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SAFETY OF MACHINERY IN HOSPITALS: AN EXPLORATORY STUDY IN THE PROVINCE OF QUEBEC, CANADA

Abstract:

Safety of machinery is a major concern in the manufacturing sector, but machines are also present in many other fields of activities, including healthcare. With the importance of machine-related accidents, the risk management practices related to the safety of machinery in the manufacturing sector are well known and documented. However, there is very little knowledge about the importance of machinery-related risks and their management practices within the hospital sector. The exploratory study presented in this paper addresses (i) the context of safety of machinery in hospitals; (ii) the characteristics of the machines used and their inherent hazards; and (iii) the level of integration of risk management practices for the safety of machinery in hospitals, such as risk assessment, machine safeguarding, lockout/tagout, inspection, and training. Five hospitals were visited and a questionnaire was used to collect the opinions and perceptions of non-medical managers and workers regarding machinery risk management. A total of 17 managers and 17 workers were interviewed. Documents related to machinery risk management practices, and information regarding the machines used and their hazards, were also collected. The results show that machine-related risks are a reality in this sector and that safeguarding of machinery is often deficient. None of the visited facilities had machine risk assessment procedures, a lockout/tagout program, or any specific document on safety rules related to machine hazards. Yet, the majority of managers and workers agree to say that these practices are relevant and can be implemented in the hospital sector. The results suggest that the hospital sector is generally aware of the best practices in machinery risk management, but that their level of implementation is lower than what can be observed in the industrial sector.

1 INTRODUCTION

1.1 Context of the Research

Occupational Health and Safety (OHS) in the healthcare sector has been an important preoccupation for many years. In the province of Quebec, in Canada, there were, in 2013, 117 hospitals employing 200,000 workers (ISQ, 2014.). Almost half of these workers comprises nursing staff (nurses, practical nurses, orderlies). The statistics of the *Commission des normes, de l'équité et de la santé et sécurité du travail* (CNESST, the governmental organization that focuses on the prevention and recovery of work accidents) show that between 2002 and 2011, general medical and surgical hospitals in the province reported 38,241 work accidents or occupational diseases involving on average 59 days of absence (CNESST, 2016). In the United States, the Occupational Safety and Health Administration (OSHA) indicates that hospitals are among the most hazardous sectors for the workers. In 2011, this sector recorded 253,700 work accidents and occupational diseases, which corresponds to 6.8 injuries and diseases per 100 workers. In comparison, the manufacturing industry reported, for the same year, 4.3 injuries

and diseases per 100 workers, and the construction sector, 3.9 injuries and diseases per 100 workers (OSHA, 2013). Still according to the OSHA, the healthcare sector has shown improvement regarding OHS in the last years, but did not do as well as other sectors (OSHA, 2013).

Many authors obviously concentrated their efforts on the numerous hazards that affect the workers in this sector. These include: biological risks (contagious and infectious diseases, needle stick injuries), ergonomic risks (patient handling, bad postures, repetitive movements), chemical risks (various chemicals used for disinfecting and sterilizing, anesthetic gases, drugs, or medications), physical risks (radiation from X-rays and radioisotopes, lasers), psychosocial risks (stress, burnout, violence), and mechanical risks (slips, trips and falls, equipment-related hazards) (Gorman et al., 2013). The vast majority of these studies often focused on the risks affecting the medical staff such as doctors, nurses, orderlies, etc. Since they represent a significant portion of the workers in this sector, it is normal to pay particular attention to them. However, it is important to note that many other workers are exposed to different risks, and that these risks can sometimes seem of second order within this sector.

It is notably the case with respect to equipment and machine risks. With the importance of machine-related accidents, the risk management practices for safety of machinery in the manufacturing sector are well known and documented. However, there is very little knowledge about the importance of machine risks and their management practices within the hospital sector. In fact, in a hospital, there are many areas where workers are exposed to machine hazards. For example, the laundry room, kitchen, mechanical workshop, boiler room, HVAC installations, as well as waste management are a few services in a hospital that present machine-related risks for the workers, in particular the non-medical staff (Tweedy, 2005).

1.2 Safety of Machinery

All around the world, accidents caused by machinery are an important issue for prevention and compensation organizations. In the United State, from 1980 to 1989, 8,505 machine-related deaths were reported, which corresponds to 0.8 deaths per 100 workers (Pratt et a. 1996). Machine-related accidents would thus be responsible for one third of the deaths at work in the United State (Etherton et al., 2008). More recently, the US Bureau of Labor Statistics reported 717 deaths associated with machinery in 2013 (US Bureau of Labor Statistics, 2014). In Turkey, fractures and amputations account for 64.9% of the injuries and diseases caused by agricultural

machinery (Akdur et al., 2010). In Germany, 37% of the safety devices on metalworking machinery are voluntarily neutralized (Lüken, K., et al., 2006). In Quebec, the CNESST reports that machine-related accidents represent approximately 15% of all compensated accidents, leading to 71.5 million dollars in annual disbursements (CNESST, 2014).

Machine-related accidents can have different causes. The main cause is the absence of a protector or protection device (54% of the cases) that is lacking at the design level, or that has been neutralized by the users (Backström & Döös, 2000). It represents a high proportion, that is actually confirmed by researchers from the *Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles* (INRS) in France, who estimated that 32% of the accidents are due to the absence of protective measures (Dei Svaldi & Charpentier, 2004). Since neutralizing protective measures can sometimes be tolerated by the employer, its frequency is increasing. The neutralization done by the workers is often the result of a flaw of the human-machine interface, or an inadequate integration of the safety measures at the design stage (Lüken, K., et al., 2006). Another important cause of accidents is the machine's residual movements, often of pneumatic or hydraulic nature, that have not been taken into account. In France, 20% of the machine-related accidents would be due to the inopportune movement of an automated machine (Dei Svaldi, & Charpentier, 2004). Poorly designed protective devices that prevent only partial access to the hazardous areas can also explain many accidents.

