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Case Study

Comparison of different methods for work accidents investigation in hospitals: A Portuguese case study

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Abstract.
BACKGROUND: The hospital environment has many occupational health risks that predispose healthcare workers to various kinds of work accidents.
OBJECTIVE: This study aims to compare different methods for work accidents investigation and to verify their suitability in hospital environment.
METHODS: For this purpose, we selected three types of accidents that were related with needle stick, worker fall and inadequate effort/movement during the mobilization of patients. A total of thirty accidents were analysed with six different work accidents investigation methods.
RESULTS: The results showed that organizational factors were the group of causes which had the greatest impact in the three types of work accidents.
CONCLUSIONS: The methods selected to be compared in this paper are applicable and appropriate for the work accidents investigation in hospitals. However, the Registration, Research and Analysis of Work Accidents method (RIAAT) showed to be an optimal technique to use in this context.

Keywords: Hospital, risk assessment, occupational accidents analysis

1. Introduction

Currently it is estimated that 1.7 million people die each year as a result of their occupation [1]. The International Labour Organization (ILO) found that, in addition to deaths, there are about 268 million non-fatal injuries which result in an average of three days of work lost by accident, as well as 160 million new cases of work-related diseases [1]. In many countries, and in particular in the European Union (EU), the risk assessment is a legal requirement as well as the notification of occupational accidents [2,3]. According to the Occupational Health and Safety Advisory Services (OHSAS) 18001:2007 on the requirements of the management of safety and occupational health, work accident (WA) is a "work-related event resulting in injury,

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health condition or death" [4]. According to the Portuguese legislation (article 8° in Lei n° 98/2009 de 4 de setembro), a WA is "one that takes place during working time and produces direct or indirect injury, functional disorder or sickness resulting in reduced ability to work or death" [5]. The accidents analysis and investigation not only represents a legal obligation (article 98° in Lei n° 102/2009 de 10 de setembro), but also aims to make improvements, both in terms of procedures, work practices and in assessment systems and risk control [6].

1.1. Accidents investigation methods

WA has negative impacts on workers' health and performance of the organization. Nevertheless WA can be understood as a source of information to process improvement and self-protection system as well as a way to provide an opportunity for correction and development [7,8]. The main objective of the accident investigation consists in the description of the course of events, however, is also essential to understand how the safety system failed and why the accident occurred. It is also important to provide feedback to decision makers about the causes of negative events since most organizations have implemented measures to prevent accidents [9,10].

The WA investigation methods might be direct or indirect, or also referred to as inductive or deductive, respectively. The direct methods are those that establish risk factors prior to the accident (Risk Assessment Methodology), while the indirect methods analyse accidents, providing information of the causal factors associated (Accident Analysis Methodologies) [11,12]. It should be noted that the causes are all factors that directly or indirectly have contributed to the accident. The WA does not result from one single cause but by multiple causes, which may be provided from all levels of an organization, such as equipment failures; action of hazardous substances; improper actions of the employee; insufficient supervision, among others [2].

Most accident models and theories applied in the field of occupational accidents are still based on the ideas in Heinrich's domino model, which is based on linear progression of events leading to the accident [13].

After that, several tools with different purposes, practices and conclusions have emerged, but all aimed to improve the occupational conditions [14]. The author Laflamme [15] ranked the models into four different approaches: decision, sequential, energy and organizational. On the other hand, Lehto and Salvendy [16] distinguished models of causality in three groups: general models of the accidents process, human error models and risk behaviours and models of mechanical damage. Kjellén [17] described five categories of models: the causal sequence, process, energy, logical tree and Safety, Health and Environment (SHE) management.

According to Hollnagel [18], the models are divided into sequential, epidemiological and systematic. In the sequential model, the accident is understood as the outcome from a series of individual steps organised according to their order of occurrence. Regarding the epidemiological model, accidents result from a sequence of events due to latent failures and active barriers in the system. These barriers, according to their position along the chain of events, delineate the presence of different work areas (safe, unsafe, and loss of control) [18]. On the other hand, the systematic model describes the accident as the result of a variability of multiple factors that are part of the production system [18].

The advanced version of Human Factors Analysis and Classification Systems (HFACS) based on Reason's model of latent and active failures has provided an applicable system for investigating human error in accidents and it is one of the most powerful tools for reconstructing human contributions to various types of accidents [19].

During the last decades, a number of methods for accident investigation has been developed and well described in the literature [8]. In this section a brief description of some selected methods are presented.

