Science Arena Publications
International Journal of Business Management
Available online at www.sciarena.com
2017, Vol, 2 (3): 56-64

Determination of the Root Causes of Errors in Dentistry and Management of Strategies in the Infection Control

Mehdi Nikfarjam[1], Hanieh Khani Jazani[2*]
[1]Assistant Professor, Department of Industrial Engineering, Faculty of Engineering, Islamic Azad University, North Tehran Branch, Tehran, Iran.
[2*]PhD. Student of Industrial Engineering, Department of Industrial Engineering, Faculty of Engineering, Islamic Azad University, North Tehran Branch, Tehran, Iran.

Abstract: Background and Objectives: *Healthcare is one of the important sectors where the level of risk is so high, hence, the errors and mistakes that occur within this sector and cause failures in the system are also very important. In this context, one of the important errors is the human error that its examination, within the framework of healthcare, infection control and dentistry, can prevent many adverse and unpleasant consequences. The present study has been conducted to identify the causes of human errors in infection control practices such as hand hygiene and the use of personal protective equipment (PPE).* ***Methodology****: Present study has been conducted in a specialized dental center. Data collection is performed by interviewing dental specialists and using analyst's reports and observations regarding those tasks of the dentist that are related to infection control practices such as the use of personal protection equipment and hand hygiene. After identifying human errors and collecting the necessary data, they were analyzed by using SHERPA technique and then, controlling strategies were presented.* ***Findings****: Considering the causes of errors, the following results were obtained: forgetfulness and distraction 34%, out-of-work fatigue 3%, inappropriateness of conditions and equipment 4/5%, lack of awareness 17%, forgetting the items taught during the training courses 20% and ineffectiveness of training materials 21.5%.* ***Conclusion****: The identified errors, results obtained from the evaluation of the causes of errors and the strategies presented to control them, all, indicate that SHERPA is a suitable and applicable technique in the field of infection control in dentistry, as it has been proved to be useful in studying other fields related to the healthcare and recognizing the root causes of identified errors through this technique, can play an important role in determining the strategies, the way of implementing and programming them.*

Keywords: *Human Error, SHERPA, Causes of errors, Strategies, Infection Control, Personal Protective Equipment, Dentist*

INTRODUCTION

Studies show that between 20% and 90% of failures in systems are related to human performance and more than 90% of accidents in industries occur due to human error [1]. The issue of human error has been also raised in the healthcare systems. There is a consensus on the fact that medical error is a significant issue in contemporary healthcare systems [2]. According to the Institute of Medical Sciences, medical error is : 1. the failure of a planned action to be completed as intended, or 2. the use of a wrong plan to achieve an aim [3]. Medical errors are the main cause of illness and death in the United States [4]. In many hospitals and

healthcare centers large number of sophisticated invasive medical procedures are suggested without considering the risk of infection. The costs of nosocomial infections, in terms of both money and human suffering, are enormous, for instance, in the U.S. these kind of infections are responsible for at least 90,000 deaths each year at a cost of more than $5 billion annually[5]. During the last two decades, there has been a significant trend for the control of severe diseases such as hepatitis and human immunodeficiency virus (HIV[1]) among health care workers (HCWs[2]) [6 ,7]. Dentists are one of the groups of HCWs. Infection control in dentistry has become an integral part of this job [6]. Preventing infection and controlling it, are the key factors in providing a safe environment for patients, staff and dentists during a dental work [8].

Reports from several countries have shown that some dentists do not use personal protective equipment such as gloves, face masks and eye protectors during the dental procedures [6]. Today, many leading healthcare organizations acknowledge the fact that human errors, side effects and system failures should be managed and controlled [9]. In this regard, many approaches and methods that are employed for developing "high-reliability organizations" have also been introduced to medical care and medical education in order to minimize the adverse effects of the errors [10]. Studies have proven that the analysis of human errors, in the pre-incident stage, can prevent the occurrence of many of these errors [11]. One of the techniques for predicting and reducing the human errors is SHERPA[3], which is one of the most acceptable methods for human error identification (HEI[4]) [12].

