Problems of *Clostridium difficile* infection (CDI) in Polish healthcare units

Zofia Kiersnowska[1,2,A-D] (iD), **Ewelina Lemiech-Mirowska**[2,3,A-D] (iD), **Dobrochna Ginter-Kramarczyk**[4,C,E] (iD),
Izabela Kruszelnicka[4,C,E] (iD), **Michał Michałkiewicz**[4,C,E,F] (iD), **Michał Marczak**[2,F] (iD)

[1] *Chief Sanitary Inspectorate, Warsaw, Poland*
[2] *Medical University of Lodz, Project InterDoktorMen, Poland*
[3] *Laboratory of Epidemiology, Military Institute of Hygiene and Epidemiology, Warsaw, Poland*
[4] *Institute of Environmental Engineering and Building Installations, Poznan University of Technology, Poland*
*A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation,
D – Writing the article, E – Critical revision of the article, F – Final approval of article*

▌ Abstract
The issue of patient safety during the provision of health services poses a key challenge in health policy. The number of hospital-acquired infections (also known as HAI – Healthcare Associated Infection) determines the level of quality of health services provided in a given health facility. Effective management reinforced by the awareness of a team of medical professionals allows not only reduction in the hospital's finances, but also the frequency of adverse events, which undoubtedly include hospital-acquired infections. Good cooperation between departments and a Hospital Infection Control Committee is one of the key aspects that translates to the rapid identification of new epidemic outbreaks. Infections caused by strains of *Clostridium difficile* (CDI, *Clostridium difficile* infection) are one of the main factors responsible for the prolonged hospitalization of patients. In the United States, *Clostridium difficile* causes almost half a million infections annually, and its treatment costs are estimated at nearly $ 4.8 billion per year. In Poland, the number of CDI cases in 2018 was 11.592 (for comparison, in 2013 the number of infections caused by this bacterium was 4.728). Hospital environment, inappropriate antibiotic therapy and development of multi-drug resistant strains increase the risk of infections. In order to improve the safety of hospitalized patients, infection risk management should be a systemic, formalized activity integrated with the overall process of managing a health facility. It is necessary that central units have interest in creating effective tools to enable successful epidemiological supervision and the implementation of strategic assumptions of health policy in this area.

▌ Key words
patient safety, risk management, hospital-acquired infections, Healthcare Associated Infection, *Clostridium difficile* infections

INTRODUCTION

Clostridium difficile (*C. difficile*) infection (CDI) has become one of the most common healthcare-associated (HA) infections in modern medicine. It is associated with increased morbidity, in-hospital mortality, prolonged hospitalization, and increased costs [1]. The reported incidence of HA CDI varies according to the country, size of the institution and ward location, and type of population studied [2, 3, 4]. Data from the Centre for Disease Control and Prevention (CDC) show that the HAI (Healthcare Associated Infection) problem affects 1 in 31 patients every day [5, 6]. According to the CDC report on the risks of drug resistance (Antibiotic Resistance Threats), *C. difficile* is classified as the main cause of antibiotic associated diarrhea (AAD) acquired in the hospital, which represents a so-called 'serious threat' [1, 2, 3, 6]. Analysis of the literature makes it clear that risk is an integral part of almost every aspect of medical practice, which is a process balanced between the effectiveness of medical procedures and risk. According to Marczak [7], risk is a feature of the system characterized by measurability and the diversity of changes taking place in this system, together with the possibility of predicting the consequences of this change

[7]. Please note that the given definition of risk assumes that this phenomenon is occurring in a certain system, which in this case is an organization – a healthcare facility. The risk generated by a healthcare facility, as mentioned above, occurs as a result of performed diagnostic, therapeutic and care procedures [8] and technical, functional and sanitary conditions. The mechanism of risk has its cause and produces certain effects [9]. Common sources of risk in inpatient care include failure to comply with sterility conditions and medical procedures, which often translates to new cases of HAI, thus causing the risk of health loss, and even the death of the patient as the most tragic consequence of an adverse event. For a healthcare institution, being the administrator and manager of the level of risk, this may result in legal and indemnification proceedings (in this case, the risk acquires an economic dimension in the form of unforeseen costs) [4, 8, 10].

Basic information about health care in Poland. The issues of risk management in healthcare in Poland pose a huge challenge for all healthcare institutions. Data from Statistics Poland [11] indicate that in Poland there are 951 stationary public general hospitals and 191 day hospitals (the so-called one-day hospitals, offering 1,200 day care places). In general hospitals, 7.8 million patients were hospitalized, whereas as part of day care carried out in stationary and day hospitals, a total of 3.4 million patients were treated, with day hospital

Address for correspondence: Zofia Kiersnowska, Medical University of Lodz, Project InterDoktorMen, Poland
E-mail: zofiakiersnowska.p@gmail.com

patients accounting for 3.4% of the total number of patients treated in day-care. Another form of medical care aimed at alleviating pain and suffering in the final stage of the patient's life are the 95 stationary hospices and 66 palliative care departments, which provided 34.6 thousand people with care. This form of care is also provided in palliative and hospice care wards in general hospitals. One of the most significant challenges in the health care system is to ensure that the medical staff are properly educated and deployed [11, 12]. In 2017, the average length of time the patient stayed in the hospital ward, on a national scale, amounted to 5.3 days. Longer stays were recorded, among others, in the following departments: haematology (1.3 days longer), rehabilitation and geriatrics (0.4 days longer), toxicological and cardiac surgery (0.3 days longer).