1.1.1. Fault tree (FT)

The fault tree analysis (FT) was developed in the early 60's by H. A. Watson Bell Telephone Laboratories [11]. This method represents a graph (logical tree) that displays various combinations of events through the use of logic gates, equipment failures, human errors and environmental factors that can result in accidents [8]. During the analysis procedure all the factors that may give a valid contribute are selected, in order to show the relationships (dependence or independence) and possible causes of the accident [12].

1.1.2. Causal Tree Method (CTM)

In the 70's the Institut National de Recherche et de Sécurité (INRS), developed the Causal Tree Method (CTM). Accidents analysis by the CTM can be associated with the sequential model [18]. The CTM assumes that accidents result from variations or deviations from the usual process, which can be related to individuals,

tasks, equipment and environment. The starting point of the tree is the final event, after that the investigator has to identify various causes for the accident, relating their causal links [14].

1.1.3. Swiss-cheese method (SCM)

The theory of "Swiss-cheese" focuses on the epidemiological model and describes the undesirable event through an analogy as an appearance of a disease or a Swiss-cheese [20]. Therefore it is understood that there are barriers along the layers of the system and that can be corrupted by active faults (committed by professionals with immediate consequences) and latent (structural conditions reflect the organization and do not have immediate consequences) of the system. Barriers that are degraded by latent conditions and active failures are classified into physical, functional, symbolic and immaterial and can be used in the analysis of pre-existing systems [21]. This classification differs from author to author, so the barriers can be also classified as administrative, management, preconditions, productive activities and defences [7].

1.1.4. Failure matrix (FM)

Failure matrix method (FM) can be applied to any system, or can be adapted to workplace accidents or other cases. The technique identifies the situation, explains the causes, consequential effects, the estimated frequency and severity. On the other hand, this procedure allows the ranking of accidents by level of risk and it might be a way to align priorities of preventive or corrective actions [22].

1.1.5. Work Accidents Investigation Technique (WAIT)

Work Accidents Investigation Technique (WAIT) was developed by Jacinto and Aspinwall [23], which integrated two approaches developed by Reason [20] and Hollnagel [18]. The method provides a complete set for their application in research and accidents analysis, comprising nine steps grouped into two sequential phases. The first consists in a simplified investigation, during which the causes and immediate circumstances and legal support are identified. In the second phase – frequently called a full investigation – other possible weaknesses and conditions within the organisation are also identified and analysed [23].

1.1.6. Registration, Research and Analysis of Work Accidents (RIAAT)

The Registration, Research and Analysis of Work Accidents method, developed in the project Coding, Analysis and Prevention of Accidents at Work (CAPTAR – "Learning to prevent") was tested with the collaboration of the Portuguese Authority for the Working Conditions (ACT) to investigate accidents and to promote good practice in matters related to accidents at work. The objective of the project was to increase the efficiency of the process and how the accident information is obtained, handled and used to improve safety [24]. The data is processed in a hierarchical cycle with different activities such as gathering initial information about the accident, their codification and interpretation (sometimes using pre-defined classification systems); research into the causes and underlying factors, and finally, how the information is used to learn and to develop prevention strategies. It is a tool that covers the entire cycle of the accident data [24].

1.2. Work accidents investigation in hospitals

Most WA investigation methods are targeted towards the industrial sector, particularly for high-risk industry [25]. However, other complex jobs with high levels of responsibility, such as hospital work where it is essential to implement measures that prevent accidents. The work performed in hospital environments is physically and psychologically intense, with the potential for burnout, stress and fatigue, which can result in errors [26]. There is also the risk of WA with serious consequences for healthcare workers and sometimes for patients.

The hospital organizations are among the most complex structures, given their diversity of services, facilities, equipment and their hierarchical system of several departments and professions (such as doctors, nurses, diagnostic and therapeutic health technicians, administrative personnel and general services). The hospital environment has many occupational health risks due to the variety of clinical and non-clinical tasks performed by healthcare workers. The exposures to psychosocial, chemical, physical, mechanical and biological hazards are common in hospital units [27] and predispose healthcare workers to different types of accidents.