In a study, *Kirwan* (1992) compared SHERPA with five other human error identification techniques in terms of comprehensiveness, speed and accuracy, stability, theoretical credibility, utility, resource utilization and acceptance. He reported that, in terms of applicability, SHERPA has obtained the highest degree of credibility [12 13]. According to *Stanton and Baber* (1996) the validity of SHERPA was 0.8 and its reliability was 0.9 in the prediction of the errors on an automatic ticket sales machine[14] and *Stanton and Stevenage* (1998) reported a concurrent validity statistic of 0.74 and a reliability statistic of 0.65 in the application of SHERPA for predicting the errors on a confectionery vending machine[15]. Despite the fact that several decades have been passed since the adoption of predictive safety techniques in the industry, *Lyons et al* (2004) found that among the published items, there are only seven techniques that are used for health care which involve: Change Analysis (CA), FMEA[5], HAZOP[6], Influence Diagrams Analysis, SHERPA, Event Tree, and Fault Tree [16]. Also, in other study that was conducted in Italy by *Verbano and Tora* (2010) SHERPA was one of the techniques that were implemented in other industries and it was potentially and effectively transferable to the Italian healthcare sector[9].

In a study conducted by *Joyce et al* in 1998, to analyze the nature and incidence of errors, identification and classification of errors during the endoscopic surgery have been performed. Human Reliability Analysis have been conducted with the aim of documenting the nature and incidence of surgical errors approved during laparoscopic cholecystectomy and in order to direct future researches and surgical training and classification of errors, in this study, has been performed on the basis of External Error Modes (EEM[7]) in the SHERPA technique[17]. In another study, conducted in 2005 by *Lane et al*, pharmaceutical errors at the hospitals have been identified by using SHERPA technique[12]. To identify potential human error at each phase of anesthesia, *Phipps et al* (2008) used SHERPA technique- in which task analysis is used to create a systematic description of the behaviors that exist during anesthesia and can serve as a framework for promoting a good

[1] The human immunodeficiency virus
[2] Health care worker

[3] Systematic Human Error Reduction and Prediction Approach
[4] Human Error Identification

[5] Failure Mode and Effect Analysis
[6] Hazard and Operability Study
[7] External Error Mode

and prominent work in worrying cases- and they have proposed methods to prevent these errors [18]. In a study that was conducted by *Tang et al.* (2005) technical errors during the laparoscopic cholecystectomy surgery have been identified and categorized by using OCHRA[8] method[19].

Statistics related to validity and reliability of the SHERPA technique, along with expert judgment reported by *Kirwan* (1992), is encouraging and it is believed that SHERPA has a logical origin [12] and since it is transferable to the healthcare sector, it has been selected to be used in the present study. Considering the previous studies, it was found that in the limited number of researches that has been done in the field of dentistry, mainly the issues of errors in the dental offices and the safety of patients have been addressed and little attention has been paid to the prediction and identification of errors and the causes of the errors through the use of a well-known method that has been designed to identify errors in dentistry, especially in the field of infection control(like personal protection equipment). Therefore, it was considered necessary to address and study this issue among dentists and take action for the following items:

- Identification of human errors
- Determination of the causes of the identified errors
- Provision of appropriate and practical solutions and strategies for any error in order to control and reduce thee errors
- Analysis of the causes of the errors and strategies

Research method

The present study is a descriptive - cross-sectional study, which was carried out to identify and evaluate human error in infection control practices such as personal protective equipment and hands hygiene among dentists in a semi-private specialized dentistry center in Tehran. 8 infection control departments in the advisory group consisting of an industrial engineer, occupational health and safety specialist, a general dentist and expert dentist (who was subject matter expert) were selected as study sample in order to evaluate human error in infection control practices such as personal protective equipment (PPE) and hands hygiene. To carry out the present study, the SHERPA technique was used and data collection was performed through observation, interviewing and reviewing reports and documentation of the clinic regarding the dentist's duties in the use of personal protection equipment and hand hygiene.

The Systematic Human Error Reduction and Prediction Approach (SHERPA) was developed by *Embrey* (1986) [12,20]. SHERPA is a comprehensive technique which includes task analysis[20]. This technique is based on the classification of human error [12]and identifies error states [20].