In the face of the progressive aging process of society, long-term care facilities play an important role in health care, providing patients with round-the-clock nursing, care and rehabilitation services, as well as the continuation of pharmacological and dietary treatment over a longer period of time. Another indicator showing the activity of the wards is the average use of beds per year. This ratio for all hospitals in Poland was 65.8%, or 240 days.

According to the Supreme Audit Office Report (2018), on 30 June 2017 in Poland, there were only 110 doctors with a specialization in medical microbiology who were professionally active. In 4 provinces there was a complete lack of physicians with this specialty, and in other provinces their number varied from 2–18. A similarly bad situation existed in the case of specialists in the field of epidemiology, of whom there were 219 in Poland. In addition, there are not enough epidemiological nurses to participate in broadly understood infection control, which involves, among others, controlling the sanitary and epidemiological status of the hospital, maintaining an infection record, staff training, supervising and monitoring the work of staff, and participating in planning care for a patient suffering from hospital infection. According to the Infection Control Act, the number of epidemiological nurses should not be less than 1 per 200 hospital beds, which is not observed in many hospitals. Keeping a record of infections in hospitals also plays an important role. The Supreme Audit Office [12] control showed that registration cards prepared by doctors were unreliable and often lacked much information. 18% of the cards audited by the Supreme Audit Office (696 cards), did not describe any risk factors, 23% of the cards did not include any antibiotic treatment, more than 15% of the cards had no record of a microbiological examination being performed, 4% of the cards did not specify the clinical form of infection, and 3% of the cards lacked patient data. In addition, 246 cards were issued by doctors with a delay of up to 288 days. In 2 hospitals, no such register was kept at all, which was in contravention of the Infection Control Act.

Risk management process. This is a process that covers all activities related to analyzing, limiting, eliminating and managing a team in a particular case [13]. It is also described with the use of detailed recognition of the nature and extent of the potential threat, allowing the selection of preventive actions within an appropriate time frame. The given definitions indicate that patient safety depends on: recognition of the risk and the adoption and implementation of actions determined on the basis of its assessment and analysis. The most important in this respect is played by the personnel policy, which will affect the effective monitoring of infections and the implementation of infection prevention procedures [13, 14].

An efficiently functioning system is flexible in relation to the active corrective actions being taken. The literature on the subject shows that the rapid spread of pathogenic microorganisms in a hospital environm (e.g. *C. difficile*) is the result of a lack of effective control and inadequate selection of tools for HAI supervision.

Risk management is a series of activities that in terms of quality issues should be put in the form of a PDCA cycle in which successive stages are repeated cyclically: Plan – Do – Check – Act, which leads to improved safety in the field of medical services provided [14]. The 'Deming wheel' scheme of cyclical actions to prevent infection is shown in Figure 1.
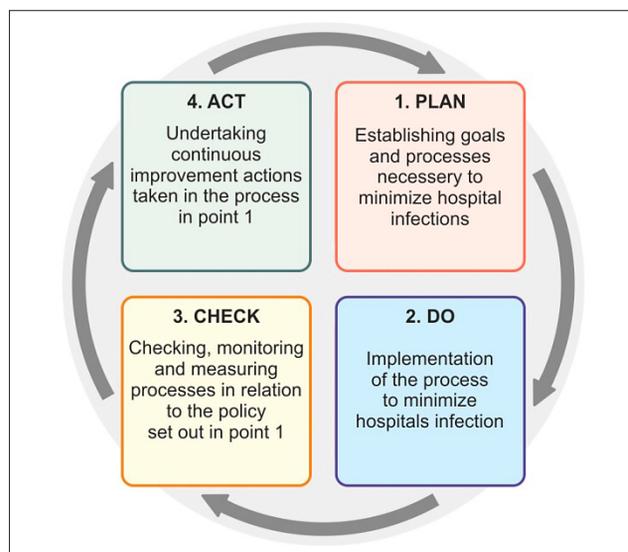

Figure 1. The 'Deming wheel' scheme of cyclical actions to prevent infection [15]

The hospital infection control team (hereinafter referred to as 'the team') should provide information on the epidemiological situation of each hospital unit on an ongoing basis, and adapt existing procedures to the current problems of the facility [16]. According to the Act, the team shall consists of: a properly trained doctor, nurses / midwives – as specialists in epidemiology, numbering not less than 1 person per 200 hospital beds, and a laboratory diagnostician as a specialist in microbiology, if the doctor does not have specialization in this field [16, 17].

Activities undertaken by the team should make reference to the 'Deming wheel' diagram and should include, among others, the following processes:
- creating a local plan of action;
- continuous and effective monitoring of the epidemiological situation;
- analyzing and actively influencing the minimization of the risk of infection in hospitalized patients;
- developing and efficiently implementing an infection prevention procedure [14].

The expected result of activities conducted in a consistent way from the aspect of HAI control is the improvement of the quality of medical services and the reduction of patient hospitalization costs. The tasks of a physician-epidemiologist

226	Annals of Agricultural and Environmental Medicine 2021, Vol 28, No 2

Zofia Kiersnowska, Ewelina Lemiech-Mirowska, Dobrochna Ginter-Kramarczyk, Izabela Kruszelnicka, Michał Michałkiewicz, Michał Marczak. Problems…

should include: supervising anti-epidemic activities in situations where the number of infections increases drastically; exercising internal control of hygiene standards on a regular basis; developing preventive programmes, participating in the work of the antibiotic therapy team, and implementing training courses for the staff.