In 2007, a total of 4593 accidents have occurred in Portuguese hospitals [28]. The professional category that presented more WA was the nurses, with 1991 cases, representing approximately 39.3% of total workers. However, the professional groups with a higher incidence rate of WA were the operational and auxiliary workers, with 93 and 90 accidents per 1000 professionals, respectively. Taking into account

the complexity of hospital organizations and the unacceptable consequences of such major WA in this environment, it is necessary to apply a suitable investigation method to obtain relevant information about accidents causes and also to prevent their occurrence. It is important to know more about the investigation methods and the performance of each one when applied to different types of accidents.

In order to take corrective and/or preventive actions to eliminate or minimize occupational hazards in these institutions, it is necessary to verify the applicability of effective models in the search of possible sources of occupational accidents in hospitals. This study aimed to compare WA investigation methods and verify their suitability in hospital environment. The study was conducted based on HFACS, a generic model that investigates the active failures by the operators combined with latent conditions upstream in the organization.

2. Methods

2.1. Characterisation of the hospital unit under study

This work was carried out between January and September of 2011. The hospital under study belongs to Portuguese public service and it is constituted by eleven stores building, two of them are located underground. It has a capacity of more than 1000 beds and various medical and surgical specialties as well as a variety of supplementary diagnostic and therapeutic support.

2.2. Definition of WA and investigation methods

The types of WA analysed were selected according to the national prevalence of WA in Portuguese hospitals [28]. Considering the numbers presented in this report the occurrence of occupational accidents, taking into account the action of an injury (an event that leads to injury), were mostly the "needle stick" with 1630 cases and "worker fall" with 1016 accidents. The agents that cause most injuries were tools/instruments with a prevalence of 43.6%, followed by floors, with 12.5%. The most common types of injuries were wounds, with 2025 occurrences, followed by sprains, with 714 cases.

A total of thirty accidents were analysed ($n = 30$). For each type of accident (needle stick, falls and inadequate effort/movement) were selected two different tasks for the application of investigation methods, as can be seen in Table 1. Different six WA investigation methods were studied: Fault Tree (FT), Causal Tree Method (CTM), Swiss-Cheese Method (SCM), Failure Matrix (FM), Work Accidents Investigation Technique (WAIT) and Registration, Research, Analysis of Work Accidents (RIAAT). These methods were applied based on the four following criteria:

Table 1
Type of accident and tasks selected for the application of investigation methods

Type of accidents	Tasks
Needle stick	Surgical procedures
	Medicines administration
Fall	Cleaning tasks
	Access to different areas
Inadequate effort/movement	Patients handling
	Manual handling

1) WA investigation method used in the studied hospital – CTM
2) The method tested by ACT – RIAAT
3) The investigation methods proposed by Hollnagel [18] – FT, SCM, WAIT
4) A simple method that allows the prioritization of corrective actions quickly – FM.

2.3. Support instruments for WA analysis

A checklist and a previously validated questionnaire were applied in order to characterise the work conditions and describe the accident situation. The checklist included six analysis topics: (I) General Conditions; (II) Working practices; (III) Materials and equipment; (IV) Other work-related factors; (V) Individual factors and (VI) Training, information, communication and awareness. The questionnaire has two main fields: (I) Professional identification; (II) Accident or incident characterisation.

The investigator was just an observer that was recording the data without intervening actively in the variables under study and analysing the cause-effect (causes of WA) [29].

2.4. Causes classification

The cause's classification was based on the Human Factors Analysis and Classification Systems (HFACS), which uses the same levels presented by Reason [19] in his model: organizational influences, unsafe supervision, preconditions for unsafe acts and unsafe acts [30]. The HFACS framework was developed by Wiegmann and Shappell [31] and it is present in Fig. 1.

