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Blood exposure accidents - risk analysis and experimentation by FMECA

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ABSTRACT

The problem of blood exposure accidents in the hospital is a real concern for the hospital administration, even for health professionals, because of the serious illnesses they cause. To prevent the occurrence of BEA in the hospital, the mutual commitment of operators and managers is essential to improve care practices through innovative solutions (attitudes, mindset, culture of change). This work aims to provide a first overview of the application of the ISO 31000 standard guidelines on the problem of BEA in a public hospital, starting with the perception of risk according to the INRS model, the identification of potential causes by Reason's model, the evaluation and prioritization by the FMECA method, and finally, proposals for improvement to control the risk of BEA among care professionals.

Keywords: Risk management, BEA, Safety, Hospital environment, Caregivers.

INTRODUCTION

Hospitals are complex organizations that mobilize many professional qualities and skills to ensure adequate care for any patient. In order to provide care, all resources (human, infrastructure, and materials) combine to produce a service appropriate for every patient in the hospital. However, caregivers are exposed to various occupational hazards. Among them blood exposure accidents (BEA). They are the most prevalent in the hospital environment and constitute a real concern for health professionals because of the seriousness of the diseases they cause.

These BEA can cause a possible transmission of certain infectious diseases (e.g., AIDS) from the patient being treated to a health care worker. Faced with this danger, hospital management must intervene to manage safe practices during the care process. There is no doubt that in the hospital environment, dysfunctions are diverse, resource shortages exist permanently, and constraints obstruct the relevance of safety measures toward risks. These factors contribute to the exposure of health professionals to biological products.

In this context, Moroccan hospitals must imbibe the health and safety policy at work to ensure the permanent protection of caregivers against the threats of infectious risk related to BEA. It is essential to refer to the ISO 31000 standard to identify and analyze the causes of exposure of health professionals to blood to

prioritize and treat them according to predetermined priorities.

This work aims to answer the following question: Can we control and evaluate the risks related to BEA in a public hospital based on the principles of the ISO 31000 standard? The current study aims to give a first overview of the application of the guidelines of the standard ISO 31000 to the problem of blood exposure accidents (BEA) in a public hospital, starting with the perception of risk according to the INRS model, the identification of potential causes by Reason's model, the assessment and prioritization by the FMECA method and finally suggestions for improvement to control the risk of BEA among the nursing staff.

The current study shows that the problem of BEA in the nursing environment has become a daily occurrence for nurses, requiring a multidisciplinary, multifactorial, and measurable prevention action plan. The testing of the FMECA method aims to respond as quickly as possible to potential failures according to the calculated criticalities to improve the detection of undesirable events, formalize new procedures, and establish an information system that allows reporting failures.

BEA IN THE HOSPITAL - THEORETICAL BACKGROUND

BEA is defined as accidental contact with blood or a biological liquid contaminated by blood following a cut (sting, cut, scratch, bite...), a projection on a mucous membrane (conjunctiva, mouth), or an injured skin (dermatosis, wound) (1). These blood exposure accidents (BEA) are among the most frequent risks in hospitals (2). They are a real concern for healthcare professionals because of the severity of the conditions they cause. The seriousness of the risk of transmission of an infectious agent during BEA concerns all blood-borne germs (bacteria, viruses, parasites, and fungi), but the human immunodeficiency virus (HIV), the hepatitis B virus (HBV), and the hepatitis C virus (HCV) (3-4) account for the majority of cases of occupational infections described in the literature.The prevalence of BEA in Middle Eastern countries is estimated at 2.3 per year (5), with the rate of BEA in Egypt equivalent to 83.0%, 42,2 % in Ethiopia, 57% in Jordan and 42.5% in Iran (6). These figures indicate the selectivity of Middle Eastern countries in reporting BEAs even with the requirements of the World Health Organization, which reflects the organizational failures of the safety management system in Middle Eastern hospitals.

Previous studies point out problems in identifying the causes of this risk in the hospital environment (7); generally, we note a shortage of studies related to the underestimation perceived by the operators of the fatality of the BEA (8) from the lack of reliable epidemiological data and regulation (9-10). The GERES survey (2021) carried out for nurses and doctors show that various circumstances favor the occurrence of BEA. These circumstances are often related to caregivers (11), patients (12), and hospital ergonomics (13).

In the course of our research, we noted that the problem of BEA had been dealt with several times in the context of hospital contamination, whereas there is a lack of studies demonstrating the impact of constraints related to hospital ergonomics on the occurrence of BEA.The graph below shows the distribution of factors related to hospital ergonomics that cause BEA by several authors cited based on Web of Science data (out of 216 articles published in 2020).