1.3 Management of Machine Risks

Considering the importance of the risks posed by machines, the manufacturing sector has, for a long time, put in place many approaches aiming at managing the risks inherent to their utilization. This sector is well documented and equipped regarding machine risk management. Machinery manufacturers first need to comply with a number of standards and design their machine in a way to eliminate or reduce the risks at the source and, where necessary, add safeguards and inform the users of the residual risks and on the measures that need to be taken to control them (CSA, 2004; ISO, 2010). Other risk management approaches also need to be implemented by the users of the machine (i.e. companies and employees that use them), in order to reduce the risks related to their specific utilization on the field. Among them, machine safety literature generally states (i) risk assessment, (ii) safeguarding, (iii) lockout/tagout procedures, (iv) machine inspection, and (v) training (Parker et al, 2016; Poisson & Chinniah, 2015; CPSSTQ, 2004; CSST, 2006; European Union, 2006). The following sections summarize each of these risk management approaches.

1.3.1 Risk Assessment

Risk assessment is a process that is part of risk management, as proposed by international standard ISO 31000 – *Risk Management – Principles and guidelines* (ISO, 2009). This general standard, that provides principles, a framework and guidelines to manage all kinds of risks (such as environmental risk, professional reputation, economical risks, etc.), promotes risk assessment as a structured method to identify hazardous situations and evaluate their level of severity. For machine risks, the international standard ISO 12100 (ISO, 2010) S*afety of machinery -- General principles for design -- Risk assessment and risk reduction*, explains the different aspects of machinery risk assessment. This standard defines risk analysis as the combination of: (i) determination of the limits of the machinery, (ii) hazard identification, and (iii) risk estimation (Figure 1). Risk analysis provides the necessary information for risk evaluation, which completes the risk assessment process and allows to make decisions regarding the necessity to reduce the risk. Although this standard is aimed mainly at the designer of the machine, its principles can also be implemented by the user, who is responsible for the safety of the machine in its context of implementation and utilization. For its part, the Canadian Standard CSA Z432-04 (2004) *Safeguarding of Machinery* provides indications with respect to the requirements that need to be followed by machine designers and machine users regarding risk assessment.

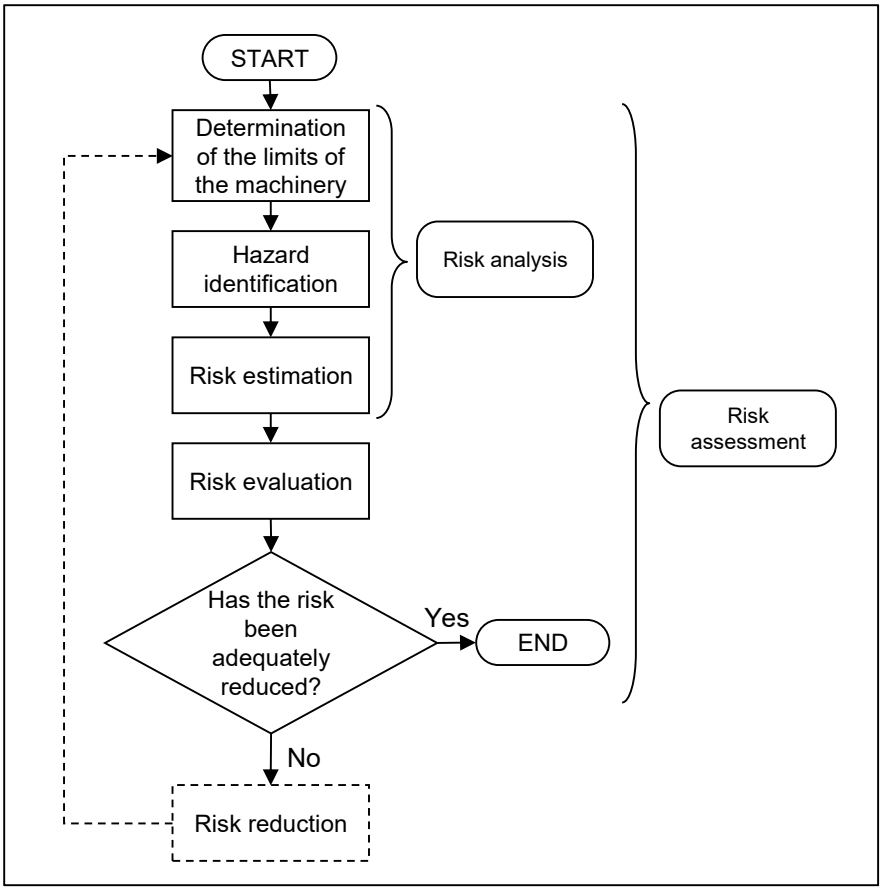

Figure 1 The risk assessment method according to the Standard ISO 12100 (ISO, 2010)

Risk assessment has been integrated to risk management practices within many organizations for several years. Risk assessment tools are well known, adapted and used in the chemical, nuclear and aeronautical industries since the 60s (Main, 2004). In response to machine risks, the mining and manufacturing sectors have also adopted this risk management practice (Pelchat & Gauthier, 2015; Mrugalska, & Kawecka-Endler, 2011). The investigation reports on severe and fatal accidents involving machinery often identify the absence of risk assessment, or a poor risk assessment, as an important contributing factor (Chinniah, 2015). Some studies also show the positive impact of good risk assessment practices on the overall safety performance of companies (Liu et al., 2014).

1.3.2 Safeguarding of Machinery

Machine-related accidents are often due to the fact that the users may access the different hazardous zones of the machines (CSST, 2005). Various safeguards can be implemented in order to prevent such hazardous situations. Machine safeguards are « *protective measures using*

safeguards to protect persons from the hazards which cannot reasonably be eliminated or risks which cannot be sufficiently reduced by inherently safe design measures" (ISO, 2010). Fixed, movable or adjustable guards and protective devices such as interlocking devices, sensitive protective equipment, and limiting devices are among the safeguards the most commonly used.

Although machine manufacturers now have the obligation to design safe machines, the literature clearly shows that the integration of safety in the design stage is a complex process, and that the level of expertise on that matter varies considerably, especially when it comes to the use of normative or regulatory documents (Sangaré et al., 2012). The study of Cordero et al. (2009) demonstrates that an important proportion of the machines available on the European market do not meet all the safety requirements of the Machinery Directive of the European Union (European Union, 2006).

