

# Assessment of the usefulness and feasibility of implementing the spaghetti diagram, Ishikawa diagram, and the HFMEA analysis in a hospital emergency department – a pilot study

Ocena przydatności i wykonalności implementacji diagramu spaghetti, diagramu Ishikawy i analizy HFMEA w szpitalnym oddziale ratunkowym – badanie pilotażowe

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## STRESZCZENIE

### OCENA PRZYDATNOŚCI I WYKONALNOŚCI IMPLEMENTACJI DIAGRAMU SPAGHETTI, DIAGRAMU ISHIKAWY I ANALIZY HFMEA W SZPITALNYM ODDZIALE RATUNKOWYM – BADANIE PILOTAŻOWE

**Cel pracy.** Celem badania była ocena możliwości wykorzystania diagramu spaghetti, diagramu Ishikawy i analizy HFMEA do identyfikacji problemów i zagrożeń, ich przyczyn, wąskich gardeł i marnotrawstwa w procesach uznawanych za kluczowe przez personel oddziału ratunkowego.

**Materiał i metody.** Badania przeprowadzono w Uniwersyteckim Szpitalu Klinicznym w Opolu. Zastosowane metody obejmowały wywiady bezpośrednie, obserwację procesów podczas spacerów gemba, opracowanie diagramu spaghetti, diagramu Ishikawy oraz analizę przyczyni skutków błędów w opiece zdrowotnej (HFMEA).

**Wyniki.** Dwa kluczowe procesy objęte badaniem obejmowały: triaż (według 15 pielęgniarek i 10 ratowników medycznych) oraz przekazywanie gabinetów kolejnym zmianom (według 10 pielęgniarek i 12 ratowników medycznych). Diagram spaghetti pokazał marnotrawstwo czasu personelu w celu udania się po telefon komórkowy i w celu udania się do umywalki by zwilżyć gazik potrzebny do badania elektrokardiograficznego. Analiza HFMEA przedstawia braki kadrowe i sprzętowe, brak wiedzy kadry zarządzającej o występujących w procesach problemach oraz deficyt szkoleń jako potencjalne przyczyny problemów.

**Wnioski.** Wdrożenie narzędzi i rozwiązań omówionych w niniejszym badaniu jest możliwe w szpitalnym oddziale ratunkowym i może zapewnić realną redukcję ryzyka wystąpienia błędów.

**Słowa kluczowe:** szpitalny oddział ratunkowy, zarządzanie ryzykiem, diagram spaghetti, Ishikawa diagram, HFMEA

## ABSTRACT

### ASSESSMENT OF THE USEFULNESS AND FEASIBILITY OF IMPLEMENTING THE SPAGHETTI DIAGRAM, ISHIKAWA DIAGRAM, AND THE HFMEA ANALYSIS IN A HOSPITAL EMERGENCY DEPARTMENT – A PILOT STUDY

**Aim.** The aim of the study was to assess the feasibility of using the spaghetti diagram, the Ishikawa diagram and the HFMEA analysis to identify problems and risks, their causes, bottlenecks and waste in processes considered to be crucial by emergency department staff.

**Material and methods.** The research was carried out at the University Clinical Hospital in Opole. The following methods used included face-to-face interviews, observation of processes during gemba walks, the development of the spaghetti diagram, the Ishikawa diagram and the use of healthcare failure mode and effect analysis (HFMEA).

**Results.** The study included two key processes: triage (according to 15 nurses and 10 paramedics) and transferring of emergency department (ED) rooms between shifts (according to 10 nurses and 12 paramedics). The spaghetti diagram showed waste of staff time wasted on searching for a cell phone and going to the sink to moisten gauze pads needed for an electrocardiographic examination. The HFMEA analysis shows staff and equipment shortages, lack of management knowledge about problems occurring in the processes and a training deficit as potential causes of these problems.

**Conclusions.** The implementation of tools and solutions discussed in this paper is possible in emergency department and can provide errors risk reduction.