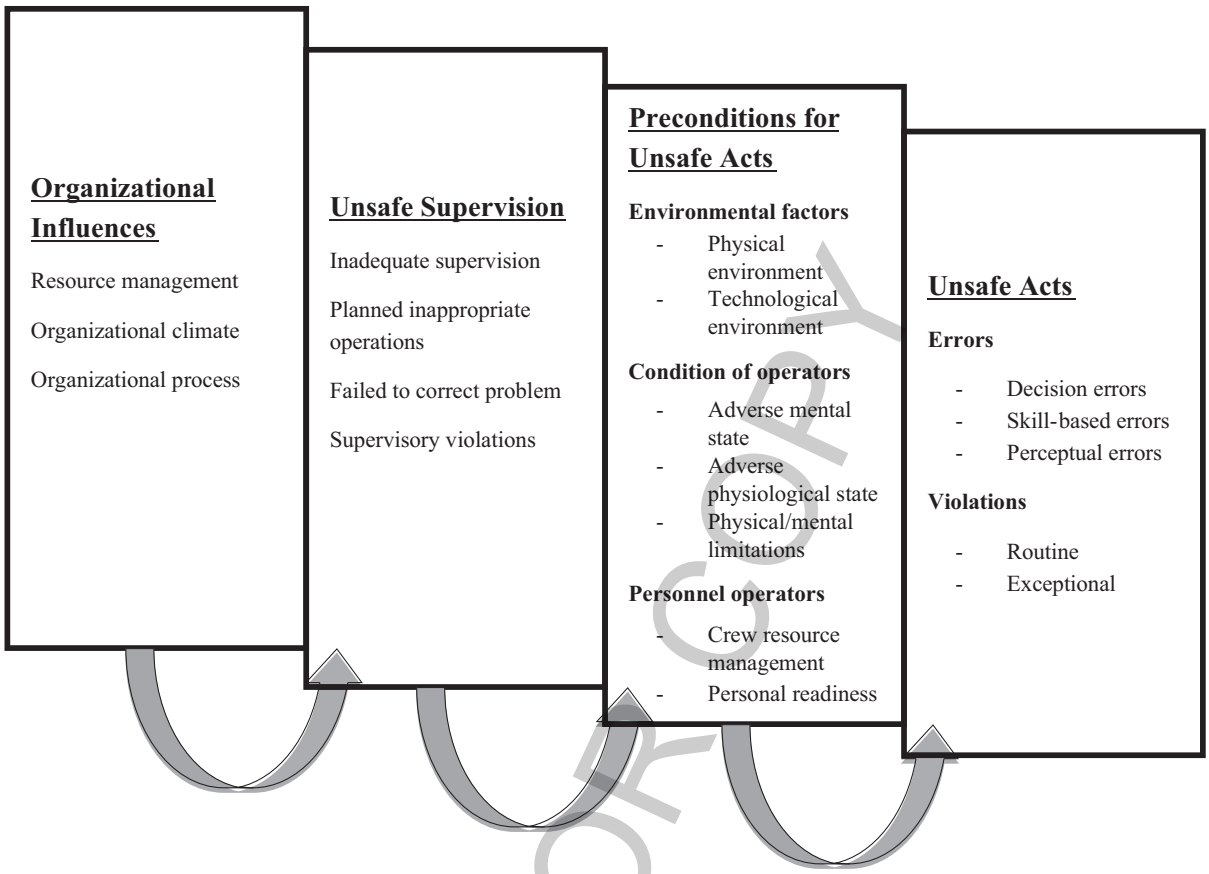

Fig. 1. Human Factors Analysis and Classification Systems (HFACS) framework (adapted from Wiegmann and Shappell [30,31]).

2.5. Analysis of selected methods for accident investigation

The advantages and disadvantages of WA investigation methods were analysed according to seven variables: 1) the degree of complexity, 2) time spent in the analysis, 3) number of variables to analyse, 4) accident complexity, 5) action plan, 6) Eurostat uniformity [32] and 7) hierarchy of action.

3. Results and discussion

3.1. Needle stick

Table 2 presents the "needle stick" WA analysed and the main causes responsible for its occurrence. The group of causes that had the greatest impact in this type of WA was organizational influences (39.5%) and it was related mainly to the lack of instructions and/or work procedures and material resources (for example, absence of containers for biological waste). However, in the accidents occurred during surgical procedures, it was observed that the causes identified were related to preconditions for unsafe acts (31.2%). In the case of accidents during medicines administration, the main cause was unsafe acts (13.3%). The WA occurred during the surgical procedures were generally associated with the lack of space and inadequate layout of the operating rooms. On the other hand, during medicines administration, inadequate elimination of perforate cutting material by healthcare workers was the most important cause for this type of WA. In fact, unsafe behaviours are involved in the increasing of the risk or probability of accidents [33]. As a matter of fact, one of the factors related to the accidents with perforate cutting material in hospitals is the negligence of healthcare workers [34].