Good cooperation of the team with other hospital units translates to:

- accelerating the process of identifying the factor responsible for the infection (in cooperation with a microbiologist);
- replacement of empirical therapy by targeted treatment;
- successful elimination of epidemic outbreaks by undertaking efficient and effective actions;
- increasing staff awareness of the correct principles of hand disinfection and hygiene (all employees);
- precise procedures for surface disinfection and sterilization of medical equipment (sterilization point);
- reducing the amount of antibiotics consumed and the number of patients hospitalized due to severe infections (hospital pharmacy, hospital antibiotic policy team);
- obtaining detailed data on the health situation in the hospital, and financial expenses resulting from the implementation of individual medical procedures (liaison nurses and a team of coordinating doctors)[18].

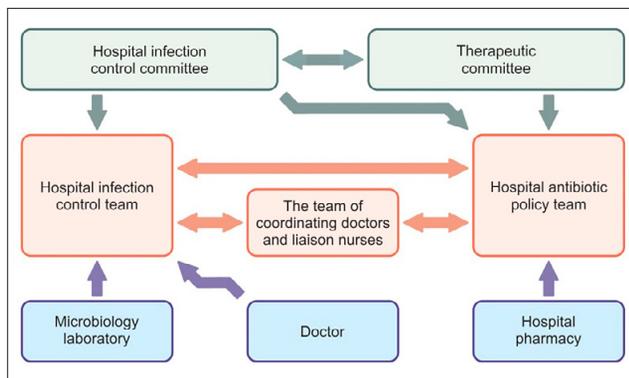The organization of the infection risk management system is shown in Figure 2.

Figure 2. Organization of infection risk management system

The risk management system should be based in schemes and procedures for which it is certain that they will translate into measurable benefits, for instance by reducing a given threat to a level that is universally acceptable and does not pose a threat to the functioning of the entity.

According to ISO 31000, the tasks of senior management include, among others, risk identification, risk assessment and evaluation, and risk management, as well as risk monitoring and related communication (Fig. 3). This paper refers to ISO 31000: 2009 Risk Management – Principles and Guidelines [19, 20]. The ISO 31000 standard is largely based on solutions developed by AIRMIC / ALARM / IRM Risk Management Standard, which is commonly referred to as the FERMA (Federation of European Risk Management Associations) standard [9]. Its primary objective, in terms of health care, is to reduce the impact of negative factors on patient safety, staff and the entire facility.

Risk management in a healthcare facility is a process that consists of many stages. The first stage, which is risk identification, involves 2 activities:
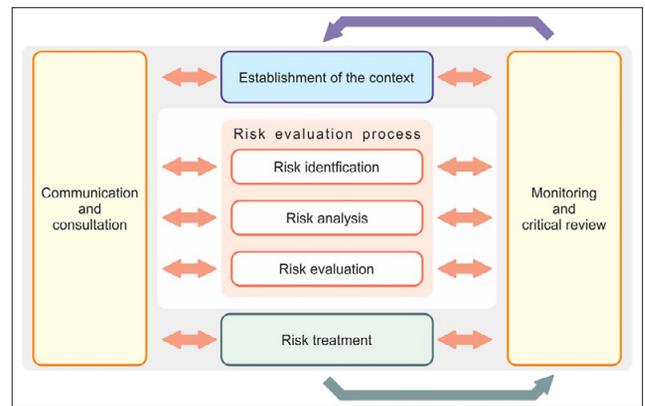

Figure 3. Risk management process

1) identification of microorganisms that cause infection, e.g. *C. difficile*, their virulence and transmission paths;
2) elimination of procedures that pose a risk to patients, visitors and staff, for instance, data from observation of hospital practices (e.g. hand hygiene), improper decontamination of medical equipment, risk of admission of a patient with an infectious disease, microbiological data (e.g. presence of multi-drug resistant microorganisms).

These activities are aimed at identifying the risk of rare events that could have serious health consequences, and identifying common problems or practices that affect the quality of hospital health care. Risk identification tools are most often based on the 'brainstorming' method or questionnaires, which, by discussing respective areas, describe both internal and external factors that may negatively affect these processes. The next step is to obtain evidence by the way of investigation, which usually requires expert knowledge.

Risk analysis is performed using a step-by-step method through a phased analysis of places and situations of ensuing omissions. Quantitative assessment is carried out mainly with the use of IT tools, and qualitative analysis is carried out with the use of a descriptive method, e.g. estimating possible consequences of risk. Thorough analysis uses reports from the infection control team, in this case those that concern the spread of *C. difficile*. The ongoing evaluation is looking for answers to such questions as: Why are there infections? How often do they happen? What are the likely consequences of not taking appropriate actions? How much does it cost to prevent this? [21]. Risk-related simulations can be performed with the use of, among others, Business Impact Analysis (BIA), SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, and event trees.

The next stage of the risk management process is risk control and an attempt to implement solutions that completely eliminate risk or reduce it to a minimum level. This is the so-called 'risk response', which directly involves its effects. One of the possible solutions is to shift responsibility onto the private sector, i.e. the use of an out-sourcing method, e.g. in the area of laundry, sterilization of medical instruments, disposal of clothing and hazardous waste, etc.