**Key words:** risk management, ED, Ishikawa diagram, spaghetti diagram, HFMEA

## INTRODUCTION

The global public healthcare problem is that hospital emergency departments (ED) are most frequently visited by high volumes of patients, especially those who are not directly in life-threatening or health-threatening condition – the number of “less urgent” patients (those who can wait for the first contact with a doctor) is about 42.6% – 47% and “non-urgent” (those who should be treated in other healthcare facilities) 2% – 10.6% [1,2] which means that the biggest number of services provided to them is of an ambulatory character [3]. Due to the nature of the symptoms, other healthcare facilities are suitable for providing medical services to this group of patients, such as primary care or out-of-hour settings, but access to them does not always allow for an appointment on the same day the symptoms appear [4]. The emergency departments face issues such as staff shortages and work under time pressure. All these factors cause the *ED overload* as patients report in at random time intervals and random day times. Some of them require more staff engagement than others, which affects both the staff and the patients themselves and is known as overcrowding [5]. Prolonged waiting time at various stages of the stay in an ED may be caused by bottlenecks in patient flow and waste in ED processes resulting in a higher risk of adverse events, as the consequences of waiting include, in particular, delays in the implementation of targeted therapy (e.g. antibiotic therapy in cases of sepsis), extended time of stay in the ED, higher morbidity and even medical errors [6,7].

Lean Healthcare (LH) is linked to the management of processes which consist of the sequences of specified activities indispensable in tasks' completion. Management of risk seems to be of high importance as well. In hospitals, the risk is connected with the occurrence of medical incidents, adverse events and potentially hazardous situations. In order to be able to fully handle them, it is essential to identify, assess and control the risk. One of the integral elements in such management is drawing up the Ishikawa diagram, also known as “fishbone diagram”, which is made during brainstorming sessions to conduct root cause analysis [8]. It helps to form the hypothesis about the causes of failures, as well as to determine the cause-effect relationships and their consequences. It is presented in the form of a fish-bone diagram. The head of the fish represents the analysed problem, the fishbones represent main root causes and smaller fishbones branching off the main ones show more detailed causes [9].

In order to analyse, measure and prevent the risk, the Healthcare Failure Mode and Effects Analysis (HFMEA) may also be applied to medical processes. It is used to analyse complex clinical processes for potential errors. As a result of the analysis, it is possible to avoid failures and their consequences in the form of extra expenses, longer hospitalizations or delays in targeted therapies. In medical institutions such methods may be used, inter alia, to evaluate the causes of nosocomial infections or formation of bedsores. It also helps to improve quality, safety and both patients and personnel satisfaction [10].

## AIM

The aim of the study was to assess the feasibility of using the spaghetti diagram, the Ishikawa diagram and the HFMEA analysis to identify problems and risks, their causes, bottlenecks and waste in processes considered to be crucial by the emergency department staff.

## MATERIALS AND METHODS

The research was carried out in the University Clinical Hospital in Opole. It is the biggest hospital in the Opolskie voivodship with 16 hospital wards, specialist outpatient clinics, the dialysis station, the diagnostic laboratory, the microbiology department as well as the diagnostic imaging and pathomorphological units. The emergency department also operates as a trauma centre for children and adults. After the pandemic, from 2022-2024, the ED provided services to approximately 50,926 patients annually, what makes up for 4,243 consultations per month. The department under review employs a total of 37 nurses and 26 paramedics, all working in shifts. The number of staff during the shift is approximately 11, and the ratio of nurses to paramedics during a given shift is not strictly defined. Each shift, the staff work in a different area of the ED, which is designated by the coordinating nurse.

The personnel examination was preceded by the approval of the Bioethics Committee of the Medical University of Silesia in Katowice (no PCN/CBN/0052/KB/93/22 dated on 31st May 2022) which concluded that the research does not require consent as it does not fall into the category of medical experiment. The research met the requirements of the Declaration of Helsinki [11]. The study participants included paramedics and nurses working in the hospital emergency department and being involved in the processes under study. Before participating in the study, staff received written information about its purpose, procedure, the possibility of withdrawing from participation at any stage, and the fact that the researchers would not collect any data that could identify participants. Interviews were conducted in the absence of other staff to ensure no third-party access to the data.

The research was carried out with the use of direct interview and observation methods. Questionnaires were administered among 53 medics (30 nurses and 23 emergency paramedical staff) working in the study ED, who were on duty during data collection. The inclusion criteria for the study were: consent to participate in the study, employment as a nurse or paramedic, and being on duty during the study period. The exclusion criteria were: lack of consent to participate in the study, employment in a position other than a nurse or paramedic, and not being on duty during the study period.