SHERPA technique is performed through eight steps:

The first step includes hierarchical task analysis (HTA), in which tasks are analyzed into the smaller components and the necessary steps which are required to perform that task. In fact, to start the analysis , the ultimate goal is specified and in order to achieve it, each task is divided into smaller components [21 ,22] that in the present study, this is done by a team consisting of an industrial engineer and a general dentist and finally the analysts' group will review and modify it. The group of analysts is consisted of an industrial engineer, occupational health and safety specialist, a general dentist, two dental experts working in the studied clinic and an expert dentist (who has been working in the field of infection control and is considered as the subject matter expert and a senior consultant in the group). Part of the drawn HTA is shown in Figure 1. The second step involves the "Task Classification", in which each step of the task is analyzed from the bottom level in order to categorize the error in one of the five categories:

1. Action (involves pulling or pressing an object)

2. Retrieval (getting information from a screen or manual)

[8] Observational Clinical Human Reliability Assessment

3. Checking (conducting and controlling a procedural check)

4. Selection (choosing another alternative with respect to the higher order command)

5. Information communication (talking to another party)

"Human Error Identification" is the third step of the technique[21 ,22] for which 16 expert dentist from a shift were interviewed to identify human errors and the errors detected at this stage were reviewed and approved by the subject's expert. The next step involves the "Consequence Analysis" and it would have practical consequences for critical errors [21 ,22]; at this stage, consequences of each error are identified by the analyst group. In the fifth step, the "Recovery Analysis" is done. At this stage, the analyst should determine the recovery potential of the identified errors. In the sixth stage, "Ordinal probability analysis" is performed, which consists of three classifications. An ordinal probability scale of low, medium or high is typically used. If the error has not occurred previously then a low (L) probability is assigned. If the error has occurred on previous occasions then a medium (M) probability is assigned. Finally, if the error has occurred on frequent occasions, a high (H) probability is assigned. The seventh phase is the "Criticality Analysis". If the resulted errors lead to unacceptable losses, then, the error is considered critical [21 ,22]. The final step of SHERPA process involves "Remedy Analysis" which is classified into four categories:

1. Equipment (redesign or modification of existing equipment);

2. Training (changes in training process);

3. Procedures (provision of new instructions or revising old procedures and modifying them);

4. Organizational (making changes in organizational policy) [23].

In the present study, the strategies were presented by using the mental storm session and they were recorded in the work sheet. During the surveys and interviews, it became clear that each error may have more than one reason. Therefore, in order to ensure the appropriateness and effectiveness of the suggested strategies, in addition to the steps of SHERPA, the reason of occurrence of every error was determined and a suitable and complementary solution or solutions were presented for each reason.

Findings

In total, in the studied dental center, 31 human errors were found in the process of infection control (personal protective equipment and hand hygiene) all of which were related to the activities of the dentist. Errors have been examined in five areas that include the use of eye protectors, gloves, protective clothing, masks, and hand-washing (Here, of course, medical cap or scarf for women and the shoes have been examined separately from the protective clothing). Among the reasons of errors, which were obtained during the interview with the dentists, we can refer to following items: lack of awareness, forgetting (due to fatigue, hurry) the materials that were taught during training courses, normalization of infection control principles and losing sensitivity towards them, considering that the observance of the principles of the use of personal protective equipment is a time consuming and an extra work, failure to understand the existing risks and considering that there is no reason to perform infection control practices.

Table 1 examines the causes of the incidence of errors and the percentage of each one is determined by the type of error, the type of tool or method of infection control and the type of strategy. For each error in each of the categories, the frequency ratio to total was expressed in the form of percentage. To display these values quantitatively, the total number of errors, with various reasons, was considered to be 100% and all strategies, with various reasons, were also considered to be 100%.

Table 1 - Percentage of the causes of error in several types of errors, tools and strategies