The final stage of the process is assessment of the implemented activities carried out by reviewing the merits of the introduced processes, audits, and monitoring of adverse events, which consists of ongoing, systematic data collection, its analysis and interpretation. The assessment of the effects

Annals of Agricultural and Environmental Medicine 2021, Vol 28, No 2

227

Zofia Kiersnowska, Ewelina Lemiech-Mirowska, Dobrochna Ginter-Kramarczyk, Izabela Kruszelnicka, Michał Michałkiewicz, Michał Marczak. Problems…

of implemented corrective actions is most often handed over to the managers of relevant units and the hospital's management in order to plan and implement appropriate preventive actions.

Characteristics of the *Clostridium difficile* strains. *Clostridium difficile* is a Gram-positive, spore-forming, strictly anaerobic bacillus which was first isolated from the stool of a healthy infant by Hall and O'Toole in 1935. The species name was chosen to reflect the difficulty with its culture and isolation. Pseudomembranous colitis was first described in 1893, but it was not until 1978, however, that George et al. associated *C. difficile* with human disease, and discovered that it was the organism responsible for the majority of cases of antibiotic-associated diarrhea. [22, 23]. This bacterium can be a normal part of the intestinal microflora detected in healthy individuals, but without causing disease by its presence (asymptomatic carrier-state affects approximately 3% of adults and two-thirds of children) [24].

C. difficile is a rod-shaped bacterium that can exist in a vegetative or spore form. In its spore form, the bacterium can survive harsh environments and common sterilization techniques. Spores of *C. difficile* are resistant to high temperatures, ultraviolet light, harsh chemicals, and antibiotics. Furthermore, because the spores are resistant to antibiotics, they can remain in the gastrointestinal tract and potentially contribute to recurrent disease following treatment and eradication of vegetative *C. difficile*. Pathogenic *C. difficile* organisms release 2 potent toxins that ultimately mediate diarrhoea and colitis. These large exotoxins, toxin A (TcdA), a 308-kDa enterotoxin, and toxin B (TcdB), a 270-kDa cytotoxin, exhibit an overall homology of approximately 63% at the amino acid level. Most enteropathogenic strains produce both toxins simultaneously. It is suggested that TcdA and TcdB work synergistically, based on the fact that a TcdB effect is dependent on tissue damage brought about by TcdA. TcdA has been regarded as the most important factor in diarrhoeal disease, but an increasing number of reports also show disease caused by TcdA-negative strains, thereby implying a more important and TcdA-independent role of TcdB in pathogenesis. Additionally, a binary toxin of *C. difficile* is currently being studied as a possible new virulence marker. This binary toxin, an actin-specific ADP-ribosyl transferase, can be present in up to 10% of *C. difficile* strains, but its prevalence is influenced by the selection of strains. The binary toxin is encoded by the cdtA gene (the enzymic component) and the TcdB gene (the binding component). The extent to which this toxin contributes to the pathogenicity of CDI is now being researched [22–33].

The clinical picture of CDI takes the form from mild self-limiting diarrhea to symptoms of toxic megacolon (*megacolontoxicum*) [22, 24]. *C. difficile* can be characterized according to its ribotyping which is performed using the polymerase chain reaction. In the last 10 years in highly-developed countries a distinct increase in the incidence and severity of antibiotic associated diarrhea caused by *C. difficile* has been observed. It is associated, for example, with the appearance of a new epidemic strain of *C. difficile* (BI/NAP1/BI/027) (*North American Pulsed Field Type*) otherwise known as PCR 027 ribotype, also producing, apart from the increased amount of toxins A and B, a so-called binary toxin (ADP-ribosyl transpherase). Recurrent infections have been identified as a special problem in CDI treatment because standard therapy failure rates are increasing. Ribotype 027 was found to have reduced susceptibility to metronidazole, rifampicin, moxifloxacin, clindamycin, imipenem, and chloramphenicol. This is clinically and financially concerning as it leads to severe disease presentation, as well as antimicrobial resistance with high morbidity and mortality rates, compared to other strains. Strains, such as ribotype 027 (especially its spores), spread more easily within the hospital because they can resist the hospital environment, cleaning, and disinfectants [1]. During an outbreak of CDI in hospitals in Poland from September 2011 – August 2013, the prevalence of this strain was shown to be 48%. The clinical symptoms of infection include fever, loss of appetite, nausea, and severe abdominal pain. A peculiar clinical and economic problem are recurrent infections, which are most often characterized by resistance to standard treatment. Risk factors for recurrence of infections include: another CDI episode in the patient's medical history, inadequate antibiotic therapy, long hospitalization, stay in the intensive care unit (ICU), age over 65 years, and infection caused by the strain of NAP1/BI/027 [26, 29, 33].

Risks associated with CDI. In Polish legislation, *C. difficile* is on the list of alarm factors [30], which means that it has been classified as a real risk to patients, staff, and the general public. Between 2013–2018 in Poland, infections caused by *C. difficile* more than doubled (Tab. 1, Fig. 1). The lowest rates of intestinal infections caused by *C. difficile* occurred in the Lubuskie, Opolskie and Podkarpackie provinces, i.e. in areas where there are no specialists in the field of medical microbiology, while the highest rates were usually recorded in the Mazowieckie province, where the number of specialist doctors is the highest. Therefore, it can be assumed that the lack of appropriate medical personnel means that the diagnostics conducted for *C. difficile* is inaccurate and incomplete, and the actual number of cases may be significantly higher. The risk of nosocomial spread of this microorganism results from its ability to produce spore forms [26, 27]. Spore forms have the ability to live outside of the human body for a long time (sometimes up to several months), and are very resistant to disinfectants. They spread rapidly in the hospital environment due to their high resistance to drying-out, temperature and chemical substances [31].