This study was designed as a pilot project to assess the potential and feasibility of using the spaghetti diagram, the Ishikawa diagram, and the HFMEA in a hospital emergency department before implementing a full-scale research project. Workload in the ED was not assessed at this stage. In order to conduct the pilot project, a team consisting of an emergency nurse and a paramedic working in the ED was established and the project plan

was developed. During a „gemba walk”, team members recorded their observations, conducted interviews, and prepared waste sheets. Then, during a brainstorming session, the team created Ishikawa and spaghetti diagrams and an HFMEA analysis, in which assigned appropriate values were assigned by consensus for calculating the risk priority index. The final stage of the team's work involved presenting the prepared documentation and conclusions to the department's management and directors. The documentation was not accessible to third parties.

The calculations were made based on the number of interview questionnaires in which the respondents' profession was recorded, which enabled the calculation of the number of nurses and paramedics. We would like to clarify that during the study, no data such as length of service or other sociodemographic variables were collected. The following questions were asked: Which processes in the ED are most important to you? Which of them cause the most problems? Which processes involve the most people, take the most time and have the biggest count of waste?

During „gemba-walk” (following a patient's route throughout all the stages of receiving medical services), which included one 12-hours day-shift and one 12-hours night – shift separately for each process, observations were made of the following processes indicated by staff during interviews as key processes in the ED: medical triage and transferring ED rooms between shifts. They were 'main processes' identified also by taking into account: the greatest number of patients undergoing the procedure, the engagement of the biggest amount of staff and the count of waste leading to high risk of possible negative outcomes.

During the observation, the identification of kinds of waste was made using the Locher's Worksheet [12]. The definition of „waste” adopted for the study accounted for the ineffective use of resources within the process and any activities irrelevant to treatment itself or putting an end to a patient's stay in the ED. The purpose of its creation was to present examples of waste for further analysis. Ultimately, the types of waste identified were those that were recurring in the observations of both project team members.

To illustrate the actual process flow and enable the detection of bottlenecks and sources of waste for triage process the spaghetti diagram was prepared. This involved creating a graphical plan of the triage room detailing the work stations. Staff movement was shown on the chart as lines representing individual steps. Overlapping lines indicated repetition of the same activities. The Ishikawa diagram for both processes were designed. The „head” means analysed problem, „spine” gathers the „bones”, which in turn represent groups of reasons causing the problem. The risk priority index was estimated and the risk analysis of failures and defects, their types and effects (FMEA – Failure Mode and Effects Analysis) was followed. The risk was estimated based on the multiplication:  $LPR = LPZ \times LPW \times LPO$  (LPR – the risk priority index, LPZ (=CI) – the impact of the failure on the effect, LPW (=PO) – the possibility of a failure or its cause occurring, LPO (=DD) – the probability to discover a failure). For LPZ, LPW and LPO, values from 1 (lowest share in risk) to 10 (highest share) were adopted. The indices were

assessed according to the following criterium: low risk when LPR 1 – 50, moderate risk LPR 51-100, high risk LPR – 101 – 200 and very high risk LPR 201 – 1000.

## RESULTS

Most respondents (25 in total: 15 nurses and 10 paramedics) identified the triage process as the most important and involving the highest number of staff in the emergency department, as it determines the identification of patients whose health or life is at risk. During one interview the nurse expressed her opinion: *“The triage process is undoubtedly the most important. It applies to every patient who comes to the ER, so it should run smoothly. Meanwhile, we have to go from room to room because of a lack of equipment.”*

The process of handing over the office to the next shift was considered crucial by 22 respondents (10 nurses and 12 paramedics). in order to illustrate one paramedic justified his opinion as follows: *“I think handing over the room to the next shift is a crucial process. The point is to ensure everything is complete and ready for use, because in the ED, you never know when the next patient will arrive or what condition they'll be in. Filling in gaps is time-consuming, so they should be updated on an ongoing basis, and this applies to every employee.”*

During „gemba-walk” (following the patient's route throughout all stages of receiving medical services), the following procedures were indicated by staff during interviews as key processes in the ED: triage and transferring ED rooms between shifts. The types of waste described by the team during a brainstorming session in the processes of medical segregation and transferring ED rooms between shifts are presented in Table 1.

In order to visualize the waste caused by excessive staff movement, a spaghetti diagram was developed (Fig. 1). After observation of the triage process, we noted excessive movement between triage rooms to take an ECG examination (there was only one ECG machine) and to get a cell phone and inform a doctor that a new patient had arrived (lines number 1 and 9). We also observed that nurses and paramedics have to go to the sink situated in opposite side of the room to moist the gauze pad needed for electrocardiography examination (lines number 5 and 6). These situations were repeated during each observation, therefore it was suggested to order the second cell phone and the second ECG machine and to put a bottle of water on the worktop near the ECG station. The remaining lines were not important for further improvements because they resulted from the construction of the room and could not be modified.