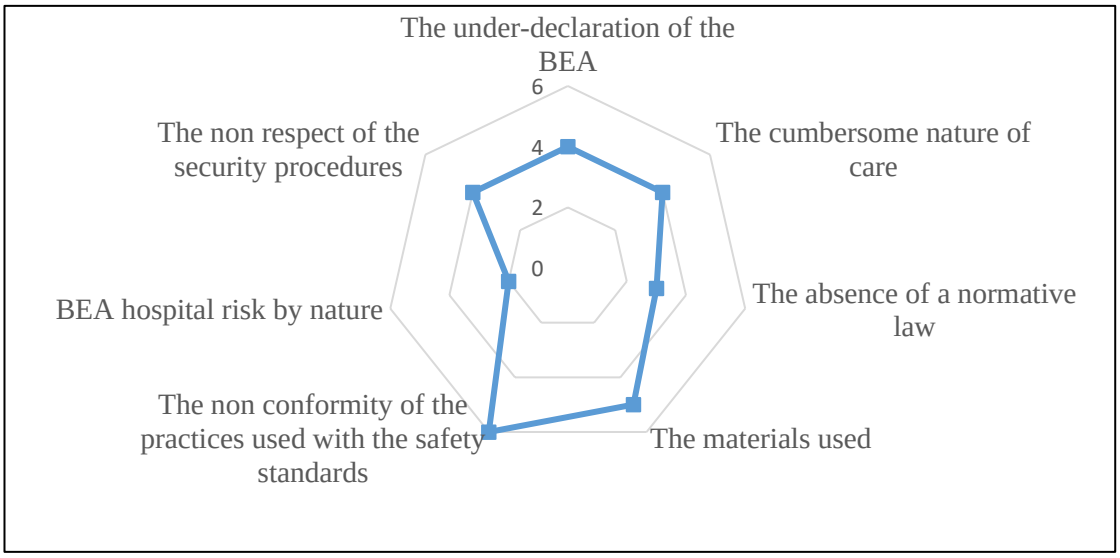

Figure (1): The distribution of factors for the occurrence of BEA.
Source: Our literature search.

Figure 1 shows a series of factors contributing to BEA occurrence. These factors are the non-conformity of staff practices with safety standards, under-reporting of BEA, the cumbersome nature of the BEA management process, the quality of the materials used, the failure to observe safety precautions, the absence of legal provisions dealing with the problem of BEA in hospitals, and the nature of the nursing profession (characteristic risk).

Concerning these results, we have also noted a lack of empirical and epidemiological representations of the factors that cause BEA, which means that there is the problem of the non-perception of the real risk of contamination by BEA, the trivialization of this risk and the underestimation of the seriousness of the diseases they cause.

Generally, we understand the term "factors of blood exposure accidents" in the hospital to mean all the factors or causes involved in the contamination of professionals by blood due to an accident at work in the hospital environment. These factors are numerous but can be classified according to human, organizational, and material factors.

In this context, managers of Moroccan hospitals must imbibe the health and safety policy at work to manage all the interactions between risk factors and ensure caregivers' permanent protection against infectious threats related to BEA.

THE RISK MANAGEMENT PROCESS - BEA IN A MOROCCAN HOSPITAL

In our work, we applied the risk management approach to determine the causes of BEA. Risk reduction is part of the qualitative approach. The implementation of risk management follows a standardized procedure consisting of 4 steps:

- Identify the risks.
- Analyze the causes.
- Evaluate in order to decide on action priorities.
- Implement action plans to prevent risks.

Therefore, we will identify all the causes of blood exposure accidents (BEA) in the hospital based on theoretical studies, followed by site visits and previous audit reports.

Identifying the factors that lead to the occurrence of BEA:

Previous research on blood exposure accidents has identified problems in identifying the causes of this risk in the hospital environment due to the lack of reliable epidemiological data and regulations.

In this context, the WHO estimates that 3 million health professionals are exposed to a needle stick with a risk of contamination by hepatitis C, hepatitis B, and HIV each year in the world (14), which generates direct costs (biological examinations, consultations, prophylactic treatments) and indirect costs (replacement of personnel, lengthening of stay,...) in addition to the legal aspect of these risks which is also an element to be taken into account because litigation generated by complications is frequent (15).

The variability of the mechanisms involved can explain this estimate: hand maladjustment of syringes (16), transferring blood from a mounted syringe into a tube (17), mouth pipetting of specimens (18) picking up sharps placed on benches, in a tray, or trash bags (19), and recapping needles (20).

These mechanisms explain the likely causes that can expose healthcare personnel to blood exposure accidents (21). The figure below groups together all the causes that can expose healthcare workers to blood exposure accidents (22).

Figure (2): The main causes of blood exposure in the hospital environment.
Source: INRS, 2020 (adapted).

According to the INRS (Figure 2), the main sources of the exposure of the healthcare team to BEA in the hospital environment are professional situations at risk (invasive procedures, etc.), contact with persons at risk (patient serology, etc.), waste management procedures (waste sorting, etc.), potentially risky equipment (scalpel blades, etc.), procedures that do not comply with safety standards (pipetting, etc.).

Especially in the case of accidental needlesticks, the severity of the risk differs depending on the source population, the intensity and duration of the carriage, the depth of the wound, the intravascular gesture, the hollow, large-bore and visibly blood-stained needle (23 – 1 – 24).

To identify the potential causes of BEA, we based ourselves on the model adopted from INRS 2020 (Figure 2). We detail all the causes of the identified BEA in the table below:

Table (1): The main causes of blood exposure extracted in our survey.

Sources of exposure	The potential risks
Professional situations at risk	Patient agitation. Decreased level of vigilance due to night work. High frequency of invasive procedures (deliveries, sutures, etc.). The direct impact of psychosocial risks during the practice of care. The reduced luminosity of the rooms. Lack of skills in the face of the care procedures practiced. The bad application of the acts of care Poor management of patient flows. Shortage of personal protective equipment. Lack of human resources to deal with the care procedures performed. Work overload.
Contact with persons at risk	Increased vulnerability to epidemics. Direct contact with known patients with communicable diseases. Direct contact with patients without knowledge of their serological status. Decrease in the rate of the population vaccinated against hepatitis B. Patient not involved in the safe care process.
Waste management procedures	Poor storage of trays. Non-compliance with waste sorting with prescribed standards. Shortage of waste sorting equipment. Shortage of waste supports. -Waste sorting without wearing PPE.
Potentially risky equipment	Hand-equipment mismatch. Maintenance not done Equipment with a potential risk of stinging and slicing.