Also, since machines can often have a considerable life span, it is not rare to find in every working environment machines that do not meet the up-to-date safety standards. Furthermore, the safety level of certain machines might have been altered through modifications made by the users over time. Modifications or bypasses of safeguards are often the cause of numerous accidents (Chinniah, 2015; Apfeld, 2010; Hopkinson & Lekka, 2013). The majority of the laws and regulations regarding OHS compel organizations to ensure that the equipment they provide to their workers is entirely safe. In the province of Quebec, CNESST inspectors have implemented since 2005 a « zero tolerance » policy concerning the access to the hazardous zones of the machines. When movable parts of the machines are accessible, inspectors may fine the company and oblige them to immediately correct the problem (CSST, 2005). Consequently, within an integrated machine risk management approach, organizations must, on a regular basis, carry on adequate inspections of the safeguards of the machinery they use. Many safety organizations propose guides on the safeguarding of machinery for machine users (Queensland Government, 2015; OSHA, 2007).

1.3.3 Lockout/tagout

Lockout/tagout consists in a series of practices and procedures that aim at neutralizing all sources of energy of the equipment before a person's intervention (CSA Z460-05, 2010). This approach allows, among other things, for a worker to make sure that he can intervene in the hazard zone of a machine during maintenance, repair and unblocking operations, and that the machine will not start operating accidentally. The lockout/tagout approach needs to be structured through a

lockout/logout program, and the workers that need to work in the hazardous zones of machinery need to implement lockout/tagout procedures (Chinniah & Burlet-Vienney, 2013; Daoust, 2009).

In light of an analysis of 106 reports on severe or fatal accidents, Chinniah (2015) indicates that in 33 cases, the company did not have lockout/tagout programs or procedures in place, and that in 21 cases, some procedures existed but were not used. As other authors (Bulzacchelli et al, 2007, 2008; Shaw, 2010) demonstrated it, the omission of the lockout/tagout procedure is a significant cause of machine-related accidents. The numerous guides published on that subject also show the importance of lockout/tagout within machine risk management (OSHA, 2007; INRS, 2014).

1.3.4 Inspection

Inspection of equipment and workplaces has always been part of the preventive approach in OHS. It is also generally included in the requirements to be met by employers, which are indicated in different OHS regulations, such as the OSHA 1910 standard (OSHA, 2016a). This standard comprises a set of systematic operations that aims at identifying the irregularities that could occur in a workplace, in order to identify the potential risks related to the machinery, tools, tasks, environment or layout of the workplace. Inspections allow to identify deviations from standards and regulations, wear and deterioration of the equipment, unsafe working methods, etc. (Government of Canada, 2007).

In an exploratory study focusing on facilitators and barriers to OHS in small and medium-sized enterprises, Nowrouzi et al. (2016) found that conducting regular external safety inspections of the workplace was statistically associated with a safer work environment. Moreover, periodic safety inspections were also the most commonly reported safety activities in a study conducted among small business in the United States (Sinclair & Cunningham, 2014).

In machine risk management, inspections play an important role in the identification of wear conditions or flaws that could result in accidents with injuries or diseases (Bourassa et al. 2016). It also allows to quickly detect safeguard bypasses on the machinery.

1.3.5 Training

Training allows to develop the worker's knowledge and necessary expertise to deal with the residual risks of a given work situation. It can also support motivation while arousing the workers'

interest towards prevention. An appropriate training allows to bridge the gap between the existing skills of the worker and the required skills in order for him to carry out his tasks safely, as well as understanding the hazards to which he is exposed. This knowledge and skill improvement through training allow the worker to adopt better working methods, thus reducing the number of potential injuries (Robson et al., 2012).

Because of its impact on the implementation of protective measures implemented by the users, training becomes an unavoidable machine risk management practice. The standard ISO 12100 (2010) specifies that the protective measures that need to be implemented by machine users include safe working procedures, supervision, work permit systems, utilization of personal protective equipment, and training. Training directly impacts the efficiency of these protective measures (CSA Z432, 2004).

1.4 Machine Safety in Hospitals

A machine is defined as an "*assembly, fitted with or intended to be fitted with a drive system consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application"* (ISO12100: 2010). Based on this definition, the hospital sector uses numerous machines. In addition to the healthcare machines (imaging devices, mechanical beds and stretchers, patient lifts, etc.), machines also used in different industrial sectors can be found in hospitals. TABLE 1 presents some examples of machines that are frequently used in different services of the hospital sector. These services employ a great proportion of the non-medical staff in the hospitals, and include the majority of the machine hazards to which are the workers exposed in this sector (Tweedy, 2005). It can be noted that these machines are used in many other sectors, and that they are the cause of numerous occupational injuries and diseases and deaths (Chinniah, 2015, Marsh & Fosbroke, 2015; Sabourin, 2008).

TABLE 1: EXAMPLE OF THE MACHINES USED IN THE HOSPITAL SECTOR

Services of the hospital sector	**Examples of machines**	
Laundry: Operations related to the washing of hospital linen.	• Industrial washing machine • Industrial drying machine • Rotary spin dryer	• Washing tunnel • Linen pressing • Folding press • Handling trolley
Food: Preparation of the meals for the patients, and management of the cafeteria.	• Whisk/blinder • Kitchen grinder • Meat slicer	• Vegetable slicer • Meat mincer • Dishwasher with conveyors
Maintenance: Maintenance and repair services.	• Band saw • Drill press • Metal lathe	• Hydraulic press • Table wood-cutting saw • Bench grinder
Physical installation: Systems related to heating, air conditioning, and ventilation.	• Ventilation systems • Furnace • Emergency generator	• Revolving shutters • Pumps • Compressors
Hygiene and salubrity: Regular and specialized housekeeping; waste management.	• Floor industrial washer • Floor polisher • Pressure washer	• Garbage compactor • Vacuum cleaner • Fan