Categories	Causes of Errors	Forgetfulness and distraction (due to hurry, fatigue or labor pressure)	Out-of-work fatigue	Inappropriateness of conditions and equipment	Lack of awareness	Forgetting the trained items	Ineffectiveness of training material	Total percentage
Type of error	Functional	13/8%	1/5%	1/5%	7/7%	7/7%	46%	37%
	Checking	13/8%	1/5%		4/6%	11%	13/8%	45%
	Retrieval			3%				3%
	Communicational	0%	0%	0%	0%	0%	0%	0%
	Selection	6%			4/6%	1/5%	3/1%	15%
	Total percentage	34%	3%	4/5%	17%	20%	21/5%	100%
Type of the employed tool	Eye protector	3%			3%	4/6%	4/6%	15/4%
	Mask	6%	1/5%	1/5%	6%	4/6%	1/5%	21/5%
	Gloves	11%	1/5%	3%		3%	4/6%	23%
	Protective clothing	1/5%				1/5%	1/5%	4/6%
	Medical cap	3%			1/5%		1/5%	6%
	scarf	3%				1/5%	1/5%	6%
	shoe	3%			1/5%	1/5%	1/5%	7/7%
	Hand-washing	3%			4/6%	3%	4/6%	15/4%
	Total percentage	34%	3%	4/5%	17%	20%	21/5%	100%
Strategies	Equipment	5/3%		2/66%		1/33%		9%

	Procedures and instructions	17/3%		1/33%			1/33%	20%
	Training	13/3%	4%	1/33%	14/66%	16%	17/3%	67%
	Organizational policy	1/33%		2/66%				4%
	Total percentage	37%	4%	8%	15%	17%	19%	100%

Each error with several reasons has been considered as a different error and the 31 identified errors have become 65 errors. 37% of the errors were functional, 45% checking errors, 30% retrieval errors, 0% communication errors and 15% were related to the selection errors. As a result, the highest percentage of errors was related to checking and the lowest percentage of errors was related to the communication as it is shown in Table 1. Errors in other category, which are related to the type of infection control tools or methods, have been identified according to the reason of occurrence of an error. Here, again, each error with several reasons has been considered as a different error. The percentage of errors that are related to the type of infection control tools are as follows: eye protector 15.4%, face mask 21.5%, gloves 23%, protective clothing 6.4%, medical cap 6%, scarf 6%, shoes7.7% and hand wash 15.4%.Therefore, the highest rate of errors is related to the use of gloves. Finally, the percentage of different types of strategies was obtained for a variety of reasons.

A strategy was presented for any kind of reason in an error and in this case, the effect of accident prevention, the effect of cost, the rate of acceptance of the strategy by the organization and staff and the practicality of the strategy were also considered. In some errors, there have been several reasons for the occurrence, and for each of the reasons, a separate strategy has been proposed, and even, in some cases, two solutions have been proposed for a cause of error in a particular error, and the presented strategies complete each other. As a result, the number of presented strategies is greater than the number of errors. The percentage of the proposed solution is as follows: equipment 9%, training 67%, procedures 20% and organization policy 4%. The highest rate, which is significantly different from other strategies, is related to the training. Among the reasons of errors, we can refer to following items: forgetfulness and distraction (due to fatigue or hurry), out-of-work fatigue, inappropriateness of conditions and equipment, normalization of infection control principles and losing sensitivity towards them, thinking that the observance of the principles of the use of personal protective equipment is a time consuming and an extra work, failure to understand the existing risks and considering that there is no reason to perform infection control practices(the last three cases can be categorized into three categories the lack of awareness, forgetting the items taught during the training courses, and the ineffectiveness of training materials [24]). The percentages of each one has been obtained from the Table 1 which is as follows: forgetfulness and distraction (due to fatigue or hurry) 34%, out-of-work fatigue 3%, inappropriateness of conditions and equipment 4/5%, lack of awareness 17%, forgetting the items taught during the training courses 20%, and the ineffectiveness of training materials 21/5%. Therefore, forgetfulness and distraction (due to fatigue or hurry) is the most common cause of human error in the control of infection.

Discussion

In the research result, it has been stated that through HTA, the human errors in surgery can be identified in a traditional way, but the reasons and causes of errors are not necessarily determined and this issue can affect the function of the novice surgeons and the technical surgery (that had been examined in that study) [