Sources of exposure	The potential risks
	Old equipment (does not meet the criteria for updating). Defective equipment. Improper storage of forceps/scissors.
Procedures that do not comply with safety standards	A total absence of audits and supervision to improve care practices. A total absence of continuous training for BEA. A total absence of a safety culture towards the BEA. Absence of follow-up procedures for victimized personnel. Trivialization of BEA. Lack of knowledge of safety standards. Lack of awareness of the risks involved in providing care. Lack of awareness of the seriousness of BEA. Non-application of emergency care after BEA has occurred. Non-reporting of BEA. Non-reporting of potentially risky procedures. Non-reporting of adverse events. Staff not vaccinated against hepatitis B. Care without wearing PPE.

Source: Our literature search.

These causes are directly involved in the exposure of healthcare workers to BEA. Therefore, analyzing these causes is part of a priori and a posteriori risk management. We will process, analyze and merge the potential causes of the blood exposure accident (BEA) to prioritize them based on the REASON model.

Analysis of the causes of BEA - Reason's Model

Cause analysis is a process for understanding the nature of hazardous events (BEA in our case) and determining the risk level. It provides an accuracy of the causes of risk and decisions related to the control of the accident.

To analyze the factors that contribute to the occurrence of BEA, we use Reason's model (Figure 3), which determines the different dimensions that influence the occurrence of BEA in hospitals.

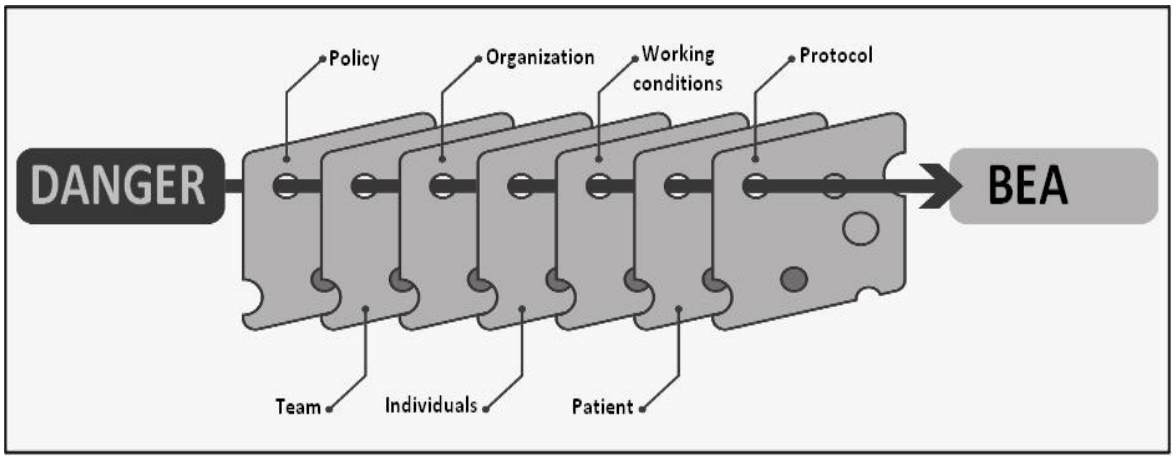

Figure (3): The main causes of BEA in the hospital environment according to Reason's model
Source: REASON, 1991 (adapted).

This model now suggests questioning the influence of a hospital's culture and organizational processes (maintenance, management, planning, etc.), whose impacts on safety can be both positive and negative.

Through these dimensions (human and team), the human factor represents the source of patent errors. These errors pose endless debates linking BEA with knowledge, attitudes, skills, training, coordination, and team communication.

On the other hand, the organization of work, its design, and governance by the hierarchy influence the frequency and type of operator error. These organizational constraints are called: latent errors; in our case, we find a total absence of continuous training for the benefit of the BEA, a total absence of safety culture towards the BEA, an absence of procedure of follow-up of the personnel victim and the trivialization of the BEA.

Most accidents result from a succession of facts or behavior that leads to the accident, for example, an invasive gesture without personal protective equipment.

Safety relies on implementing "defenses in depth," standards defined by the hospital organization to recover from caregiver errors. None of these procedures is sufficient on its own to provide total safety, but their stacking allows to block almost all the propagations of errors in the system and to prevent the accident (in our case, we have: the promotion of the safety culture, the requirement to wear PPE, the habit of carrying out care in conformity with the safety standards).

As seen previously (Figure 3) in the description of the REASON model, there are two causes of BEA in the hospital environment: latent causes, often related to hospital ergonomics and organization, and patent causes, often due to human factors.

The table below represents the main risk factors linked to BEA in the hospital and health centers visited during our study, proposing, in particular, the 7 dimensions (2 patent and 5 latent):

Table (2): The main risk factors for blood exposure in the hospital environment.

Dimension	Type	Risk Factors
Patent	Patient	- Complex or serious health condition, emergency. - Difficulty expressing or communicating (traumatized). - Social factors (dignity). - Personality (agitation).
	Individuals	- Lack of knowledge, skills, knowledge. - Lack of experience (seniority), adaptation to the position. - No qualification. - Physical, mental, moral health, stress management, circumstance, character, and help-seeking.
Latent	Policy	- Lack of strategies (security), general policy, and priority. - Social context (social segmentation not included). - Personnel management policy (Lack of a turnover plan, poor burn-out management). - Financing problems (shortage of equipment). - Conflicting or inappropriate strategies (between strategic and operational levels).
	Organizational	- Assignment of responsibilities. - Definition of required skills. - Resources in terms of premises and equipment (shortages). - The general organization of the service is not defined. - General organization between services not defined. - Relationship between hierarchical levels (lack of communication). - Distribution of staff (HR, materials, etc.).
	Working conditions	- The workload is too high. - Availability of the place or material, limitation of access. - Inadequate staffing, qualitative or quantitative. - Weak ergonomics, adequacy of the place or material. - Specific hours (night, weekend, vacations). - Mode of transmission (accidental). - Inadequate level of caregivers (nursing assistants). - Quality of maintenance and waste management.
	Protocol	- Additional procedures not performed (hygiene).