As for work accidents, statistics show that a strong proportion of the injuries and diseases in the hospital sector are sprain and strain injuries associated with patient handling, and mainly affect the nurses and nursing aides, that actually represent almost half of the workers in this sector (CNESST, 2016; Sharan et al., 2015; OSHA, 2013; Government of Alberta, 2011a). Accidents specifically affecting the non-medical staff in hospitals are less obvious in terms of statistics. However, as mentioned by the OSHA (2016b) *"In addition to the medical staff, large healthcare facilities employ a wide variety of trades that have health and safety hazards associated with them. These include mechanical maintenance, medical equipment maintenance, housekeeping, food service, building and grounds maintenance, laundry, and administrative staff."* The statistics still show that the contact with objects accounts for 10% to 13% of hospital workers' injuries (OSHA, 2013, Government of Alberta, 2011b). However, these accidents can be provoked by many different sources other than machines. In fact, because of their low relative impact, data on machine-related accidents are rarely found in the literature. TABLE 2 below shows some statistics for the hospital sector (general medical and surgical hospitals) from the CNESST in the province of Quebec, between 2002 and 2011.

TABLE 2: STATISTICS REGARDING MACHINE-RELATED ACCIDENTS IN THE HOSPITAL SECTOR FROM 2002 TO 2011 (CNESST, 2016)

Source of injury	Injuries and diseases resulting in days away from work
Machines used to work special materials, wood or metal	30
Machines, diverse	67
Handling machines	40
Machines, not specified	30
Heating, cooling and air conditioning machines or devices	157
Machines used for special processes	184

Although this data provide little indications of the relative scale that can represent machine risks in the hospital sector, they show that machine-related accidents are well present in this sector. The study of Bédard and Métra (2010) indicates that, from 2006 to 2008, 20.8% of the accidents in the food service of the healthcare sector were caused by machines, parts, material, or tools, including many events involving meat slicers. A Brazilian study concludes that cooks (e.g. injured when handling machines to cut vegetables) and woodworkers (e.g. injured when using electrical saws) were the positions in which there were higher risks of typical accidents in a university hospital (Sêcco et al., 2008). In 2015, a laundry worker was seriously injured after being caught up in machinery at Kelowna General Hospital, in the province of British Columbia, Canada (McDonald, 2015). These examples show that even if machine risks do not represent the main preoccupation of this sector, their impact is not insignificant in hospitals.

Concerning the machine risk management practices, very little is known regarding the situation within the hospital sector. In 2005, Bédard & Metra (2005) carried out an investigation regarding the obligation to lockout/tagout, as well as the awareness with respect to the regulation in Quebec's healthcare facilities. The results show that only 25 out of the 106 responding facilities have some sort of a written structure to manage lockout/tagout. One fifth of the facilities considered that lockout/tagout did not seem to apply to the healthcare sector, and more than the third of them stated not knowing the risks associated with omitting to lockout/tagout. This survey also reveals that sources of hazard (hazardous tasks and phenomena) are identified in a little less than 15% of the cases, and are documented in one healthcare facility out of six. It is also mentioned that among the facilities that do have a lockout/tagout program, an inventory of the machines is done in less than one third of the cases, and only 7% of the latter have identified the sources of hazards on these machines. These numbers, thus raise the following reflection: *"if*

risk assessment is not carried out in the first place, what is the relevance, exhaustiveness, and efficiency of the implemented measures?" (Bédard & Metra, 2005).

Some safety organizations have published guidelines presenting the best practices revolving around the management of general risks in the hospital sector. These documents make some references to the management of machine risks, but insist mainly on the main risks in the sector, such as sprain and strain injuries, and biological risks (OSHA, 2013, Government of Alberta, 2011a, European Agency for Safety and Health at Work, 2011, European Commission, 2011). The *Association sectorielle pour la santé et la sécurité du travail du secteur affaires sociales* (ASSTSAS – an OHS association for the social services sector) as released a few documents on the management of machine risks, notably lockout/tagout, risk assessment, and equipment inspection in order to support its member organizations, including many hospitals (Chinniah & Bourbonnière, 2007; Metra, 2009, 2010; Metra & Rossignol, 2010; Villeneuve & Metra, 2010).

2 OBJECTIVES AND METHODS

The literature review presented in the introduction of this article demonstrates that only a few researchers showed an interest in machine safety in the hospital sector, and more particularly, regarding the management of machine risks. The portrait of the sector on that matter remains incomplete, both at the national and international levels. Many observations can be made from the analysis of the current context that dominates in hospitals:

i. We found in hospitals many machines presenting hazards known in other sectors;

ii. Even though machine risks represent a low proportion of the inherent risk in this sector, machine-related accidents do occur in hospitals;

iii. Occupational health and safety remains an important preoccupation for this sector, which has improved its OHS results in the last years, but did not do as well as other sectors;

iv. Machine risk management practices are well-known and well documented in many industrial sectors, such as the manufacturing and mining industries;

v. Machine risk management practices currently put in place in the hospital sector are very little documented.

In light of these observations, the main objective of this study was thus to characterize the level of integration of safety of machinery management practices in different hospitals in the province of Quebec, based on factual data, perceptions, and opinions of the people working in this sector.

In order to achieve this objective, a field investigation was carried out in five hospitals of the province. This investigation focused on four services where the non-medical staff concerned with machine safety mainly work: (i) laundry service, (ii) food service, (iii) maintenance and physical installation service, and (iv) hygiene and salubrity service. In these services, different people affected by machine safety were interviewed. Documents related to machine risk management practices in effect in each facility were also collected. The study was completed by visits of the different services, which allowed to collect information regarding the machines used and their hazards.

The next sections present the main methodological components of the study.

2.1 Preparation of the Questionnaire

A questionnaire was prepared by the authors in order to collect the opinions and perceptions of the people working in the sector regarding machine safety in general, as well as machine risks management practices. The questionnaire was based and structured around the five machine risk management practices defined in section 1.3, namely (i) machine risks assessment, (ii) safeguarding of machinery, (iii) lockout/tagout, (iv) machine and equipment inspection, and (v) training.