3.2. Falls

The main causes of WA involving "falls" are presented in Table 3. For this type of WA, the results show

Table 2
Number and type of causes identified with different investigation methods in "needle stick" accident

Causes[a] / Methods[b]	Accident – Needle stick ($n = 10$)				
	A	B	C	D	Total
Surgical procedures					
CTM	1	4	1	2	8
FT	1	4	1	2	8
SCM	1	3	1	6	11
FM	1	3	1	2	7
WAIT	4	5	3	9	21
RIAAT	4	5	5	8	22
	12 (15.6%)	24 (31.2%)	12 (15.6%)	29 (37.7%)	77 (100%)
Medicines administration					
CTM	4	0	1	2	7
FT	4	0	1	2	7
SCM	3	0	1	5	9
FM	4	0	1	2	7
WAIT	2	5	5	10	22
RIAAT	3	5	5	10	23
	20 (26.7%)	10 (13.3%)	14 (18.7%)	31 (41.3%)	75 (100%)
Total	32 (21.0%)	34 (22.4%)	26 (17.1%)	60 (39.5%)	152 (100%)

[a]A – Unsafe acts; B – Preconditions for unsafe acts; C – Unsafe supervision; D – Organizational Influences; [b]CTM – Causal Tree Method; FT – Fault Tree; SCM – Swiss-Cheese Method; FM – Failure Matrix; WAIT – Work Accidents Investigation Technique; RIAAT – Registration, Research and Analysis of Work Accidents.

Table 3
Number and type of causes identified with different investigation methods in "falls" accident

Causes[a] / Methods[b]	Accident – Falls ($n = 10$)				
	A	B	C	D	Total
Cleaning tasks					
CTM	2	3	0	4	9
FT	2	3	0	4	9
SCM	2	3	2	7	14
FM	2	4	1	6	13
WAIT	5	7	1	8	21
RIAAT	3	7	0	7	17
	16 (19.3%)	27 (32.5%)	4 (4.8%)	36 (43.4%)	83 (100%)
Access to different areas					
CTM	1	4	1	4	10
FT	1	4	1	4	10
SCM	1	4	1	7	13
FM	1	4	1	7	13
WAIT	3	7	4	10	24
RIAAT	2	7	2	11	22
	9 (9.8%)	30 (32.6%)	10 (10.9%)	43 (46.7%)	92 (100%)
Total	25 (14.3%)	57 (32.6%)	14 (8.0%)	79 (45.1%)	175 (100%)

[a]A – Unsafe acts; B – Preconditions for unsafe acts; C – Unsafe supervision; D – Organizational Influences; [b]CTM – Causal Tree Method; FT – Fault Tree; SCM – Swiss-Cheese Method; FM – Failure Matrix; WAIT – Work Accidents Investigation Technique; RIAAT – Registration, Research and Analysis of Work Accidents.

that organizational influences were further the main group of causes, accounted 43.4% during cleaning tasks and 46.7% on access to different areas essentially associated with inadequate maintenance of infrastructure and lack of instructions and/or of work procedures. The second most important group of causes was preconditions for unsafe acts, representing 32.5% during cleaning tasks and 32.6% on access to different areas. These causes were related to low-light level conditions and disorganised workplaces. The unsafe acts had more influence in accident occurrence during cleaning tasks (19.3%) than during access to different areas (9.8%).

3.3. Inadequate effort/movement

Table 4 presents the main causes associated to WA involving "inadequate effort/movement" during patients handling and during manual handling, respec-

Table 4
Number and type of causes identified with different investigation methods in "inadequate effort/movement" accident

Causes[a] / Methods[b]	Accident – Inadequate effort/movement ($n = 10$)				
	A	B	C	D	Total
Patients handling					
CTM	4	1	0	6	11
FT	4	1	1	6	12
SCM	5	3	1	7	16
FM	4	1	1	6	12
WAIT	8	8	9	9	34
RIAAT	6	4	5	8	23
	31 (28.7%)	18 (16.7%)	17 (15.7%)	42 (38.9%)	108 (100%)
Manual handling					
CTM	5	0	0	6	11
FT	5	0	0	6	11
SCM	5	4	0	9	18
FM	5	0	0	6	11
WAIT	7	6	2	12	27
RIAAT	5	5	2	11	23
	32 (31.7%)	15 (14.8%)	4 (4.0%)	50 (49.5%)	101 (100%)
Total	63 (30.1%)	33 (15.8%)	21 (10.0%)	92 (44.0%)	209 (100%)

[a]A – Unsafe acts; B – Preconditions for unsafe acts; C – Unsafe supervision; D – Organizational Influences; [b]CTM – Causal Tree Method; FT – Fault Tree; SCM – Swiss-Cheese Method; FM – Failure Matrix; WAIT – Work Accidents Investigation Technique; RIAAT – Registration, Research and Analysis of Work Accidents.