Dimension	Type	Risk Factors
		- Necessary data unavailable, poor quality (non-reporting). - Protocols not followed (BEA declared not followed). - Safety protocols are unavailable. - Safety protocols are non-existent and of poor quality.
	Team	- Lack of written communication. - Lack of oral communication. - Lack of help-seeking advice. - Poor team cohesion. - Quality of supervision. - Quality of cross-functional relationships. - Quality of vertical relationships.

Source: Our results.

In conclusion, most blood exposure accidents result from a succession of facts and/or behaviors that lead to the infectious contamination of healthcare professionals by a BEA.

It is essential to carry out a study using the FMECA method to identify the most determining factors of these accidents and to propose preventive and corrective actions.

Assessing the risk of BEA: the FMECA method

To assess the risk factors identified and prioritized by Reason's model, it is essential to quantify the causes identified to classify them according to Farmer's diagram. The table below represents the rating grid for the severity and frequency of occurrence of BEA.

Definition of quotation

We followed the scoring below (Tables 3 and 4). Based on the frequency and severity rubrics adopted by the HAS in 2019.

Table (3): The rating grid for the frequency of identified risks.

FREQUENCY (F)			
F1	Highly improbable	1	Never seen, or it is almost impossible for this event to happen again.
F2	Very unlikely to occur	2	Seen once or event should not happen again, but it is not impossible.
F3	Unlikely	3	We have already seen this in other healthcare facilities where this event may occasionally recur.
F4	Probably	4	This event occurs in our facility or will likely occur again, but not frequently.
F5	Very probable that certain	5	It occurs in hospitals where it is certain to happen many times.

Source: HAS, 2019 (adapted).

Table (4): The grid for rating the severity of identified risks.

GRAVITY (G)			
G1	Minor	1	Event with minor consequences: For example, for the professional (occasional stress) or the work team (delay of a professional).
G2	Significant	2	Event causing temporary damage: for the patient (ambiguity of serological status, stress), for the professional (overload of activity), and the work organization (temporary disorganization of the activity).
G3	Major	3	The event led to a prolonged prejudice: for the professional (demotivation, acute injury) and work organization (lack of an essential element of the activity).
G4	Critical	4	The event led to serious damage: to the professional (work stoppage) and the work organization (interruption of activity).
G5	Catastrophic	5	Event with very serious consequences: for the professional (disability) and the work organization (closure of the structure).

According to these rating grids, the criticality levels found in our study have been classified in the following figure.

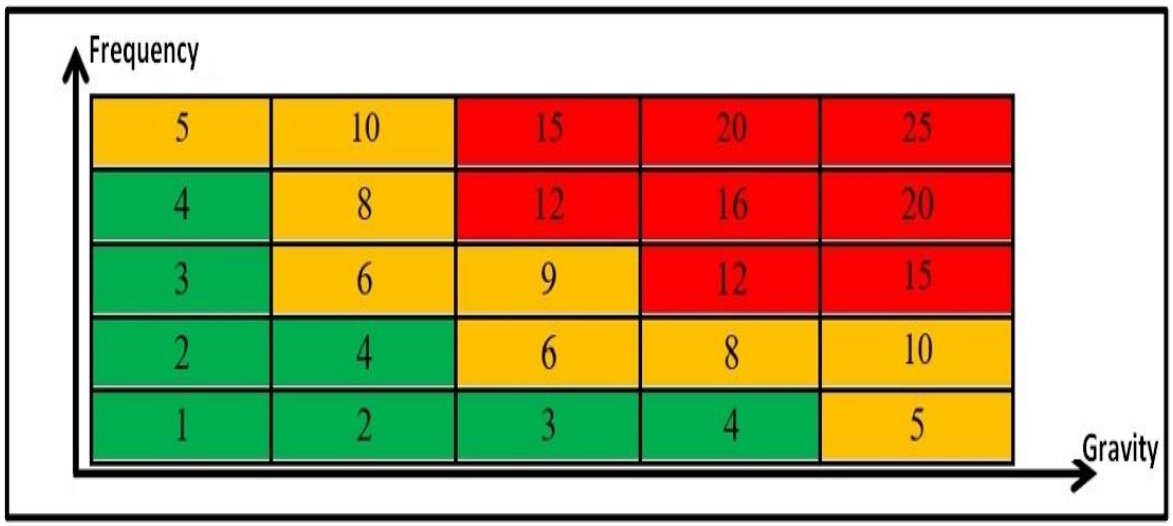

Figure (4): The rating grid of the calculated criticalities.
Source: Our results.

The colors represent the levels of risk acceptability, with the green zone representing tolerable risks, the yellow zone representing risks to be controlled, and the red zone representing intolerable risks.

Risk hierarchy - the FMECA grid:

To prioritize the causes of the SEAs, we chose the FMECA-security grid (CEI 60812) (Figure 5) and found the results announced below. According to the FMECA grid, the representativeness of the identified failures is shown in the figure below: (see the appendix of the document for more details on the FMECA results).