The key elements of these practices were extracted from the literature and edited into specific statements. Some elements contained in Quebec *Regulation respecting occupational health and safety* were also included in the questionnaire (Éditeur officiel du Québec; 2016). For each statement, a scale of 1 (strongly disagree) to 6 (strongly agree) was used. When the participant did not have any opinion regarding the statement, he or she could choose “Do not know.” For the analysis of the results, it was deemed that the respondents were essentially disagreeing with a statement when the average of the results of this statement was equal or below 3.0 (out of 6). The answers “Do not know” were not taken into account.

A field trial carried out with one OSH manager and one worker ensured that the potential participants understood the statements, and allowed to establish the time required to answer the

questionnaire. Minor modifications to some questions were made before conducting the full investigation. TABLE 3 presents an example of a part of the questionnaire used.

TABLE 3: STRUCTURE OF THE QUESTIONNAIRE

Person interviewed: _____ Theme: Machine risk assessment	Your opinion						
	Do not know	Strongly disagree					Strongly agree
1. Machine risk assessment consists in a useful preventive approach in the hospital sector.		1	2	3	4	5	6
2. Machine risk assessment is a well-known method within our facility.		1	2	3	4	5	6
3. …		1	2	3	4	5	6

2.2 Description of the Sample

The OHS manager in the five facilities visited were the initial contact for the study. The job titles of these people were as followed: OHS head, OHS advisors (2), physical facility manager, and OHS clinician nurse. Seventeen (17) service managers were then interviewed: physical facility manager, head of the laundry service, head of the food service, head of production of the food service, head of the hygiene and salubrity service, head of operations of the food service, and food service coordinator. Seventeen (17) employees were also selected by their respective manager to participate in the study. TABLE 4 presents the distribution of the managers and workers interviewed in the five hospitals visited.

TABLE 4: DISTRIBUTION OF THE MANAGERS AND WORKERS PER SERVICE

Hospital	Services	Managers	Workers
A	Laundry room	1	2
	Food service	2	2
	Maintenance and physical installation	2	3
	Hygiene and salubrity	0	0
B	Laundry room	1	0
	Food service	1	1
	Maintenance and physical installation	1	2
	Hygiene and salubrity	1	0
C	Laundry room	0	1
	Food service	1	0
	Maintenance and physical installation	1	1
	Hygiene and salubrity	1	0
D	Laundry room	0	0
	Food service	1	1
	Maintenance and physical installation	1	1
	Hygiene and salubrity	1	1
E	Laundry room	0	0
	Food service	1	1
	Maintenance and physical installation	1	1
	Hygiene and salubrity	0	0
Total persons met		17	17

2.3 Visits and Interviews

For each healthcare facility, an explanatory letter was sent to the OHS manager in order to obtain the necessary authorizations for the realization of this project. Within this letter were specified the information sought, including a list of documents asked with respect to the management of machine risks (TABLE 5), the targeted services, the persons to be met, as well as the time required for the interviews. The typical length for a facility visit was of about one day, but when the hospital had many buildings, the visit could last two days. The visits started with a meeting of 45 to 90 minutes with the OHS manager to collect factual data related to the machinery risk management practices in place in the hospital. The list of requested documents (TABLE 5) was then reviewed. Copies of some documents were obtained, while other documents could only be consulted on-site.

An observatory visit in each of the services then allowed getting an overview of the situation concerning the machines used and their potential hazards. With the consent of each facility, some pictures were taken, and a summary list of the equipment and machines was composed. Considering the time granted for the visits, this part of the data collection was not systematic and not all sectors and machinery could be properly observed. The main objective was for the researchers to become familiar with the typical machines and related hazards found in each service, not to produce a comprehensive list of machines or a detailed risk assessment. Therefore, this qualitative information could not be directly compared with the results from the questionnaire.

Individual interviews of 60 to 90 minutes were carried out (in French) with the managers and the workers of the visited services. The questionnaire aiming at collecting their opinions and perceptions was used.

3 RESULTS AND DISCUSSION

3.1 Machine-Safety Related Documentation Available

TABLE 5 shows the list of documents related to the management of machine risks consulted or obtained through the OHS manager in the different hospitals visited. The availability or non-availability of these documents are indicators of the level of implementation of machine risk management practices. As shown by the table, all the hospitals mention having an accident, incident and first aid register, but only one has a prevention program in place. Moreover, none of them could present a procedure or guide related to machine risk assessment, a document providing specific safety rules related to machine hazards, a document showing the results of a machinery risk assessment, nor a document presenting a project linked to the safeguarding of machinery. It can also be noted that none of the five hospitals visited had a formal equipment lockout/tagout program.

TABLE 5: COMPILATION OF THE DOCUMENTS COLLECTED

Documents sought	Compilation of the documents	
	Existing	Obtained or consulted
The prevention program of the facility	1	0
Accident, incident and first aid register	5	3
Statistics of accidents and incidents related to machines and equipment used by non-medical staff	3	2
Machine risk assessment procedures	0	0
Document providing specific safety rules related to machine risks	0	0
Document communicating the risk assessment results and follow ups regarding corrective measures	0	0
Document presenting a project linked to the safeguarding of machinery	0	0
Lockout/tagout program	0	0
Inspection register	1	0
Inspection grid or checklist	1	0
Training register	1	0
Other documents obtained		
Preventive maintenance program for the equipment	1	1
Occupational health and safety policy	1	1
Maintenance procedures for kitchen equipment	2	1

In some cases, the OHS manager mentioned having in place an inspection register, an inspection grid or checklist, as well as a training register, but none of these documents could be consulted.

Other documents were also obtained. One of the hospitals had a general occupational health and safety policy. Another one had preventive maintenance procedures for some equipment, and two other facilities could provide maintenance procedures for some equipment in the food service, for example for a bagging machine and an electric slicer.

3.2 Typical Machines and Hazardous Situations

During the visits, more than a hundred hazardous situations or nonconformity regarding machines could be observed and documented. Theses hazardous situations or nonconformity were observed without any specific risk assessment.