While designing the Ishikawa cause-effect diagrams for both processes investigated in the study (Fig. 2 and 3), the final customer's profile was determined – the patient. Coefficients for calculating the risk level factor showed in Table 2, were: Customer Importance (CI), Probability of Occurrence (PO), Defect Detectability (DD). The FMEA analysis for both processes is showed in Table 3, which presents potential causes and hypothetical solutions for department and hospital management staff.

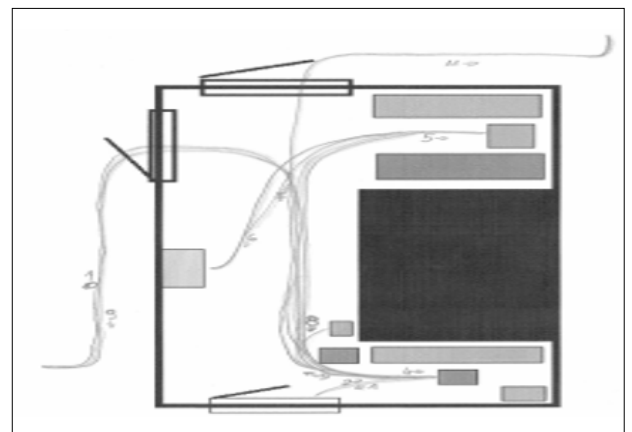
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■ Tab. 1. Waste identification worksheet

| Waste category                                                                                                              | Observations                                                                                                                                                                                                                                                               | Activities suggested                                                                                                                                                   | Impact on cost, service, quality and safety                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Overproduction</b><br>Processing bigger amount of information or earlier than the process and the following one require. | Admitting scheduled patients to various hospital wards in the ED.                                                                                                                                                                                                          | Admitting the patients in the scheduled admission unit.                                                                                                                | Extended waiting time for other patients to be segregated and to have the first contact with a doctor.                                                                                   |
| <b>Supplies</b><br>Processing excessive information with reference to one patient/one piece of supplies.                    | Excessive, compared to necessary, amount of disposable equipment resulting in its expiration of use.                                                                                                                                                                       | Replenishment of supplies according to the needs.                                                                                                                      | Cost increase.                                                                                                                                                                           |
| <b>Corrections</b><br>Improper or incomplete information and work 'checking'.                                               | The necessity of verification if a given patient is really scheduled for admission to a particular ward by the segregation staff. Incorrect interpretation of referrals by the registration staff resulting in directing patients to the ED instead of outpatient clinics. | Admitting patients in the scheduled admission unit. Every day reports with patients' names to be admitted to hospital wards. Staff training.                           | Extended waiting time for other patients to be segregated and to have the first contact with a doctor.                                                                                   |
| <b>Excessive processing</b><br>Unnecessary or too time-consuming processes or their particular stages.                      | Mirroring paper and electronic documentation.                                                                                                                                                                                                                              | Enabling to print electronic information.                                                                                                                              | Possibility of damaging or losing paper documents. Lower quality of health care. Extended waiting time for other patients to be segregated and to have the first contact with a doctor.  |
| <b>Waiting</b><br>Information in a queue to be processed.                                                                   | Waiting for the information from the hospital wards on whether to admit a patient. Waiting for the equipment to be repaired.                                                                                                                                               | Admitting patients in the scheduled admission unit.                                                                                                                    | Lower quality of services. Extended waiting time.                                                                                                                                        |
| <b>Unnecessary movement</b><br>Unnecessary or excessive movement of the staff.                                              | Lack of a work phone in second segregation room.                                                                                                                                                                                                                           | Purchasing a phone.                                                                                                                                                    | Extended waiting time for patients. Lowered level of satisfaction in both patients and the ED staff.                                                                                     |
| <b>Unnecessary transportation</b><br>Unnecessary or excessive movement of personnel or information (manual or electronic).  | Multiple transportations of the patient to the Radiology Unit for examinations prescribed additionally by subsequent doctors. Long distance to the equipment storeroom.                                                                                                    | Doctors' training. Working out a routine analysis of checking all necessary scheduled imaging examinations during the first consultation. Creating hand-held storages. | The risk of delays in implementing treatments. The risk of complications connected with multiple movements of a patient from a portable bed to the diagnostic table in the imaging unit. |
| <b>Unused human</b><br>resources Incomplete use of possibilities and abilities of the staff.                                | Delegating qualified medical staff to assist the patient during imaging examinations which lasts tens of minutes instead of taking advantage of non-medical staff.                                                                                                         | Employing hospital attendants/paramedics qualified in first aid to transport patients within hospital premises.                                                        | Extended waiting time to receive a nursing, rescuing or medical treatment due to the absence of qualified staff.                                                                         |