Among the important factors increasing the risk of CDI, are the use of broad-spectrum antibiotics that destroy the intestinal microbiota, creating a niche for the free reproduction of pathogenic bacilli. Medicinal products that are most likely to contribute to diarrheal symptoms or complications in the form of pseudomembranous colitis include: penicillins, cephalosporins, fluoroquinolones and clindamycin [32]. CDI risk factors also include: advanced age, the use of immunosuppressive drugs, cytostatics, proton pump inhibitors, concomitant diseases, gastrointestinal surgery procedures, long hospitalization, and incorrect medical procedures related to the patient's stay in hospital [26, 33]. National Institute of Hygiene statistics indicate that the most vulnerable persons are those over 65 years of age, whereas women only slightly prevail in the overall number of cases.

In the United States, CDI cases are identified with similar intensity to infections caused by methicillin-resistant

228   Annals of Agricultural and Environmental Medicine 2021, Vol 28, No 2

Zofia Kiersnowska, Ewelina Lemiech-Mirowska, Dobrochna Ginter-Kramarczyk, Izabela Kruszelnicka, Michał Michałkiewicz, Michał Marczak. Problems…

Table 1. Intestinal infections caused by *Clostridium difficile*: number of cases, incidence rate and number of hospitalized persons by provinces in selected years, according to: National Institute of Hygiene Reports, Department of Infectious Disease Epidemiology and Surveillance, Laboratory of Monitoring and Analysis of Epidemiological Situations [3]

Province	No. of cases per year				Incidence rate per 100 thousand				No. of hospitalized persons			
	Year				Year				Year			
	2013	2014	2016	2018	2013	2014	2016	2018	2013	2014	2016	2018
Dolnośląskie	176	187	160	315	6.0	6.4	5.5	10.9	168	186	156	301
Kujawsko-pomorskie	297	324	456	736	14.2	15.5	21.9	35.4	277	308	364	554
Lubelskie	202	243	736	1319	9.3	11.3	34.5	62.2	195	233	661	1255
Lubuskie	32	28	112	239	3.1	2.7	11.0	23.5	27	27	111	238
Łódzkie	280	270	576	1057	11.1	10.8	23.1	42.8	280	266	496	1041
Małopolskie	265	364	505	545	7.9	10.8	15.0	16.0	263	356	495	516
Mazowieckie	1112	1658	1627	1984	21.0	31.1	30.4	36.8	922	1096	900	1083
Opolskie	233	229	249	284	23.1	22.8	25.0	28.7	220	220	243	272
Podkarpackie	183	194	250	312	8.6	9.1	11.8	14.7	180	188	242	280
Podlaskie	67	168	233	368	5.6	14.1	19.6	31.1	65	165	231	361
Pomorskie	205	758	1082	763	8.9	33.0	46.8	32.8	198	731	972	698
Śląskie	858	956	1424	1784	18.6	20.8	31.2	39.3	844	935	1396	1753
Świętokrzyskie	104	247	348	405	8.2	19.5	27.7	32.5	103	198	225	320
Warmińsko-mazurskie	97	155	210	375	6.7	10.7	14.6	26.2	95	147	204	364
Wielkopolskie	284	338	375	569	8.2	9.7	10.8	16.3	282	326	370	541
Zachodniopomorskie	343	307	373	537	19.9	17.9	21.8	31.5	338	306	364	507
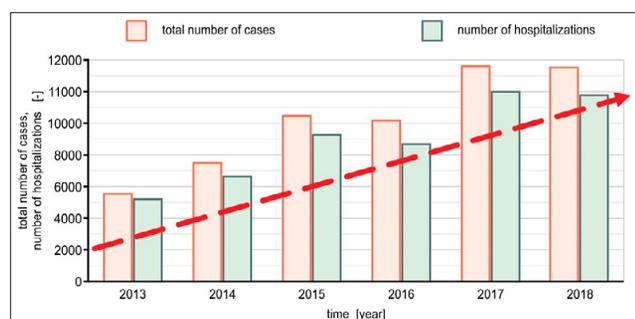
Figure 4. Situation of *Clostridium difficile* in Poland (overall number of cases and hospitalizations) [3]

Figure 5. Incidence rate per 100,000 inhabitants of *C. difficile* in Poland [3]