Table 5
Overview of the application of analysis methods – advantages and disadvantages

	Degree of complexity	Time spent	Number of variables to analyse	Accidents complexity	Action plan	Eurostast uniformity	Hierarchy of action
CTM	Simple	3–5 min.	None in particular	Simple	No	No	No
FT	Simple	3–5 min.	None in particular	Simple	No	No	No
SCM	Intermediate	5–7 min	5 – No standardized	Intermediate	No	No	No
FM	Intermediate	5–7 min	None in particular	Intermediate	No	No	Yes
WAIT	Complex	Above 7 min.	4 – Standardized	Simple to complex	Yes	Yes	Yes
RIAAT	Complex	Above 7min.	4 – Standardized	Simple to complex	Yes	Yes	Yes

tively. In this type of accident, the organizational influences had also more influence in the WA occurrence, ranged between 38.9% and 49.5%. These results suggest that it is crucial to develop procedures and work instructions and create training programs focused on the manual handling activities. It is known that injuries occur most often while the patient is being transported and rarely associated to lifting operation [35]. Hence, the training programs should focus more in transporting activities than on that method of lifting. The unsafe acts had similar influence in WA occurrence on the two tasks analysed (ranged between 28.7% and 31.7%). For each group of causes, adoption of inadequate postures was the main factor identified. The influence of preconditions for unsafe acts was also similar in the different tasks, accounted for 16.7% during patients handling and 14.8% during manual handling. In fact, for both tasks, the lack of adequate equipment (for example, adjustable equipment) and the inadequate conception of workplaces were the main factors identified in this group of causes. Also note that for all accident type analysed, results showed that unsafe supervision had less influence in accidents occurrence.

3.4. Comparison of WA investigation methods

The results obtained in this study show that independently of the WA investigation method applied and the task analysed, the organizational influences was the main cause responsible for WA occurrence, highlighting the influence of top management on safety in the organizations [36]. As a result, the WA investigation methods should include variables capable to analyse factors associated with top management and their influences.

Table 5 presents the results relative to the perspective of the investigator according to seven variables defined on Section 2.5.

Even though the causes obtained after the application of the WA investigation methods were common, more complex methods (WAIT and RIAAT) were able to find new causes (of different levels of organization)

that complement the analysis of the simple methods. This can be seen Tables 2, 3 and 4. Many of the accident investigation methods are complementary and not mutually exclusive, such as CTM and FM methods [7]. The application of these methods depends on the experience and technical knowledge of WA because there are no predefined variables, but only an idea that causes can be related to the individual, task, equipment and environment. The main advantage of CTM and FM methods is that it requires little time to process information. Nevertheless, most hospital accidents are quite complex and depend heavily on administrative policies and management, which causes problems in interpreting the possible causal factors [14].

The theory of Swiss Cheese depends on the investigator (experience, qualifications, etc.) but it has already guidelines for analysis, called barriers. Their absence or outdating originates a failure, allowing the occurrence of WA. These barriers can cause difficulties, due to the inexistence of uniform literature for its analysis. In order to overcome this disadvantage, CTM or FT methods can be used not with the purpose of classifying the barriers but to provide information that can support this analysis [7]. These methods can be used as a complement of other techniques, such FM. This method ranks the priority intervention in accidents depending on the frequency, severity and/or probability of occurrence.

The application of WA investigation methods selected in hospitals are feasible, however, the WAIT and RIAAT methods have pre-defined variables that contribute for WA analysis, unlike the rest which depend on the investigators practice in relation to knowledge of the infrastructure, the functioning of the workplace and activities carried out by workers. The WAIT method is easy and practical to use in work accidents and incidents analysis on industries [2]. This application in hospital context is practicable because it takes into account the Eurostat pre-defined variables [32], contributing to the harmonization of European statistical analysis by integrating these variables [2,3,24]. Other advantage of this method is the ability to be compared and associated with the OSH Management System – OHSAS 18001:2007, as well as the prioritization of recommendation in terms of time and cost [2].

The RIAAT method is also considered a practical and structured tool, applied to learn and develop new prevention strategies, such as WAIT. These methods have several variables that simplify the interpretation of WA and should be applied in more serious and complex accidents. The correct application of WAIT and RIAAT methods implies that the investigators know every step of the method and have enough time for its application. The RIAAT allows, through a decision tree, to select more basic or detailed causes depending of the WA type. This makes the RIAAT method an adequate tool for use in hospitals.