■ Tab. 2. Coefficients for calculating the risk level factor

| Customer Importance (CI=LPZ) | Probability of Occurrence (PO=LPW) | Defect Detectability (DD=LPO) |
|------------------------------|------------------------------------|-------------------------------|
| 1 irrelevant                 | 1- accidental                      | 1- very high                  |
| 2-3 low                      | 2-3 low                            | 2-3 high                      |
| 4-6 moderate                 | 4-6 moderate                       | 4-6 moderate                  |
| 7-8 high                     | 7-8 high                           | 7-8 low                       |
| 9-10 very high               | 9-10 very high                     | 9-10 lack of detectability    |



■ Fig. 1. Spaghetti diagram for the triage process

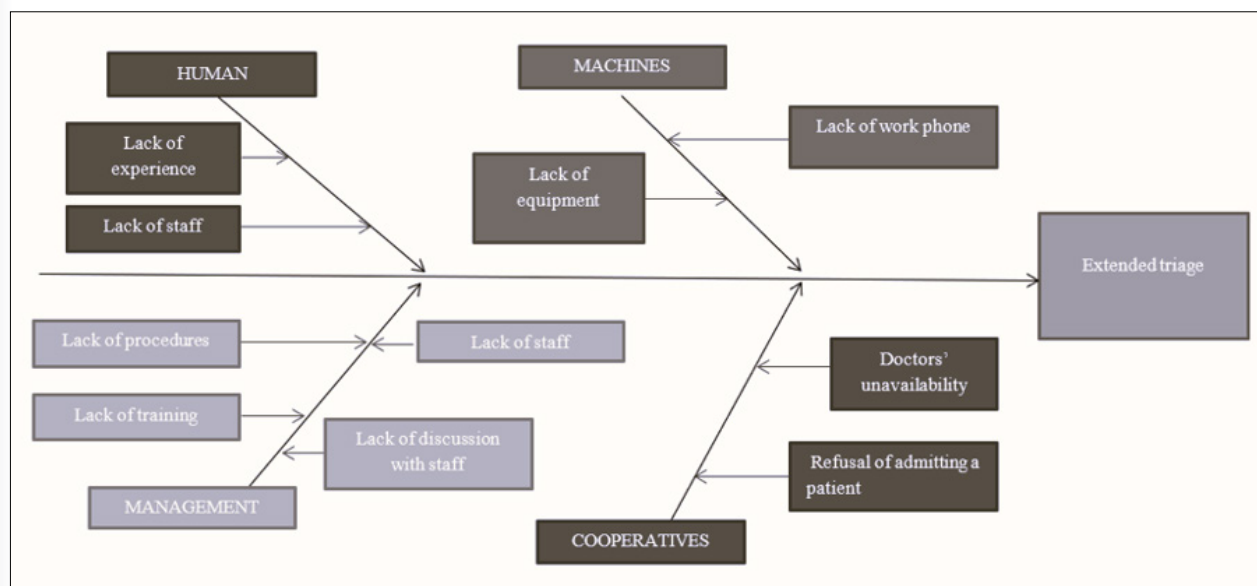
■ Tab. 3. The FMEA analysis for triage process and transferring ED rooms between shifts