25], so we can conclude that it would be a very appropriate practice to determine the reason and causes of the errors. By examining the errors related to each of the tools and methods of infection control and the strategies presented in the SHERPA work sheet, it becomes clear that the highest percentages were related to the strategy of training for the use of gloves, the strategy of training for the methods of hand-washing and the strategy of provision of procedures and instruction for wearing gloves. Since, here, we have examined the training strategy for preventing all errors related to the infection control tools and methods and also it has been proposed in the all identified causes of errors, therefore, it is more comprehensive and prioritizing it, would result in more improvements. In the present study, the training strategy includes the training of dentists and nurses. As it was shown in Table 1, the solutions and the causes of the highest percentage of training strategies has been for eliminating the reasons for ineffectiveness of training materials 17/3%, forgetting the trained material 16%, lack of awareness 14/66%, and forgetfulness and distraction (due to hurry, fatigue and labor pressure) 13/3%. The effect of learning and forgetting processes on the performance of repetitive tasks has been widely studied and accepted in many sectors, including the healthcare sector [26]. *Di Pasquale et al.* (2016) examined variables such as the rate of forgetfulness and learning rates in the SHERPA model and presented a new model for greater efficiency and less error in laparoscopic surgery [26].

The highest rate in the provision of instructions and procedures is related to forgetfulness and distraction (due to the hurry, fatigue and labor pressure) with 17.3% and as mentioned earlier, 13.3% of the training strategy is related to the same reason. In order to get a significant result to avoid this type of errors, it is necessary to employ the training and instructional strategies together. In the studied dentistry clinic, there is no training program for infection control. Due to the importance of the training of night-shift workers in the hospitals, Sinha et al., have conducted a study about the several programs of night-shift doctors and it was found that 75% of these programs had no formal didactic training and 89.5% had no written policy [27]. By examining the percentages of the causes of errors that are related to the training strategies, it becomes clear that it is necessary to use techniques for effective training in the formulation of educational content. Therefore, educational and training planning should be performed with regard to the following items: events that had occurred in the clinic, most common errors obtained from the present study, issues that dentists and nurses are unaware of them and the patient's reports to the presiding office; of course, all of the mentioned items should be done according to educational standards. After planning and providing educational content, it would be very useful to hold training sessions throughout the year to remind the importance of infection control and to prevent forgetfulness. Educational and retraining classes can also increase the sensitivity of the individual towards the aforementioned items and, as a result, they can reduce the errors that occur because of forgetfulness and distraction (due to hurry; fatigue and labor pressure). For effective training, it is necessary to provide the critical instruction for individuals. Therefore, planning and implementing instructional guidelines and instructions must be done simultaneously. The proposed equipment should also be examined by clinical director and the appropriate instruction and guidelines should be presented to be used by dentists after training.

Finally, since the strategy of organizational policy possesses the lowest value and errors related to it do not impose a critical risk, its implementation and decision making about it can be placed in the last priority. According to the results, it seems that an IT-based knowledge management system would be effective in preventing the infection control in dentistry in the long run.

Present study has confronted with some limitations which are referred to below:

- Time limitation for dentists in the compressed work shift and the difficulty of making changes to their schedule for interviews
- Negligence of the importance and usefulness of conducting such studies by dentists in the clinic
- The difficulty of justifying and assuring the specialist dentists to cooperate with the researcher, given the lack of required educational and cultural contexts and their scientific level

Because of the three mentioned cases, the waiting time for interviewing and the duration of each interview was increased.

Conclusion

The present study has been conducted to identify the human errors and their causes in infection control practices such as hand hygiene and the use of personal protective equipment (PPE) among the specialized dentists. Findings show that one of the most common causes that result in errors is forgetfulness and distraction. After analyzing the errors and their reasons, strategies related to equipment, instructions, training, and organizational policies were presented for preventing or reducing errors. Since the training strategy has the highest value among other strategies, it is necessary to design and implement an educational program according to the needs of the dentist and nurses. It is suggested to hold annual training session on the use of personal protective equipment and hand hygiene for dentists in the clinics and in this session, the principles of personal protection should be instructed after the training needs assessment with an emphasis on the errors and their common causes, so that the dental errors can be prevented in the field of personal protection in infection control. According to the results of this research and similar studies [12 ,19 ,26 ,28], SHERPA can be a useful tool for identifying and evaluating human errors in healthcare. Also, the present study showed that identification of the causes of the errors can play an important role in the way of decision-making about strategies and the way of implementing and programming them.