Staphylococcus aureus (MRSA), and both of these pathogens are responsible for the majority of healthcare-associated infections, more precisely as an adverse event of this care [13]. Data from the USA and Europe indicate a range from 10 to up to 90 cases of CDI per 10,000 hospitalizations annually [34]. Research conducted at the University Hospital in Kraków, Poland, in 2008–2014 showed that over 2/3 of patients diagnosed with *C. difficile* were infected during their stay in hospital [35]. *Reports on the incidence rate of infectious diseases, infections and poisoning in Poland* (Polish: *Raporty ws. zachorowań na choroby zakaźne, zakażenia i zatrucia w Polsce)*, prepared for the needs of NIZP-PZH/PIS for the years 2013–2018, show that the incidence rate of CDI more than doubled [3]. The incidence rate in Poland in 2013 was 12.3 per 100,000 inhabitants, while by 2018 it reached 30.2, with a total of 11,592 cases (Fig. 5). In England, over the past year, the incidence rate of *C. difficile* was 24 cases per 100,000 inhabitants, giving a total of 13,286 patients diagnosed with CDI. Intensive anesthesiological and surgical departments (including neurosurgery, general surgery) invariably excel at the forefront in terms of infection risk analysis.
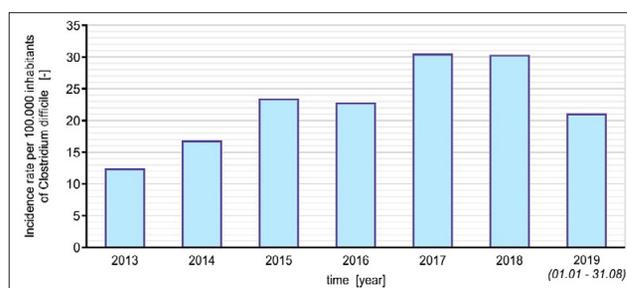
The risk of *C. difficile* infection during hospitalization is due to many factors, not only the individual traits of the patient, the primary disease and associated conditions that cause endogenous infection, but results also from the invasiveness of procedures, activities of the medical staff, work organization, antibiotic policy, and technical, functional and sanitary conditions, i.e. the accepted risk management system in a healthcare facility [32].

Risks and costs. In the literature, there are no unambiguous and accurate data on the costs incurred due to infections caused by *C. difficile.* They can exhibit significant variations due to methodological differences and gaps related to the indirect medical costs, and other factors classified in the category of hidden costs that directly translate to the costliness of CDI. The discrepancies can be partly explained by differences in the analyzed reimbursement systems. A recent meta-analysis focusing on costs in patients from the USA for 2005–2015, showed that the average cost of treatment for a patient diagnosed with CDI was USD 21,448. Financial expenses associated with the treatment of post-antibiotic diarrhea in inpatient treatment was 1.5 times higher compared to outpatient treatment [34]. Research from 2014 showed that 606,058 cases of *C. difficile* infections (429,237

Annals of Agricultural and Environmental Medicine 2021, Vol 28, No 2

229

Zofia Kiersnowska, Ewelina Lemiech-Mirowska, Dobrochna Ginter-Kramarczyk, Izabela Kruszelnicka, Michał Michałkiewicz, Michał Marczak. Problems…

primary cases and 166,821 recurrent cases) cost the system nearly USD 5.4 billion [36]. Previous research conducted in 2009–2011 indicated that the individual costs of therapy for a patient with CDI was USD 27,408, while the duration of the patient's stay at the facility, on average, was longer by 5.7 days. A significant difference was also observed in the mortality of patients hospitalized with primary and secondary *C. difficile* infection – 10.2% and 23.2%, respectively [36].

In France, it was estimated that the average cost of treating a patient with CDI is Euro 9,575, which meant an additional Eurro 163.1 million contributed by the State to the health care system [37]. In Germany, the additional costs associated with *C. difficile* infection for patients with primary and secondary diagnosis reached Euro 536 and 6,299, respectively. For patients who had recurrent CDI episodes, the additional costs increased to Euro 7,654. In the United States, the economic impact of recurrent *C. difficile* infections has been estimated at USD 1.5 billion [38]. Data analysis showed that CDI recurrence during the period of 42 days occurs in up to 10.6% of patients, and the average additional costs of treatment reach USD 11,631. *C. difficile* infections (CDIs) are becoming more common and more serious. About 42.9 CDI cases/10,000 patient-days are diagnosed each day in Europe, whereas in Poland, 5.6 CDI cases/10,000 patient-days are reported; however, the median for European countries is 2.9 CDI cases/10,000 patient-days. Corresponding studies concerning the costs incurred in treating *C. difficile* infections have not been conducted on the Polish population, but available epidemiological data and results of studies from other countries suggest that the economic trends are similar to other European countries [31, 39, 40]. European analysis shows that the overall cost of treatment of a patient with CDI amount to Euro 33,840. These costs will increase from year-to-year due to the progressive aging of the population. It is estimated that in Europe in 2050, there will be over 134 million people aged at least 65 years [41].

impact on the prolonged hospitalization of patients, thus causing an increase in financial expenses incurred by hospitals. The main predisposing factors for the occurrence of CDI concern such factors as: lowered immunological response, previous CDI episode in the patient's history, exposure to other antibiotics, kidney failure, age over 65 years, weakened immunological response to toxin *C. difficile*, serious basic illness, long hospitalization, stay in an intensive care unit, and infection with the NAP1/BI/027 strain. Existing methods of first line therapy of CDI (vancomycin, metronidazole) do not always lead to healing, but they also do not protect from recrudescence because they do not eliminate the spores of *C. difficile*. The main therapeutic options include drugs such as metronidazole, vancomycin, and to a lesser extent, fidaxomicin, and graft intestinal bacteria – faecal microbiota transplantation (FMT) (Tab. 2) [42].

Fidaxomicin is a therapeutic option with justifiable hope, this is a new macrocyclic antibiotic which is not absorbable from the digestive tract, fights spores, is selectively aimed at *C. difficile,* and in clinical trials has had better results than vancomycin. The current study has presented CDI prevention in the clinical work environment, its risk factors, the principles of recognizing it, and the increasing availability of less experimental therapies for first and recurrent infections.