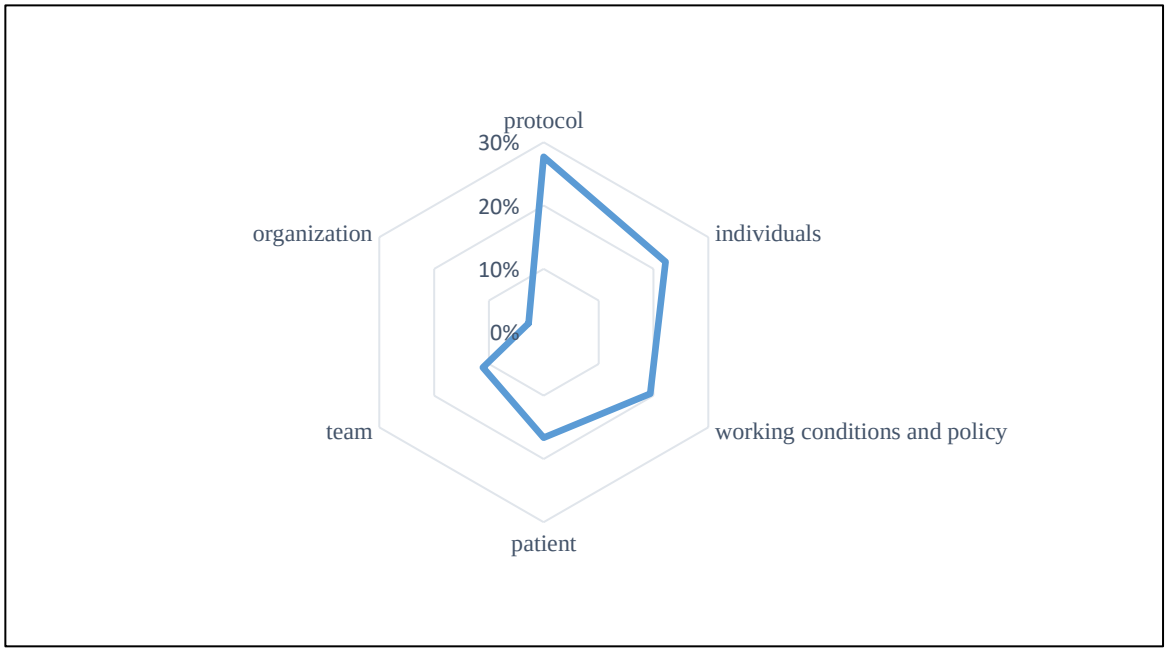

Figure (5): represents the identified failures according to the typology of Reason's model.
Source: Our result.

According to the FMECA grid used, we found that the most representative causes of BEA (Figure 5) are related to protocol (27,7%), individuals (22,2%), working conditions and policy (19,40%), patients (16,66%), teams (11,11%) and organization (2,77%).

Criticality levels - Risk representation matrix

Based on the FMECA-security grid, the diagram below represents a hierarchy of risks according to the calculated criticality (figure 6).

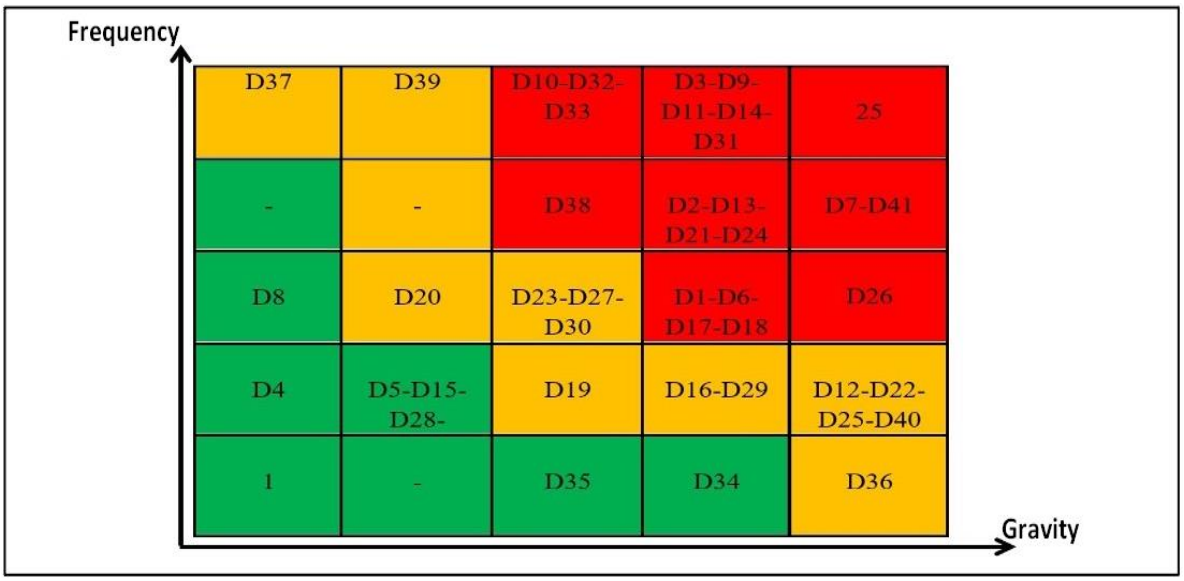

Figure (6): The Farmer diagram according to the criticalities calculated in the FMECA.
Source: Our result.

From the diagram (Figure 6), we see that:

Acceptable deficiencies are: (D4) Direct impact of psychosocial risks during care practice; (D5) Reduced room lighting; (D8) Poor management of patient flow; (D15) Decreased rate of hepatitis B vaccination; (D28) Total absence of audits and supervision to improve care practices; (D34) Lack of awareness of the risks involved in care practice; and (D35) Lack of awareness of the severity of BEA.

The failures to be controlled are: (D12) Increased vulnerability to epidemics; (D16) Patient not involved in the process of making care safer; (D19) Shortage of waste sorting equipment;(D20) Shortage of waste supports;(D22) Material-hand mismatch; (D23) Maintenance not done; (D25) Old materials (does not meet the criteria for updating) ; (D27) Poor storage of forceps/scissors; (D29) Total absence of ongoing training for BEA; (D30) Total absence of safety culture towards BEA; (D36) Non-application of emergency care after the occurrence of a BEA; (D37) Non-reporting of BEA; (D39) Non-reporting of adverse events; (D40) Staff not vaccinated against hepatitis B.