The following figures illustrate a sample of these observations in different services of the five facilities. In the laundry service, Figure 2a shows an industrial washing machine that does not have a protection panel to prevent access to the hazard zone at the back (Figure 2b).

a) Industrial washing machine

b) No protector

Figure 2 Examples of observations in the laundry service

In the food service, a machine used to slice vegetables do not have a hand protector (Figure 3a). It can be noted that the openings of this vegetable slicer allow an easy access to the knives (Figure 3b).

a) Vegetable slicer

b) Accessible knives

Figure 3 Examples of observations made in the food service

In the maintenance and physical installation service, some furnaces were equipped with multiple pumps, valves, and many support systems that ensure their good operation. Figure 4a illustrates a bench grinder without any protection against projections. As for Figure 4b, it shows a non-compliant protector on a pump motor that does not prevent access to the drive belt.

a) Bench grinder not well fixed, with no protector

d) Drive belt without protector

Figure 4 Examples of observations made in the maintenance and physical installation services

Finally, in the hygiene and salubrity service, the majority of the hospitals visited are equipped with waste management machines, including compactors. Figure 5 shows one of these equipment with its mobile part with no adequate protector.

Stationary waste compactor without protector

Figure 5 Examples of observations made in the hygiene and salubrity service

3.3 Participants' Opinions and Perceptions about Machine Safety

In order to verify the validity of the questionnaire, the Cronbach's alpha coefficient method was applied to the collected data. This analysis technique for checking reliability allows to study the attributes of the measurement scale and the involved components. It also allows to determine in

which extend the components of the questionnaire are related to one another, as well as to obtain a general index for the internal consistency of the scale as a whole. Nunnally (1978) suggests an alpha superior to 0.7 to be able to assess the reliability of the measurements. The alpha coefficient calculated for this questionnaire is of 0.96, which indicates that the reliability of this measurement tool is satisfactory.

In the following sections, an individual analysis of the participants' opinions and perceptions regarding the five machine risk management practices is presented. The results are discussed for each statement of the questionnaire, and a comparative analysis between the individual results from the managers and the workers is also presented, where relevant. However, the analysis of the overall results from the managers and the workers (overall average scores for each part of the questionnaire) did not show any significant difference.

3.3.1 Risk Assessment

This part of the questionnaire included nine statements. TABLE 6 presents the perceptions and opinions of the managers and workers regarding the means used to assess machine risks. The opinion averages below or equal to 3.0 were considered to essentially disagree. As for the number of respondents agreeing or disagreeing, this value gives additional information in order to establish the overall portrait of the opinions of the service managers and workers.

According to the results obtained for the statements 1 and 4 (TABLE 6), all the managers and most of the workers agree to say that machine risk assessment is a meaningful method to identify the corrective measures to be implemented, and that it is a useful prevention approach in a hospital context. However, for the statement 2, it is interesting to note that 14 service managers out of the 17 met, and 13 workers out of the 17 met affirm that machine risk assessment is not a well-known aspect within their hospital. Furthermore, for the statement 3, it can be observed that 15 service managers and 12 workers share the similar opinion that machine risk assessment is not sufficiently used within their facility. These observations suggest that even if they believe that machine risk assessment may be a good approach to make their machinery safer, they do not implement it. It can also be surprising to see that for the statement 5, five managers answered, "Do not know." This can lead to suppose that the respondents were not totally aware of the full meaning of risk assessment.

Actually, the OHS managers confirm that they do not have, within their respective facility, procedures or an approach to be followed regarding risk assessment: none of the hospitals could provide a related document or indicate the existence of a machine risk assessment procedure (TABLE 5).

TABLE 6: DETAILED RESULTS FOR RISK ASSESSMENT

Statements	Managers (n = 17)				Workers (n = 17)			
	Average*	Do not know	Disagree	Agree	Average	Do not know	Disagree	Agree
1. Machine risk assessment consists in a useful preventive approach in the hospital sector.	5.88	0	0	17	5.65	0	1	16
2. Machine risk assessment is a well-known method within our facility.	2.50	1	14	2	2.82	0	13	4
3. Machine risk assessment is sufficiently used within our facility.	2.12	0	15	2	2.67	2	12	3
4. Risk assessment is a meaningful method to determine the corrective measures to be implemented on the machinery.	5.76	0	0	17	5.50	1	1	15
5. Machine risk assessment allowed to significantly improve safety within our facility.	3.25	5	7	5	3.94	0	6	11
6. The analysis of the statistics related to accidents and incidents is a useful indicator to help prioritize risk assessments.	5.31	1	2	14	5.67	2	0	15
7. The workers' participation is solicited as much as required to identify the hazards.	4.41	0	6	11	3.41	0	9	8
8. The workers have the opportunity to give their opinions in order to find solutions.	5.06	0	2	15	5.12	0	2	15
9. The workers' participation is adequate when it comes to carrying out risk assessments.	3.64	3	7	7	3.43	3	7	7

*Note: Opinion averages below or equal to 3.0 were considered to essentially disagree with the statement

Concerning the participation of the workers in the identification of hazards (statement 7) the results indicate that the majority of the respondents agree with the statement. However, the average is one point higher among the service managers, i.e. 4.41, while the workers' is of 3.41. These results can indicate that the managers believe that they reasonably solicit the workers to identify the hazards, while the workers consider they could be more solicited. However, the results of the statement 8 indicate that 15 service managers and 15 workers consider that the workers have the opportunity to give their opinions in order to find solutions. The workers seem

more involved in seeking solutions than they are in the machine risk assessment process. During the meetings with the OHS managers, none of them could specify the role of the workers in the risk assessment process.

3.3.2 Safeguarding of Machinery

This part of the questionnaire comprised 8 statements. TABLE 7 presents the detailed results regarding the opinions of the service managers and workers about safeguarding of machinery.

For the statement 5, most of the respondents agree to say that the machines used in their facility are safe. Also, 15 service managers and 12 workers agree with the statement 7 *"When a modification is made on a machine or a piece of equipment, the workers involved are quickly informed."* It is thus possible to conclude that they consider that their working environment is safe, despite the numerous machine hazards that were observed during the visits.