4. Conclusion

Accident investigations are an integral part of any good safety and health initiative. It also, should be a formalized part of a company's safety and health commitment [37]. In many European Union countries, including Portugal, the existing legislation requires the occupational risk assessment and notification of occupational accidents and the investigation of its causes. These legislative measures provide improvements, according to the practices/procedures and the risk control systems, as a way to minimize the impact of work on workers' health.

This study showed that "organizational influences" are the most relevant cause of WA in hospitals, independently of the method applied. The methods used are not mutually exclusive. They can complement each other and be adaptable to the hospital environment.

The most complex methods have the disadvantage of being more time consuming. However, the RIAAT method in the implementation phase of the decision tree analysis allows the distinction between simple accidents (e.g. entrapment between objects) and more complex/frequent/severe accidents (e.g. needle stick). This method includes pre-defined variables of the WAIT method, making it a complete and proper technique. Besides that, experience from accidents shows that major accidents almost never result from one single cause, but usually involves multiple and interrelated causal factors.

This study pretends to be a contribution for the selection of methods for the analysis of occupational accidents in hospitals and a helpful contribute to improve the investigation system of WA in these institutions and in similar sectors such as Health Centre's and laboratories. Furthermore, this study can be expanded with further developments, such applying other investigation methods and by the analysis of more complex WA.

References

[1] International Labour Organization [homepage on the Internet]. Joint Press Release ILO/WHO Number of Work related

Accidents and Illnesses Continues to Increase ILO and WHO Join in Call for Prevention Strategies.: Communication and Public Information Unit; 2005 [cited 2011 May 20]; Available from: http://www.ilo.org/global/about-the-ilo/press-and-media-centre/news/WCMS_005161/lang–en/index.htm.

[2] Jacinto C. Análise de Acidentes de Trabalho. Método de Investigação WAIT (Work Accidents Investigation Tecnique), 4th ed., Lisboa: Verlag Dashofer; 2011a.

[3] Jacinto C, Soares CG, Fialho T, Antao P, Silva SA. An overview of occupational accidents notification systems within the enlarged EU. Work. 2011b; 39(4): 369-78.

[4] British Standards Institution. OHSAS 18001: 2007: Occupational Health and Safety Management Systems – Requirements. London: British Standards Institution (BSI) Publishers, 2007.

[5] Lei n° 98/2009, de 4 de Setembro de 2009: Regulamenta o regime de reparação de acidentes de trabalho e de doenças profissionais, incluindo a reabilitação e reintegração profissionais, nos termos do artigo 284.° do Código do Trabalho, aprovado pela Lei n.° 7/2009, de 12 de Fevereiro. DR, 1ª Série. 2009 Set 4;(172): 5894-5920.

[6] Lei n° 102/2009, de 10 de Setembro de 2009: Regime jurídico da promoção da segurança e saúde no trabalho. DR, 1.ª Série. 2009 Set 10; (176): 6167-6192.

[7] Ballardin L, Franz LA, Saurin TA, Maschio A. Analysis on the interfaces between causal models for accidents: A case study on maintenance activities in a hospital complex. Interface – Comunicação, Saúde, Educação. 2008; 12: 835-52.

[8] Sklet S. Comparison of some selected methods for accident investigation. Journal of Hazardous Materials. 2004; 111(1–3): 29-37.

[9] Harms-Ringdahl L. Analysis of safety functions and barriers in accidents. Safety Science. 2009; 47(3): 353-63.

[10] Lundberg J, Rollenhagen C, Hollnagel E, Rankin A. Strategies for dealing with resistance to recommendations from accident investigations. Accident Analysis & Prevention. 2012; 45: 455-67.

[11] Miguel AS. Manual de Higiene e Segurança do Trabalho. 10th ed. Porto: Porto Editora, 2007.

[12] Roxo MM. Segurança e Saúde do Trabalho: Avaliação e Controlo de Riscos. 2nd ed. Lisboa: Almedina, 2009.

[13] Heinrich WH. Industrial Accident Prevention. New York: McGraw-Hill, 1931.

[14] Katsakiori P, Sakellaropoulos G, Manatakis E. Towards an evaluation of accident investigation methods in terms of their alignment with accident causation models. Safety Science. 2009; 47(7): 1007-15.