Intolerable failures: (D1) Patient agitation; (D2) Decreased level of vigilance due to night work; (D3) High frequency of invasive procedures; (D6) Lack of skills in relation to the care procedures performed; (D7) Poor application of care procedures; (D9) Shortage of personal protective equipment; (D10) Shortage of human resources in relation to the care procedures performed; (D11) Work overload; (D13) Direct contact with patients known to be suffering from transmissible diseases; (D14) Direct contact with patients without knowledge of their serological status; (D17) Poor storage of trays; (D18) Non-compliance

of waste sorting with prescribed standards; (D21) Waste sorting without wearing PPE; (D24) Equipment with potential risk of pricking and cutting; (D26) Defective equipment; (D31) Absence of procedure for monitoring victim personnel; (D32) trivialization of BEA; (D33) Lack of knowledge of safety standards; (D38) Non-declaration of potentially risky actions; (D41) Practice of care without wearing PPE.

After prioritizing the failures according to the calculated criticalities, it was important to calculate the residual criticality to determine the level of control of the failures after the application of the corrective and/or preventive actions.

Figure 7 below shows the expected impact of the proposed actions.

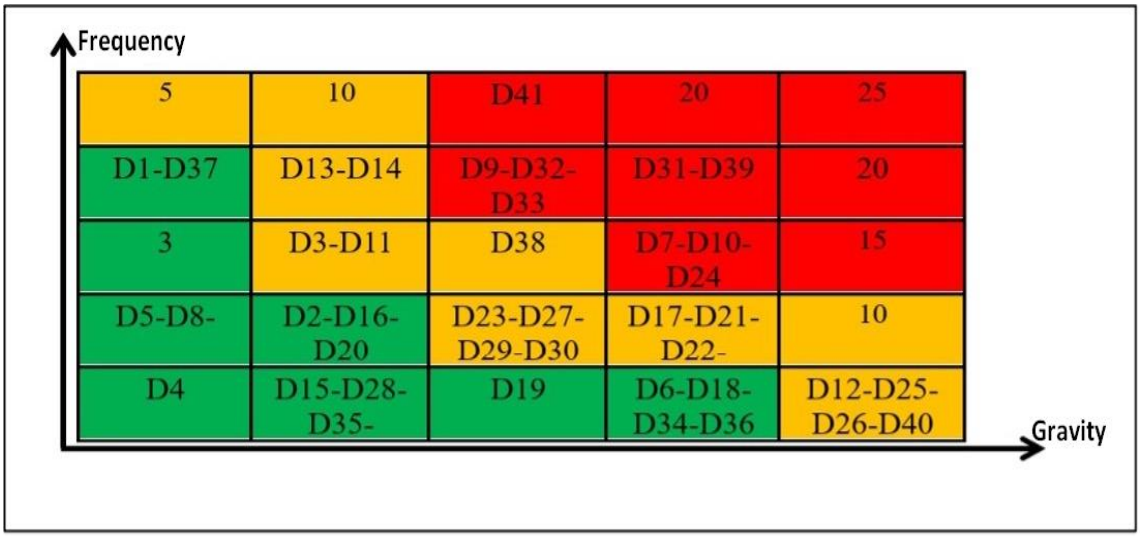

Figure (7): The Farmer diagram according to the residual criticalities calculated in the FMECA.
Source: Our results.

This diagram shows that the hospital system does not ensure operational safety (during care practice). It is limited to the organizational contribution in controlling the risk of a blood exposure accident.

However, it is important to find ways of monitoring and control, such as workplace inspections for the 16 acceptable risks (green zone). On the other hand, reviewing the 16 risks to be controlled through periodic review and ongoing risk analysis (yellow zone) is mandatory.

For the 9 intolerable risks (red zone), it is necessary to find ways of complying with decisions, such as management review, to protect personnel and mitigate the fatality of these risks.

Results - Evaluation of the performance of the security system towards the BEA

To assess the extent of the problem of blood exposure accidents and the impact of the FMECA method for analyzing our problem, we collected data using an anonymous

self-administered questionnaire to Moroccan health professionals.

This questionnaire is intended for all healthcare staff according to their professional categories: doctors, surgeons, specialists, pharmacists, midwives, nurses, and healthcare technicians. Our study population is made up of healthcare personnel practicing in our country.

The data collected was processed using SPSS software, and the consent of the participants was obtained in a written, free and informed manner. Ethical considerations such as voluntary participation, authorization to use the questionnaire, and confidentiality of information were respected.

A total of 117 healthcare professionals agreed to participate in this study; eighty-eight had experienced a BEA. Eighty-eight of them had experienced a BEA. 55.6% were women (n=65), and 44.4% were men (n=52).

Respondents stated that 88% (n=103) had experienced one or more HAIs during their care. Of these, 68.4% were not reported (Table 5). Of the 31.6% reported, 72.6% had not respected the official reporting period: 48 hours following the BEA.

Table (5): Reporting BEAs.

The type of BEA	Frequencies	percentages
BEA declared	37	31,6%
BEA non-declared	80	68,4%
Total	117	100%

Source: Our results.

During health care, massive and frequent use of sharps exposes health professionals to blood exposure accidents (see Table 5). 64.1% of respondents confirmed that the most significant type of BEA is the pricking of previously used needles.

In addition, 79.5% of the respondents stated that preventive safety precautions were not properly observed during BEA: care without wearing personal protective equipment.

Table (6): The typology of BEAs

The typology of BEA	Frequencies	percentages
Cut	8	6,8%
Mucocutaneous projection	24	20,5%
Sting	75	64,1%
All three	5	4,3%
Others	5	4,3%
Total	117	100%

Source: Our results.

Concerning the evaluation of health professionals' knowledge of the FMECA method, 86.3% of respondents considered that openness to risk management methods contributes to improving the care process, establishing action plans, and preventing infectious risks related to contamination by BEA.