On the other hand, for the statement 8, the service managers and workers have a different perception regarding the work carried out by subcontractors. In fact, the results indicate that eight service managers agree, and five disagree, while only two workers agree. Could this situation be explained by the fact that the workers are in a better position to observe if the machine safety rules are respected by external workers? It is also interesting to comment on statement 3, because the results indicate that the service managers and the workers confirm that the safety rules are not always clearly defined within their facility. With an average of 2.88 for the workers, and 3.13 for the managers, the workers seem to think that the rules are not always well-defined. This can lead to suppose that the workers may not be well informed of the safety rules, when they exist.

TABLE 7: DETAILED RESULTS FOR SAFEGUARDING OF MACHINERY

Statements	Managers (n = 17)				Workers (n = 17)			
	Average*	Do not know	Disagree	Agree	Average	Do not know	Disagree	Agree
1. The machine safety standards and rules are relatively well-known within our facility.	3.13	3	12	4	3.25	1	9	7
2. The safeguarding of machinery is sufficiently prioritized within our hospital.	3.18	0	12	5	3.41	0	8	9
3. Safety rules related to machines and equipment are clearly defined within our facility.	3.13	1	11	5	2.88	0	11	6
4. Information regarding the safeguarding of machinery is sufficiently communicated within our facility.	2.94	0	12	5	2.71	0	13	4
5. Generally speaking, the machines used within our facility are safe.	4.12	0	4	13	4.41	0	4	13
6. When machine hazards are identified, safeguarding measures are quickly taken within our facility.	4.53	0	5	12	4.47	0	4	13
7. When a modification is made on a machine or a piece of equipment, the workers involved are quickly informed.	4.94	0	2	15	4.18	0	5	12
8. The external workers (subcontractors) are quite well informed about machine safety rules.	3.62	4	5	8	2.36	6	9	2

*Note: Opinion averages below or equal to 3.0 were considered to essentially disagree with the statement

The service managers and workers predominantly agree with the statements 6 and 7. They all affirm that in the presence of a machine hazard, safety measures are quickly implemented, and that the workers are also quickly informed if modifications are made. However, for the statement 4, most of the managers and workers disagree with the following statement: *"Information regarding the safeguarding of machinery is sufficiently communicated within our facility."* Thus, it seems to exist a contradiction between the results of the statement 4 and the results of the statements 6 and 7. On the one hand, the participants state that information regarding the safeguarding of machinery is not sufficiently communicated, and on the other hand, they agree to say that the safeguarding measures are quickly implemented, and that the workers are quickly informed when a modification is made. This could be explained by the fact that none of the facility could present a document stating the specific safety rules regarding machine hazards, nor a document communicating the risk assessment results and the corrective measures taken, as well as no document on projects related to the safeguarding of machinery (see TABLE 5). This also leads to the assumption that the information is mostly communicated verbally, since

there is no written document on this subject to refer to and to encourage information sharing. Furthermore, during the visits within the different services in the hospitals, it was possible to observe that no information regarding the safeguarding of machinery was posted on employee bulletin boards, which supports the results obtained for the statement 4. Clarifications to these questions regarding the perception of the term “communicated” (verbally or in writing and by what means), for the employees may be required.

3.3.3 Lockout/tagout Procedures

TABLE 8 presents the participants’ opinions for the 9 statements regarding lockout/logout procedures. Concerning statements 1 and 2, both the service managers and workers agree to say that machine lockout/tagout is not only a useful prevention approach, but also a method that can be easily implemented in a hospital.

Pursuing the analysis of the statements 3 and 4, it can be noted that the service managers and workers agree that the lockout/tagout procedures are not well-known nor sufficiently used within their hospital. This is confirmed by the managers with the statement 7, for which the overall average of 2.82 indicates that they consider that the lockout/tagout method did not allow to significantly improve machine safety within their facility. It is also interesting to underline that for the statement 7, six managers and six workers do not have any opinion regarding the significant improvement of machine safety within their facility through lockout/tagout. Moreover, none of the OHS managers could demonstrate the application of any lockout/tagout procedure, nor present a document on that matter (see TABLE 5).

Besides, for the statement 5, the managers and workers agree to say that *“lockout/tagout can easily be implemented on the machines within our facility.”* Thus, they believe that lockout/tagout procedures could be easily applied, but in the absence of training, lockout/tagout material (lockout tag, single key padlock, hasps, etc.), and a lockout/tagout program, implementing lockout/tagout procedures is difficult to do.

TABLE 8: DETAILED RESULTS FOR LOCKOUT/TAGOUT PROCEDURES

Statements	Managers (n = 17)				Workers (n = 17)			
	Average*	Do not know	Disagree	Agree	Average	Do not know	Disagree	Agree
1. Machine lockout/tagout consists in a useful prevention approach in the hospital sector.	5.41	0	2	15	5.94	0	0	17
2. Lockout/tagout can easily be implemented in the hospital sector.	4.81	1	3	13	5.06	0	4	13
3. Machinery lockout/tagout is a well-known method within our facility.	3.00	2	11	4	3.00	0	9	8
4. Machinery lockout/tagout is sufficiently used within our facility.	2.36	3	11	3	2.71	0	11	6
5. Lockout/tagout is easily applicable on the machines within our facility.	4.24	0	5	12	4.12	0	8	9
6. New workers quickly receive instructions regarding lockout/tagout procedures.	2.00	5	10	2	1.69	4	12	1
7. Lockout/tagout allowed to significantly improve machine safety within our facility.	2.82	6	7	4	3.73	6	5	6
8. Lockout/tagout mainly concerned the maintenance workers.	3.56	1	7	9	4.00	0	7	10
9. The lockout/tagout procedures are respected by the external workers (subcontractors).	3.45	4	6	5	2.90	7	7	3

*Note: Opinion averages below or equal to 3.0 were considered to essentially disagree with the statement

3.3.4 Inspection of the Machinery

This section of the questionnaire comprised 8 statements (TABLE 9). According to the statements 1 and 2, almost all of the respondents agree to say that machinery inspection is a useful prevention approach and a practice that can easily be implemented within a hospital. However, they essentially disagree with the statements 3 and 4 regarding the implementation of this practice within their facility, which indicates that inspection of the machinery is not a common practice within the hospital sector. It is important to remember that out of the five facilities, four of them do not have in place an action plan or a register regarding the inspections carried out by the non-medical staff. Furthermore, the results for the statement 5 suggest that the managers do not participate to machine inspection within their service, as it is usually done in the manufacturing industry.