| Failure Mode and Effects Analysis (FMEA)        |                                                                                |                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                             |                                                                                                                                                        |    |    |    |     |                                                                                                                                                                                                      |    |    |    |     |
|-------------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|-----|
| A. triage process                               |                                                                                |                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                             |                                                                                                                                                        |    |    |    |     |                                                                                                                                                                                                      |    |    |    |     |
| B. transferring ED rooms between shifts process |                                                                                |                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                             |                                                                                                                                                        |    |    |    |     |                                                                                                                                                                                                      |    |    |    |     |
| Ward: <b>Emergency Department</b>               |                                                                                |                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                             |                                                                                                                                                        |    |    |    |     |                                                                                                                                                                                                      |    |    |    |     |
| No                                              | Potential drawback                                                             | Potential effects                                                                                                                                                                                                                                                                 | Potential causes                                                                                                                                                                                            | Preventive actions                                                                                                                                     | CI | PO | DD | LPR | Results                                                                                                                                                                                              |    |    |    |     |
|                                                 |                                                                                |                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                             |                                                                                                                                                        |    |    |    |     | Improvement actions                                                                                                                                                                                  | CI | PO | DD | LPR |
| A1.                                             | ED staff shortages                                                             | <ul style="list-style-type: none"> <li>long waiting time for triage</li> <li>high risk of medical error and missing important symptoms in the physical examination</li> </ul>                                                                                                     | <ul style="list-style-type: none"> <li>inept human resources management</li> <li>staff shortages</li> </ul>                                                                                                 | Analysis of creating of staffing schedules.<br>Analysis of patient attendance by time of the day, day of the week, the season and staffing adjustment. | 6  | 3  | 3  | 54  | Increased control of human resources management.<br>Delegation of staff from other hospital departments to assist in crisis situations.                                                              | 6  | 2  | 3  | 36  |
| A2.                                             | Poorly trained medical staff                                                   | <ul style="list-style-type: none"> <li>improperly performed medical triage</li> <li>slower and chaotic work</li> </ul>                                                                                                                                                            | <ul style="list-style-type: none"> <li>lack of verification when hiring new staff</li> <li>lack of periodic training in physical examination and history taking</li> </ul>                                  | Increasing the amount of internal training.                                                                                                            | 7  | 6  | 6  | 252 | Modification of the Periodic Training Plan.<br>Introduction of mandatory training and enforcement of attendance.<br>Creation of the procedure for the induction and adaptation of new medical staff. | 7  | 3  | 5  | 105 |
| A3.                                             | Unavailability of doctor/ refusal to admit patient.                            | <ul style="list-style-type: none"> <li>extending the process</li> <li>risk of deterioration of the patient's condition</li> <li>reduced patient satisfaction with the services provided</li> </ul>                                                                                | <ul style="list-style-type: none"> <li>too few medical staff in the Emergency Department</li> <li>too much workload</li> <li>one doctor shifting workload to another</li> <li>lack of discipline</li> </ul> | Analysis of the process of creating and staffing schedules.<br>Increase in the number of medical staff on duty in the Emergency Department.            | 9  | 7  | 4  | 252 | Modification of the existing triage procedure.<br>Enforcement of the culture of discipline through management.                                                                                       | 9  | 7  | 4  | 252 |
| A4.                                             | Hardware shortages                                                             | <ul style="list-style-type: none"> <li>extending the process</li> <li>wasting staff time and energy, and wasting the patient's time</li> <li>risk of worsening the patient's condition</li> </ul>                                                                                 | <ul style="list-style-type: none"> <li>too few company cell phones</li> <li>lack of attention to replenishing office equipment</li> </ul>                                                                   | Internal staff training.<br>Office condition inspections.                                                                                              | 6  | 6  | 3  | 108 | Equipping medical triage rooms with a company mobile phone.                                                                                                                                          | 6  | 6  | 3  | 108 |
| A5.                                             | Lack of knowledge among management about the problems occurring in the process | <ul style="list-style-type: none"> <li>lack of control over the process</li> <li>reduced patient satisfaction with the services provided</li> <li>reduced staff satisfaction with their work</li> <li>reduced competitiveness and innovation risk for the organization</li> </ul> | <ul style="list-style-type: none"> <li>lack of dialogue with staff</li> <li>insufficient branch management staff</li> <li>lack of awareness of existing problems</li> </ul>                                 | Regular meetings with front-line staff.                                                                                                                | 1  | 8  | 8  | 64  | Standardisation of procedures by creating appropriate procedures.                                                                                                                                    | 1  | 8  | 8  | 64  |
| B1.                                             | ED staff shortages                                                             | <ul style="list-style-type: none"> <li>high risk of overlooking deficiencies and/or equipment failures</li> </ul>                                                                                                                                                                 | <ul style="list-style-type: none"> <li>poor human resources management</li> <li>too few medical personnel</li> </ul>                                                                                        | Analysis of creating and staffing schedules.                                                                                                           | 6  | 3  | 3  | 54  | Increased control of the management department over the department's human resources management.<br>Delegation of personnel from other hospital departments to assist in crisis situations.          | 6  | 2  | 3  | 36  |