Minimizing the scale of nosocomial infections requires effective risk management which should be based on consistent control of the epidemiological status of the healthcare facility. A special role is played by preventive actions involving the rationalization of the applied antibiotic therapy, effective disinfection of medical equipment, improvement of the sanitary condition of patient wards, and the implementation of quick microbiological diagnostics which, in a short time, will allow identification of the source(s) of infection, as well as the isolation of patients.

Increasing the quality of medical services is inherent in reducing the number of adverse events. Achieving satisfactory results in terms of improving patient safety requires changes in the system, especially in the area of monitoring and recording new cases of contracting a disease.

CONCLUSION

Infections caused by *C. difficile* are becoming an increasingly serious problem for health care units. They have a significant

Table 2. Current treatment guideline of CDI by ESCMID [42]

| Episode | Treatment | | | Non-antibiotic treatment |
	First choice	Second choice	Third choice	
First episode of non-severe CDI	Metronidazole orally 500 mg three times a day for 10 days	Vancomycin orally 125 mg four times a day for 10 days	Fidaxomicin orally 200 mg twice a day for 10 days	For mild cases; stop inducing antibiotic and observe clinical response at 48 hours
Severe episode of CDI	Vancomycin orally 125 mg four times a day for 10 days	Fidaxomicin orally 200 mg twice a day for 10 days		In the case of colon perforation or severe systemic inflammation, surgery is indicated
Severe episode when oral treatment is not possible	Metronidazole 500 mg three times a day 10 day and oral vancomycin 500 mg four times a day for 10 days			In the case of colon perforation or severe systemic inflammation, abdominal surgery is indicated
First recurrence of CDI	Vancomycin orally 125 mg four times a day for 10 days	Fidaxomicin orally 200 mg twice a day for 10 days		
Multiple recurrences of CDI	Fidaxomicin orally 200 mg twice a day for 10 days	Vancomycin orally 125 mg four times a day for 10 days, followed by vancomycin pulse strategy or taper strategy		FMT added to antibiotic treatment

230   Annals of Agricultural and Environmental Medicine 2021, Vol 28, No 2

Zofia Kiersnowska, Ewelina Lemiech-Mirowska, Dobrochna Ginter-Kramarczyk, Izabela Kruszelnicka, Michał Michałkiewicz, Michał Marczak. Problems…

REFERENCES

1. Dubberke ER, Olsen M.A. Burden of Clostridium difficile on the Healthcare System. Clin Infect Dis. 2012; 55(2): 88–92. doi: 10.1093/cid/cis335.
2. Magill SS, Edwards JR, Bamberg W, Zintars G, at al. Multistate Point-Prevalence Survey of Health Care–Associated Infections. N Engl J Med. 2014; 370: 1198–1208. doi: 10.1056/NEJMoa1306801
3. NIZP-PZH Reports on cases of infectious diseases and poisonings in Poland http://wwwold.pzh.gov.pl/oldpage/epimeld/index_p.html
4. Carroll R. Risk Management Handbook for Health Care Organizations. Hoboken. Wiley & Sons 2009; 78: 113.
5. Center for Disease Control and Prevention. Healthcare-associated Infections (HAI). HAI Data:1.2018.https://www.cdc.gov/hai/data/index.html
6. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States. 2013: 11–21.
7. Marczak M, et al. Risk Control in Health Care System, Methodology and Chosen Examples, Edited by Marczak M., Technical University of Lodz. 2008; 7.
8. Ozorowski T. Zarządzanie ryzykiem zakażeń związanych z opieką zdrowotną. Forum zakażeń. 2018; 9(4): 203–207. doi: 10.15374/FZ2018032
9. Tworek P. Risk Management System as a Source of Knowledge About Hazards in Public Organizations in Poland. Studia Ekonomiczne. 2014; 199: 314–325.
10. Turner NA, Smith BA, Lewis SS. Novel and emerging sources of Clostridioides difficile infection. PLoS Pathog. 2019; 15(12): e1008125. doi:10.1371/journal.ppat.1008125
11. Zdrowie i ochrona zdrowia w 2017 r. Analizy statystyczne. 100 lat GUS, Warszawa, Kraków 2018. ISSN 2084-0470.
12. Raport NIK. Zakażenia w szpitalach poważnym problemem; 2018.
13. Michalski T. Ryzyko w działalności człowieka. Podstawy ubezpieczeń – Mechanizmy i funkcje, Wyd. Poltext, Warszawa. 2001; 1: 20–25.
14. Coia J. C. difficile infection – Can we do better? Clin Microbiol Infect. 2018; 24(5): 450–451 doi: 10.1016/j.cmi.2017.12.009
15. Hamrol A, Mantura W. Zarządzanie jakością. Teoria i praktyka, PWN Warszawa. 2002; 200–210. https://www.nik.gov.pl/.
16. Act on combating infections and infectious diseases in humans (Dz. U. z 2018 r. pos. 151, 1669); p.12.
17. Regulation on the qualifications of members of the hospital infection control team (Dz. U. 2014 pos. 746); p.1.
18. Paszko K. The role of the epidemiological nurse in the Infection Control Team. Forum Zakażeń 2011; 2(2): 57–60.
19. Kevin W. Knight AM, Applying ISO 31000:200 in Regulatory 2011.
20. Leitch M. ISO 31000:2009—The New International Standard on Risk Management. Risk Analysis, vol. 30, no. 6, 2010:887–892. doi: 10.1111/j.1539-6924.2010.01397.x
21. Damani N. Risk management. IFIC Basic Concepts of Infection Control, 3rd edition, 2016.
22. Badurek S, Muszytowski M, Stróżecki P, Manitius J. Clostridium difficile-associated disease in patients with chronic kidney disease. Forum Nefrol. 2016; 9(3): 141–148.
23. He M, Miyajima F, Roberts P, et al. Emergence and global spread of epidemic healthcare-associated Clostridium difficile. Nat Genet. 2013; 45(1): 109–113. doi: 10.1038/ng.2478
24. Gateau C, Couturier J, Coia J, Barbut F. How to: diagnose infection caused by Clostridium difficile. Clin Microbiol Infect. 2018; 24(5): 463–468. doi: 10.1016/j.cmi.2017.12.005
25. Lemiech-Mirowska E, Kiersnowska Z, Ginter-Kramarczyk D., Kruszelnicka I. Toksynotwórcze szczepy Clostridium difficile-diagnostyka. Badania i rozwój młodych naukowców w Polsce 2019;3: 28–33.