TABLE 9: DETAILED RESULTS FOR INSPECTION OF MACHINERY

Statements	Managers (n = 17)				Workers (n = 17)			
	Average*	Do not know	Disagree	Agree	Average	Do not know	Disagree	Agree
1. Inspection of the machinery is a useful prevention approach in the hospital sector.	6.00	0	0	17	5.88	0	0	17
2. Inspection of the machinery is a practice that can be easily implemented in the hospital sector.	5.88	0	0	17	5.59	0	1	16
3. Inspection of the machinery is a well-known practice within our facility.	3.53	0	9	8	3.69	1	8	8
4. Inspection of the machinery is a practice sufficiently implemented within our facility.	2.94	0	11	6	3.13	1	11	5
5. Managers regularly participate in the inspection process in their respective service.	2.65	0	11	6	1.87	2	13	2
6. Inspection of the machinery allowed to significantly improve occupational safety within our facility.	3.60	2	7	8	4.54	4	3	10
7. During the inspection of a workstation, the opinion of the worker is regularly solicited.	4.13	1	6	10	4.53	0	6	11
8. The involvement of the workers is well enough valued during inspections within our facility.	3.75	1	6	10	4.29	0	5	12

*Note: Opinion averages below or equal to 3.0 were considered to essentially disagree with the statement

3.3.5 Machine Safety Training

By analyzing the opinions collected regarding machine safety training (TABLE 10), it can be observed that the global averages for the 7 statements with respect to this machine risk management practice are lower. The statement 5 also shows that the workers consider that they do not receive enough training regarding machine safety. By looking at TABLE 5, it can actually be noted that only one facility has a training register.

It is thus not surprising to observe that according to the statement 6, the workers do not receive an adequate training regarding lockout/tagout. As for the statement 7, "*An adequate number of persons have received a training revolving around the machine risk assessment methods within our facility,*" the same number of managers and workers do not agree with the statement. Besides, five managers and seven workers answered "Do not know" to this statement, probably not knowing if some people had actually been trained within their facility.

TABLE 10: DETAILED RESULTS FOR MACHINE SAFETY TRAINING

Statements	Managers (n = 17)				Workers (n = 17)			
	Average*	Do not know	Disagree	Agree	Average	Do not know	Disagree	Agree
1. Preventive OHS training is widely given in the hospital sector.	2.94	1	12	4	2.75	1	11	5
2. OHS training is sufficiently provided within our facility.	2.35	0	15	2	2.35	0	14	3
3. Workers' training related to machine risk prevention is sufficient within our facility.	2.41	0	13	4	2.59	0	12	5
4. The concerned workers receive an adequate training regarding the machinery and equipment they need to operate.	3.61	0	8	9	3.00	0	12	5
5. The concerned workers receive an adequate training regarding machine safety.	3.18	0	11	6	2.65	0	13	4
6. The concerned workers receive an adequate training with respect to lockout/tagout procedures.	1.83	5	11	1	2.21	3	10	4
7. An adequate number of persons have been trained regarding the machine risk assessment methods within our facility.	1.25	5	12	0	2.57	7	5	2

*Note: Opinion averages below or equal to 3.0 were considered to essentially disagree with the statement

4 CONCLUSION

This study aimed at highlighting the machine risk management practices of the non-medical staff in the hospital sector in the province of Quebec. Although accidents caused by machinery only represent a low proportion of the accidents reported in this sector, this study demonstrated that machine-related risks are a reality. Moreover, the facilities visited do not have a machine risk assessment procedure, nor a lockout/tagout program, and no specific document on safety rules related to machine hazards could be consulted.

Furthermore, certain opinions formulated by the individuals met lead to believe that machine risk assessment is not a well-known approach in this sector. Yet, the different studies cited in this research indicate that risk assessment is the basis of the machine risk management best practices. As shown by the numerous examples of hazardous situations and non-compliance observed during the visits, the safeguarding of machinery is often deficient. This situation can actually be considered as a consequence of the lack of risk assessment.

Also, the efficiency of lockout/tagout procedures, inspections and machine risk training is now widely recognized in the industrial sector. Once again, the level of implementation of these practices in the hospital sector seems relatively low, even marginal. Yet, the majority of the managers and workers agree to say that these practices are relevant and can be implemented in the hospital sector. In light of these results, it is reasonable to conclude that the hospital sector is generally aware of those machine risk management best practices, but that their level of implementation is lower than what can be seen in the industrial sector.

The qualitative nature of this exploratory study and the small number subjects interviewed prevented the use of analytical statistics of the individual results. Moreover, because of the time limitation, the results of the on-site observations of machines and hazards were not comprehensive and systematic and could not be directly associated with the opinions and perceptions of the participants. Further investigation by means of a more systematic risk assessment should be undertaken to get a more comprehensive picture of the machine related hazardous situations and non-compliance. Possible correlations between the managers and workers' opinions and perception towards machine safety and the resulting risk levels of each hospital or service could then be explored.

However, and despite its limited scope, the results of this study suggest that hospitals need to change their way to do in order to equip themselves with more efficient means to reduce machinery related risks. Moreover, this study confirms that the sector comprises machine hazards that can notably be explained by the lack of protectors; little knowledge about the equipment and power sources; absent, incomplete, unknown or non-implemented lockout/tagout procedures; a lack of machine safety-related training for the workers; and a poor design of the equipment or the protective measures.

The observations made on the field also bring forward the importance to develop a "machinery safety culture" in this sector. Consequently, it would be appropriate that hospitals put in place a machine risk assessment method and develop an action plan specific to their reality. This action plan could urge healthcare facilities to establish a safeguarding program and a lockout/tagout program, to provide training to their concerned staff, and to put in place an inspection register in all relevant services. It would also be useful that the managers involve the workers in identifying

hazards, communicating information regarding the risk assessment results, as well as making sure to follow up on the corrective measures for all the appropriate staff.

This exploratory study draws a portrait that needs to result in the implementation of projects aiming at improving risk management practices, as well as in specific training or guides for the facilities in this sector.

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