■ cont. Tab. 3. The FMEA analysis for triage process and transferring ED rooms between shifts

|     |                                                                          |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                     |   |   |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                     |   |   |   |     |
|-----|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----|
| B2. | Poorly trained medical staff                                             | <ul style="list-style-type: none"> <li>lack of proper filling in disposable equipment;</li> <li>lack of knowledge on how to operate medical devices</li> <li>slower and chaotic teamwork</li> <li>lack of commitment to a culture of discipline</li> </ul> | <ul style="list-style-type: none"> <li>lack of knowledge levels verification when hiring new staff.</li> <li>insufficient periodic training.</li> <li>lack of professional development assessments verification.</li> <li>lack of employee awareness of organizational culture.</li> <li>the need to bring equipment and devices to the office when performing medical procedures on the patient.</li> </ul> | <p>Knowledge and skills testing</p> <p>Increasing the number of internal training sessions.</p> <p>Verifying the level of professional development of medical staff</p> <p>Verifying the level of existing organizational culture.</p> <p>A standardized list of equipment and devices necessary in the office.</p> | 7 | 6 | 6 | 252 | <p>Creating a procedure for the onboarding and adaptation of new medical staff.</p> <p>Modification of the Periodic Training Plan for the use of new devices.</p> <p>Mandatory training attendance.</p> <p>Procedure for settling professional development for medical staff.</p> <p>Training for staff on tools for work optimization.</p> <p>Introducing checklist templates as attachments to the procedure.</p> | 7 | 3 | 5 | 105 |
| B3. | Unrepaired hardware failures                                             | <ul style="list-style-type: none"> <li>insufficient training of technical department staff in troubleshooting</li> <li>lack of spare parts</li> <li>lack of appropriate tools for repairs</li> </ul>                                                       | <ul style="list-style-type: none"> <li>manufacturing defects, improper use.</li> <li>long waits for authorized service.</li> </ul>                                                                                                                                                                                                                                                                           | <p>Providing the Technical Department with the necessary tools and replacement parts.</p>                                                                                                                                                                                                                           | 8 | 7 | 3 | 168 | <p>Training of technical department staff by device manufacturers.</p>                                                                                                                                                                                                                                                                                                                                              | 8 | 7 | 3 | 168 |
| B4. | Inefficiency of the Public Procurement Department and the main warehouse | <ul style="list-style-type: none"> <li>lack of on-time deliveries</li> <li>lack of steady patient care</li> </ul>                                                                                                                                          | <ul style="list-style-type: none"> <li>-lack of communication between emergency department and other departments</li> </ul>                                                                                                                                                                                                                                                                                  | <p>Introduction of CITO mode for issuing equipment from the warehouse to the Emergency Department and for troubleshooting equipment failures.</p> <p>Optimization of emergency purchases.</p>                                                                                                                       | 3 | 4 | 7 | 84  | <p>Developing appropriate procedures.</p> <p>Introducing regular communication between departments.</p>                                                                                                                                                                                                                                                                                                             | 3 | 4 | 7 | 84  |

Legend: CI - the impact of the failure on the effect; PO - the likelihood of a failure or its cause occurring; DD - the probability to discover a failure; LPR - risk priority index