26. Pépin J, Routhier S, Gagnon S, Brazeau I. Management and outcomes of a first recurrence of Clostridium difficile-associated disease in Quebec, Canada. Clin Infect Dis. 2006; 42(6): 758–764. doi: 10.1086/501126
27. Martirosian G, Hryniewicz W, Ozorowski T, Pawlik K, Deptuła A. Zakażenia Clostridioides (Clostridium) difficile: epidemiologia, diagnostyka, terapia, profilaktyka 2018. Narodowy Program Ochrony Antybiotyków na lata 2016–2020.
28. Marra AR, Perencevich EN, Nelson RE, et al. Incidence and Outcomes Associated With Clostridium difficile Infections: A Systematic Review and Meta-analysis. JAMA Netw Open. 2020; 3(1): e1917597. doi: 10.1001/jamanetworkopen.2019.17597
29. Marsh JW, Arora R, Schlackman JL, Shutt KA, Curry SR, Harrison LH. Association of relapse of Clostridium difficile disease with BI/NAP1/027. J Clin Microbiol. 2012; 50(12): 4078–82. doi: 10.1128/JCM.02291-12.
30. Regulation the Minister of Health regarding the list of alert factors, hospital infection registers and alert factors as well as reports on the current epidemiological situation of the hospital (Dz. U. 2011 nr 294 poz. 1741).
31. Jośko-Ochojska J, Spandel L. Clostridium difficile infections as a public health problem. Probl Hig Epidemiol. 2014; 95(3): 568–573.
32. Ziółkowski G, Ziółkowska B, Ochocka B. Infekcje Clostridium difficile, niedoceniane zakażenia w aspekcie klinicznym i epidemiologicznym. Polskie Stowarzyszenie Pielęgniarek Epidemiologicznych, Katowice 2012.
33. Albrecht P, Pituch H. Clostridium difficile — a growing diagnostic and therapeutic problem. Onkologia w Praktyce Klinicznej 2013; 9(1): 22–31.
34. Zhang S, Palazuelos-Munoz S, Balsells EM, Nair H, Chit A, Kyaw MH. Cost of hospital management of Clostridium difficile infection in United States-a meta-analysis and modelling study. BMC Infect Dis. 2016; 16(1): 447. doi: 10.1186/s12879-016-1786-6
35. Czepiel J, Kędzierska J, Biesiada G, Birczyńska M, Perucki W, Nowak P, Garlicki A. Epidemiology of Clostridium difficile infection: results of a hospital-based study in Krakow, Poland. Epidemiol Infect. 2015; 143(15): 3235–43. doi: 10.1017/S0950268815000552
36. Desai K, Gupta SB, Dubberke ER, Prabhu VS, Browne C, Mast TC. Epidemiological and economic burden of Clostridium difficile in the United States: estimates from a modeling approach. BMC Infect Dis. 2016; 18(16): 303. doi: 10.1186/s12879-016-1610-3
37. Le Monnier A, Duburcq A, Zahar JR, Corvec S, Guillard T, Cattoir V, et al. Hospital cost of Clostridium difficile infection including the contribution of recurrences in French acute-care hospitals. J Hosp Infect. 2015; 91(2): 117–22. doi: 10.1016/j.jhin.2015.06.017
38. Zimlichman E1, Henderson D, Tamir O, Franz C, Song P, Yamin CK. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med. 2013; 173(22): 2039–46. doi: 10.1001/jamainternmed.2013.9763
39. Dubberke ER, Schaefer E, Reske KA, Zilberberg M, Hollenbeak CS, Olsen MA. Attributable inpatient costs of recurrent Clostridium difficile infections. Infect Control Hosp Epidemiol. 2014; 35(11): 1400–7. doi: 10.1086/678428
40. Jachowicz E, Pobiega M, Różańska A, Wójkowska-Mach J. Growing consumption of antibiotics and epidemiology of Clostridioides difficile infections in Poland: A need to develop new solutions. 2019; 9: 1–8. doi: 10.1556/030.66.2019.024
41. Albrecht P, Pituch H. Clostridium difficile — narastający problem diagnostyczny i terapeutyczny. Clostridium difficile — a growing diagnostic and therapeutic problem. Gastroenterol Klin. 2013; 5(1): 40–51.
42. Ooijevaar RE, van Beurden YH, Terveer EM, et al. Update of treatment algorithms for Clostridium difficile infection. Clin Microbiol Infect. 2018; 24(5): 452–462. doi: 10.1016/j.cmi.2017.12.022