References

1. Brauer, R.L., *Safety and health for engineers*2006: John Wiley & Sons.
2. Shivanand, H., *Flexible manufacturing system*2006: New Age International.
3. Kusiak, A. and S.S. Heragu, *Group technology.* Computers in Industry, 1987. **9**(2): p. 83-91.
4. Kohn, L.T ,.J.M. Corrigan, and M.S. Donaldson, *To Err Is Human:: Building a Safer Health System*. Vol. 627. 2000: National Academies Press.
5. Macías, A.E. and S. Ponce-de-León, *Infection Control: Old Problems and New Challenges.* Archives of Medical Research, 2005 :(6)36 .p. 637-645.
6. Al-Rabeah, A. and A.G. Moamed, *Infection control in the private dental sector in Riyadh.* Ann Saudi Med, 2002. **22**(1-2): p. 13-7.
7. Alavian, S.-M., et al., *Concerns regarding dentists' compliance in hepatitis B vaccination and infection control.* American Journal of Infection Control, 2005. **33**(7): p. 428-429.
8. .Smith, A., et al., *Management of infection control in dental practice.* Journal of Hospital Infection, 2009. **71**(4): p. 353-358.
9. Verbano, C. and F. Turra, *A human factors and reliability approach to clinical risk management: Evidence from Italian cases.* Safety Science, 2010. **48**(5): p. 625-639.
10. Wu, X., H. Huang, and G. Yang, *Group technology and its relation with CIM.* Computers in Industry, 1992. **19**(1): p. 143-149.
11. Sandom, C. and R.S. Harvey, *Human factors for engineers*2004: Iet.
12. Lane, R., N.A. Stanton, and D. Harrison, *Applying hierarchical task analysis to medication administration errors.* Applied Ergonomics, 2006. **37**(5): p. 669-679.
13. Kirwan, B., *Human error identification in human reliability assessment. Part 1: Overview of approaches.* Applied Ergonomics, 1992. **23**(5): p. 299-318.
14. Baber, C. and N.A. Stanton, *Human error identification techniques applied to public technology: predictions compared with observed use.* Applied Ergonomics, 1996. **27**(2): p. 119-131.
15. Stanton, N.A. and S.V. Stevenage, *Learning to predict human error: issues of acceptability, reliability and validity.* Ergonomics, 1998. **41**(11): p. 1737-1756.
16. Lyons, M., et al., *Human reliability analysis in healthcare: a review of techniques.* The International Journal of Risk and Safety in Medicine, 2004. **16**(4): p. 223-237.
17. Joice, P., G.B. Hanna, and A. Cuschieri, *Errors enacted during endoscopic surgery—a human reliability analysis.* Applied Ergonomics, 1998. **29**(6): p. 409-414.

18. Phipps, D., et al., *Human factors in anaesthetic practice: insights from a task analysis.* British journal of anaesthesia, 2008. **100**(3): p. 333-343.
19. Tang, B., et al., *Competence assessment of laparoscopic operative and cognitive skills: objective structured clinical examination (OSCE) or observational clinical human reliability assessment (OCHRA).* World journal of surgery, 2006. **30**(4): p. 527-534.
20. Embrey, D.E., *SHERPA: A systematic human error reduction and prediction approach*, in *Paper presented at the International Meeting on Advances in Nuclear Power Systems, Knoxville, Tennessee.*1986.
21. Stanton, N.A., et al., *Handbook of human factors and ergonomics methods*2004: CRC Press.
22. Harris, D., et al., *Using SHERPA to predict design-induced error on the flight deck.* Aerospace Science and Technology, 2005. **9**(6): p. 525-532.
23. Stanton, N., et al., *Handbook of Human Factors and Ergonomics Methods*2005, the United States of America: CRC Press
24. Warren, K „.*Strategic management dynamics*2008: John Wiley & Sons.
25. Al-Hakim, L., et al., *Human error identification for laparoscopic surgery: Development of a motion economy perspective.* Applied Ergonomics, 2015. **50**: p. 113-125.
26. Di Pasquale, V., et al., *Integration of learning and forgetting processes with the SHERPA model.* IFAC-PapersOnLine, 2016. **49**(12): p. 197-202.
27. Dhingra, K.R., A. Elms, and C. Hobgood, *Reducing error in the emergency department: a call for standardization of the sign-out process.* Annals of emergency medicine, 2010. **56**(6): p. 637-642.
28. Shams Ghareneh, N., et al., *Identification and evaluation of dentistserrors in Infection Control in a specialized clinic in Tehran.* Iran Occupational Health, 2015. **12**(5): p. 100-110.