■ Fig. 2. The Ishikawa diagram for triage process

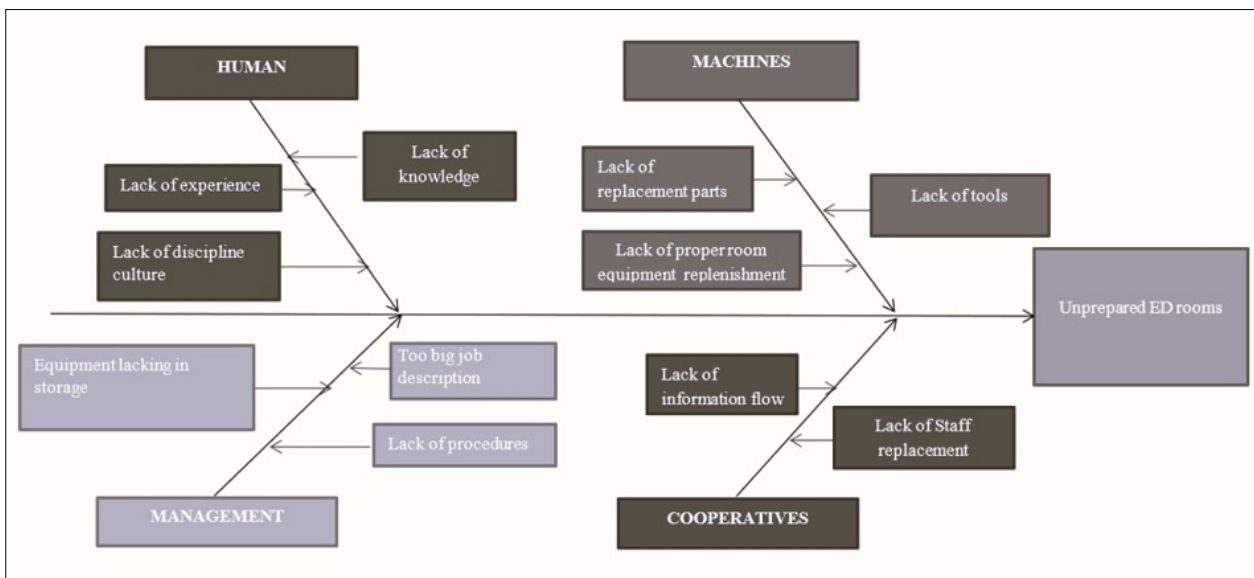


Fig. 3. The Ishikawa diagram for transferring ED rooms between shifts process

## DISCUSSION

There is limited evidence in the current research regarding the use of specific management concepts in Polish emergency departments. Globally, risk analysis and HFMEA are commonly used in hospital settings, particularly in intensive care units, operating rooms and pharmacies [13]. The most important factor influencing the level of risk is the enormous overload of the EDs as almost 48-50% of all the visits are consultations and only about 29% are of an emergency character [14].

The overload of EDs caused by work interruptions resulting from the addition of new tasks, affects the quality of work and can lead to medical errors [15]. Work interruptions may also be caused by bottlenecks in processes, such as equipment deficiencies demonstrated in our own research or equipment failures not reported when rooms were transferred to the next shift. The Ishikawa diagram may help to identify the following failures in the ED: the deficit of quality trainings among staff, the lack of standards in the documentation process, the inefficient system of reporting problems, staff shortages, the lack of experience, the lack of knowledge of medical segregation by a nurse specialised in triage, the lack of designed training schedule, the lack of a team responsible for increasing work quality in the ED and issues in communication [16,17]. Similar conclusions result from our own research, in which the fishbone diagram allowed us to identify, among others, insufficient level of training and staff shortages as the causes of the identified problems.

The mentioned above diagram helps develop the analysis of the type and effect of the FMEA analysis, which might be used to improve the triage process, which is crucial for patient safety, especially in the case of a mass casualty incident causing overload of the ED [18]. In our study, the HFMEA analysis indicated staff training and improvement of medical personnel's clinical education as necessary steps to reduce risk. This corresponds with the results of Dadashi et al. [17] and Jen-Shu et al. [18], in which the authors, based on the FMEA analysis, indicated insufficient training of medical personnel, low risk

awareness and staff shortages as risk factors for errors and waste. These factors in the hospital ED environment are in 62.3% of cases the cause of failures and they might come from the malfunctions in the processes, in 13.8% from the errors in communication, in 15.7% from the administrative mistakes, in 8.1% from the lack of knowledge or experience and 99% of the respondents identified prolonged time of waiting to be the most common cause of the failures [19]. The risk of adverse events and increased mortality increases with the length of the patient's stay in the emergency department and with staff shortages. The self-reported research has found the failure in the prolonged time of medical segregation process and unprepared rooms in the process of transferring ED rooms between shifts. Both issues constituted threats to patients' health or life.

The risk analysis is a tool which could and should be implemented in all Polish hospitals [20]. According to the specific work environment, such a method would be of particular benefit to hospital emergency departments.

## CONCLUSIONS

The implementation of risk assessment tools in hospital emergency departments appears to be essential. The practical and research implications in the field are that introduction of the tools and solutions discussed in this paper is possible in ED and can provide a real reduction in the risk of errors. Moreover they may serve to minimise inequalities in access to healthcare by shortening waiting times for services through the elimination of bottlenecks and improving patient safety by streamlining and optimizing the functioning of hospital emergency departments.

## Limitations of the study

Due to differences in ED workload resulting from the seasonality of calls, the day of the week and time of day and clinical condition of patients, the observation should last longer to reflect real-life conditions. There was also no post-intervention evaluation and the research was conducted in only one Emergency Department. It is advisable

to extend the study to other such departments in order to identify the most common types of waste and sources of problems and develop uniform standards of conduct aimed at eliminating them using management tools, as those presented in the article, to reduce the risk of waste, errors or problems occurrence. Suggested next steps include conducting the research in all emergency departments in Poland using more detailed interview questionnaires and exploring more processes with validated instruments and those used in our research.

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