DISCUSSION

Following the experimentation with FMECA, we were able to follow a reliable managerial approach. Indeed, the certification of hospitals by ISO 31000 is necessary to propose adequate improvements in the context of professional risks. Especially the phase of analysis of the causes, which is essential to any policy of prevention and correction of risks.

According to our results, the knowledge of the different causes linked to the dimensions of the risk of a BEA would positively

influence the identification of the probable consequences; therefore, hospital managers must actively contribute to understanding the origins of the exposures in order to reduce their criticalities.

This view determines the scope of risk control, as this level is linked to the relevance of the prevention actions established. However, it should be emphasized that certain criteria are assessed based on experience and not on objective data derived from real feedback from health professionals regarding BEA.

In this sense, we have divided the discussion of our problem into 3 axes corresponding to the calculated criticality of BEA.

Acceptable risks

According to our results, we find that the existence of a set of failures that are considered acceptable, starting with: (D4) Direct impact of psychosocial risks during the practice of care, because of their human nature, PSRs directly influence the proper workflow by manifesting in the various types of violence (25) which can be a probable cause of BEA.

During care practice, BEA caused by PSRs is preventable. It is sufficient to isolate patients during the care procedure while requesting the support of security guards in case of a potential risk of aggressiveness from the patient.

In addition, ergonomic constraints can be a probable cause of BEA; for example, we noted the D5 relating to the reduced luminosity of the rooms. This cause is easily correctable; it is enough to declare this dysfunction to the hospital administration for urgent repair.

Concerning the poor management of patient flows (D8), health professionals are always faced with interruptions of tasks following questions from patients who are disoriented and their companions. At the same time, a simple well-marked circuit can be a radical solution to this problem (26).

We also noted the decrease in the rate of the population vaccinated against hepatitis B (D15); it is known that health professionals are always faced with various communicable diseases that can be transmitted from the caregiver to the cared. This finding was already addressed by MIHINDOU in 2015 (12), although SOULY et *al*. (2016) (26) consider that without vaccination of the population, the vulnerability of hepatitis B increases, so the danger of BEA will always threaten surgeons and nurses while the severity of this risk in health professionals is considered avoidable with simple gestures: vaccination campaign of health professionals against hepatitis B and the obligation to wear PPE.

In addition, certain organizational constraints may be probable causes of BEA, such as (D28) Total absence of audits and supervision to improve care practices; (D34) Lack of knowledge of the risks incurred by the practice of care, and (D35) Lack of knowledge of the seriousness of BEA.

These constraints have already been addressed in previous research, especially among medical and nursing students (28- 29). Therefore, it is necessary to set up training and information actions on BEA and their means of prevention for student nurses before the beginning of their hospital internships, to oblige and monitor their vaccination against hepatitis B, and especially to make available and within reach all the necessary material to protect themselves.

The risks to be controlled are

According to our results, the causes of BEA that exist with a fairly high frequency during the practice of care are evaluated in the box of risks to be controlled, among which (D12) the increase in the vulnerability of epidemics.

Indeed, health professionals regularly express the increase of cases contaminated by infectious diseases, which demonstrates the feeling of insecurity in the workplace (30-31), especially at the time of the exploitation of biological products, even with wearing of PPE. Therefore, checking all patients' serological and vaccination status has become a priority.

We also found that patients are not involved in making care safer (D16). In this context, it is important, as shown by the priority placed on the international agenda by the WHO, "Patients for Patient Safety," which encourages patients to participate in improving the quality and safety of care. This invites us to think deeply about the conditions of this new role of the patient and its implications for the health and safety of professionals in the care setting (32).

On the other hand, the shortage of waste sorting equipment (D19) and the shortage of waste carriers (D20) reflect frequently reported ergonomic constraints in hospital settings, where the likelihood of being contaminated by an infectious disease depends on many associated factors such as the source patient's viremia, the depth of the wound Health professionals as well as the actors of the waste sector can be confronted with it, in particular when the hygiene precautions are badly respected. The waste from care activities with infectious risks is badly conditioned (19).

Among the ergonomic constraints that can cause BEA, we also find maintenance not done (D23) and the application of tasks using old equipment (D25). Hospital managers must, therefore, aim to improve working conditions through direct involvement: allocation of financial resources for the purchase of materials that meet the standards of safety of caregivers (e.g., self-locking syringes), and indirect involvement: outsourcing the function of maintenance of hospital materials to qualified companies (33).

The knowledge of health professionals can also be a cause of BEA. In this regard, we found: a total absence of continuous training on BEA (D29). EL GUEZZAR (34) already exploited this finding in 2008, and KONE and MALLE in 2015 (2) considered that continuous training for the benefit of healthcare personnel on the risks related to BEA is the best remedy against the occurrence of BEA.

By adding that the exploitation of knowledge in the assurance of the safety of care remains a permanent lever to readjust the practices of care towards a safe attitude, failing which it can remedy the probable causes of BEA as Improper storage of forceps/scissors (D27), mismatch of equipment/hand (D22), non-reporting of BEA (D37) and Non-reporting of adverse events (D39) towards a serious commitment to preventing the occurrence of BEA through the development of safety culture (D30), urgent application of care after BEA (D36) and vaccination against hepatitis B (D40).

Intolerable risks

According to our results, we found a very large number of very frequent and severe risks. They are considered very likely, and extremely severe is a serious problem.

Among these risks, we found that patient agitation (D1) promotes the exposure of healthcare professionals to BEA (35). Protective measures can be forgotten in an emergency and unforeseen context, putting caregivers at increased risk of blood exposure accidents. The risk in this context remains very high, so caregivers must know how to protect against it to reduce the likelihood of their occurrence (12).

