in which the SFDs, SFDEs, OSH risks, and the PPMs are considered as factors of the fuzzy cognitive map for the ORs in which the causality relationships are evaluated by using the fuzzy linguistic variables. With this approach, the critical SFDs and the critical OSH risks can be identified so that the PPMs can be allocated according to the prioritization levels. The hypothetical data is used for the illustration of the basic steps of the methodology, and the steps of the methodology are clearly elucidated so that the real data from different OR environments can be adapted based on this methodology with some customization.

The structure of the paper is as follows: In Section 2, the literature review for the observational tools, methodologies, analytical approaches and interventions developed for the SFDs is provided. In this section, the literature review of the HRA in the ORs, the basics of FCM, and the literature review of FCM in healthcare are also given. In Section 3, an integrated OSH risk management approach for the ORs is proposed by considering the SFDs as the factors of the FCM, and the approach is illustrated with the hypothetical data. Finally, in Section 4, the conclusions, the limitations of the study, and the potentials for improvement are discussed in detail.

2. Literature review

In this section; the literature review of the observational tools, methodologies, analytical approaches and interventions developed or used for the SFDs, the literature review of the HRA in the ORs, the basics of the FCM, and the literature review of the FCM in healthcare will be provided.

2.1. The observational tools, methodologies, analytical approaches and interventions developed or used for the SFDs

A literature research has been carried out by using the search terms "surgical flow disruption" and "tool" in the electronic databases Web of Science, Scopus, Sciencedirect, Springer, Taylor & Francis, and IEEE. Among these databases, Web of Science provided 1 result, Scopus provided 3 results, Sciencedirect provided 25 results, Taylor and Francis provided 0 result, Springer provided 9476 results, and IEEE provided 14,670 results. Although Springer and IEEE seemed to provide many results, after initial screening, only the first 25 pages of the results from the Springer database, and the first 3 pages of the results from the IEEE database have been evaluated as relevant. A literature research has also been conducted by using the keywords "surgical flow disruption" and "methodology" in the same electronic databases. As a result of this search; Sciencedirect provided 17 results, Scopus provided 1 result, Web of Science, IEEE and Taylor & Francis provided no results, and Springer provided 5861 results, however, after the initial screening, the first 25 pages have been considered in the Springer database. The searches in the databases Sciencedirect, Springer and Scopus by using the search terms "surgical flow disruption" and "intervention" provided 28 results, 11 results, and 3 results, respectively; while the databases Web of Science, IEEE and Taylor & Francis provided no results. Following the title and abstract screening, the papers with a potential of proposing a tool, methodology, and analytical approach for describing, classifying and analyzing the SFDs, and proposing any means of interventions for the SFDs have been selected and further analyzed. Those papers with the field studies that merely provided the observation results including the types, duration, number and the reasons of the SFDs for a specific surgical environment have been mainly excluded. The papers that are further analyzed have been provided in Tables 1 and 2.

The observational tools, methodologies, and analytical approaches as outlined in Table 1 have been developed for the systematic evaluation of the SFDs. As evident from Table 1; communication and other teamwork related issues, the physical layout of the ORs, and the equipment related failure and usability problems are some of the factors leading to the SFDs.

One of the earliest observational tools applied for the SFDs was HFACS that was originally proposed for the aviation accidents by Wiegmann and Shappell (2003) based on Reason's "Swiss Cheese model". HFACS was later adapted to the SFDs by Elbardissi et al.