[15] Laflamme L. A better understanding of occupational accident genesis to improve safety in the workplace. Journal of Occupational Accidents. 1990; 12(1–3): 155-65.

[16] Lehto M, Salvendy G. Models of accident causation and their application: Review and reappraisal. Journal of Engineering and Technology Management. 1991; 8(2): 173-205.

[17] Kjellén U. Prevention of Accidents through Experience Feedback. 1st ed. London: Taylor and Francis, 2000.

[18] Hollnagel E. Understanding accidents – from root causes to performance variability. 7th IEEE Human Factors Meeting; Scottsdale, Arizona, 2002, pp. 1-6.

[19] Reason J. Human Error. 1st ed. Cambridge: University Press, 1990.

[20] Reason J. Managing the Risks of Organisational Accidents. 1st ed. Ashgate Publishing Ltd, 1997.

[21] Hollnagel E. Barrier analysis and accident prevention. Ashgate Publishing Ltd, 2004.

[22] Freitas LC. Segurança e Saúde no Trabalho. 2nd ed. Lisboa: Edições Sílabo, 2011.

[23] Jacinto C, Aspinwall E. Work Accidents Investigation Technique – WAIT Part 1. Safety Science Monitor [serial on the Internet]. 2003; 7(IV-2): Available from: http://ssmon.chb.kth.se/vol7/4-2.pdf.

[24] Jacinto C, Guedes C, Fialho T, Silva A. RIAAT – Recording, Investigation and Analysis of Accidents – User's manual. 2010. Available from: http://www.mar.ist.utl.pt/captar/images/RIAAT%20Users%20Manual_revision%201.1_May%202010.pdf.

[25] Sklet S. Safety barriers: Definition, classification, and performance. Journal of Loss Prevention in the Process Industries. 2006; 19(5): 494-506.

[26] Mahmood A, Chaudhury H, Valente M. Nurses' perceptions of how physical environment affects medication errors in acute care settings. Applied Nursing Research. 2011; 24(4): 229-37.

[27] Rogers B. Health hazards in nursing and health care: An overview. American Journal of Infection Control. 1997; 25(3): 248-61.

[28] Amaral JC. Acidentes de Trabalho no Ministério da Saúde – Ano 2007. Lisboa, Portugal: Administração Central do Sistema de Saúde – Unidade Funcional de Estudos e Planeamento de Recursos Humanos, 2009. Administração Central do Sistema de Saúde. Acidentes de Trabalho no Ministério da Saúde – Ano 2007 [Internet]. Lisboa, Portugal; 2009 p. 27. Available from: http://www.acss.min-saude.pt/Portals/0/ Acidentes de Trabalho_2007.pdf.

[29] Roegiers X, De Ketele JM. Metodologia da Recolha de Dados, Fundamentos dos métodos de observações, de questionários, de entrevistas, e de estudos de documentos. Lisboa: Instituto Piaget, 1993.

[30] Wiegmann A, Shappell S. The Human Factors Analysis and Classification System – HFACS. Washington, DC: U.S. Department of Transportation – Federal Aviation Administration. 2000 Contract No.: DOT/FAA/AM-00/7.

[31] Wiegmann A, Shappell S. Applying Reason: The human factors analysis and classification system (HFACS). Human Factors and Aerospace Safety. 2001; 1(1): 59-86.

[32] Eurostat. European statistics on accidents at work (ESAW) – Methodology: DG EMPL D-5 and EUROSTAT E-3, 2001.

[33] Navarro JLM. El factor humano en la seguridad laboral. Psicología de la seguridad y la salud laboral. 1st ed. Bilbao: Lettera Publicaciones, 2007.

[34] Marziale MHP, Robazzi, MLCC. Occupational accidents with piercing and cutting instruments in hospital nurses. Nure Investigación [serial on the Internet]. 2004; 2: Available from: http://www.bvsde.paho.org/bvsacd/cd49/original2.pdf.

[35] St-Vincent M, Tellier C, Petitjean-Roget T. Accidents that occurred in three hospitals in one year. Safety Science. 1999; 31(3): 197-212.

[36] Rollenhagen C, Westerlund J, Lundberg J, Hollnagel E. The context and habits of accident investigation practices: A study of 108 Swedish investigators. Safety Science. 2010; 48(7): 859-67.

[37] Reese CD. Accident/Incident Prevention Techniques. 2nd ed. Boca Raton, FL: Taylor & Francis, 2012.