We can also add to the circumstances related to the patients the knowledge of the serological status of the patient (D13, D14) because of the patients, whatever their physical appearances, are contagious potential (36).

The working hours' factor in the hospital environment could also be an unfavorable factor in the incidents feared by health professionals. Working at night causes several biological variables: the attention and concentration of the person in the work situation, especially with increased fatigue. In this sense, ABITBOUL et *al*. (37) believe that the incidence of blood exposure accidents (BEA) per nurse is twice as high at night compared to during the day due to the decrease in the level of vigilance (D2).

In addition to the patient and time factor, GERES (2016) (35) considers that the density of invasive procedures (D3) in several healthcare departments increases the frequency of probable BEA projections (for example, in the Operating Room), so a reflection should be carried out on the indications of procedures with a higher risk of BEA and transmission to propose the drafting of written prevention protocols (adequate care procedures, type of equipment used).

The attitude at work is also considered one of the crucial factors of BEA in hospitals; it is the lack of skills in front of the acts of care practiced (D6), the bad application of the gestures of care (D7), the bad tidying of the trays (D17) and acts of care without PPE (D18, D21, D33, D41)

These failures have already been addressed in previous studies (38 – 39 - 40), which state that the relationship of BEA with the practice of care remains in the period of internship of caregivers (the privileged place of acquisition of skills), that is to say, the practices of care of professionals must be correct and following the safety standards.

In addition, we have also revealed the factor of potentially dangerous (D31) and/or defective (D26) materials, which may be a dominant cause in the reports of BEA; the fact of handling soiled materials consists of using sharp, prickly, and other hospital materials soiled with blood or other biological fluids, the handling is most often done by recapping and de-capping the dirty needles. Beyond the fact of not wearing PPE (D9) and handling the materials used.

In addition, certain organizational constraints linked to the shortage of human resources (D10) and work overload (D11) are also evaluated as intolerable, and they highlight the commitment of health professionals to the safety processes (demotivation, exhaustion) and even negatively influence the promotion of the safety culture in hospitals (D38).

Finally, we note that the absence of a follow-up procedure for victimized personnel (D31) allows the underestimation and non-perception of risk to be shared or else promotes the trivialization of BEA (D32) as a defensive strategy among health professionals.

The appreciation of the impact of the FMECA method in the management of BEAs

From the questionnaire, we observed that BEA in healthcare facilities could affect all operators, regardless of the work department, the age of the workers, and the work schedule (41).

The predominance of women in our study (55.6%) is superimposed on the overall predominance of women in healthcare facilities; this finding is similarly found in some studies: 56.5% in France (42), 65.5% in Senegal (24), 76.9% in Côte d'Ivoire (43)

The prevalence of BEA is higher in emergency departments in our study (13%), which is equivalent to Lebanon (10%) and Kuwait (8.80%) (6).

Concerning the most important mechanism in our results, we find the skin-mucous projections during the various acts of care; this result was already proved in our survey, which concerns the socio-professional characteristics of the BEA; thus, the offer of the services of care in Morocco is a discipline which exposes the professionals of health to the infectious risks (33).

While the FMECA method has a very positive impact on the control of the infectious risk related to BEA, it ensures at the same time the identification, evaluation, prioritization, and improvement of the safety of this risk.

In the literature, it is rarely used in the hospital environment, whereas our experience has shown this method's feasibility for managing BEA.

CONCLUSION

This study shows that the problem of BEA in the care environment has become a daily occurrence for the caregiver, which requires a multidisciplinary, multifactorial, and measurable prevention action plan.

The experimentation with the FMECA method aims to act as soon as possible on potential failures according to the calculated criticalities to improve the detection of undesirable events, formalize new procedures and establish an information system that allows reporting malfunctions.

In this study, the active participation of the people involved directly influenced the effectiveness of the measures taken (field research); the discussions and brainstorming allowed the sharing of knowledge and a collective awareness of the reality of operating at full risk (BEA in our case).

The usefulness of the FMECA in the case of BEA represents advantages that will allow an evaluation before (Criticality) / after (Residual Criticality); it will be appropriate to appreciate the reduction of the identified failures by the re-evaluation of the actions brought.

The combination of Reason's Model with the FMECA method gave coherence to our study; we identified potential hazards, prioritized the failures, proposed actions, and re-evaluated them.

Moreover, the FMECA is not an end in itself. The risk analysis must lead to the definition of a real action plan. The recommended actions must be implemented, controlled, and monitored.

In this respect, the FMECA has helped us to introduce four general areas of

improvement: Strategic (linked to hospital policy and working conditions), Structural (linked to a hospital organization, team, and individual management), Cultural (suitable for patients) and Technical (linked to procedures).

These areas of improvement make it possible to control the risk of infection from BEA among healthcare professionals, which appeared to be effective and fairly easy to implement, although it required effort, follow-up, and several meetings.

To conclude, the insertion of the risk management system in the hospital environment should be integrated into the establishment's life. This approach will allow the implementation of actions to secure care practices against BEA, which truly influences the level of risk control.

Finally, it is essential to consider the residual criticality results to evaluate the risk management system and pilot the program for improving working conditions and combating occupational risks, especially BEA.

Consent for publication

Not applicable

Availability of data and materials

Most data generated or analyzed during this study are included in this manuscript. Other data that supported the findings of this study and an- analyzed during the current study are available from the corresponding author upon reasonable request.

Authors Contribution

Ayman KASSBI: writing original draft, data curation, formal analysis, investigation, visualization, and writing review & editing. This research is based on Ayman KASSBI's graduation thesis. **Souad FILALI EL GHORFI and Hicham ACHELHI**: conceptualization, accompaniment, draft correction, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, and writing review & editing.

COMPETING INTEREST

The authors declare that they have no competing interests.

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