CHAPTER 16

Dissemination of multi-resistant bacterial strains associated with the community and the hospital: an overview of public health risk

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ABSTRACT
The evolutionary process of microorganisms favors their survival in hyspid environments. Annually thousands of lives are claimed as a result of resistant bacteria, pathogens previously restricted to the hospital environment can now be easily found in the community. The main objective of the present study is to provide information on the microbiological dissemination pathways in the community, focusing on food and surfaces. The study is a systematic review, in which several studies published in journals originally in the English language were analyzed and evaluated, during the period from 2017 to 2022. In order to select the studies with the greatest scientific evidence, favoring controlled and randomized clinical trials, in addition to systematic and bibliographic reviews. The lack of biosecurity when handling products of animal origin is a major risk to public health, these failures involve not washing hands after handling, using the same container for preparing or storing raw meat to ingest the cooked meat, without due prior cleaning. According to a survey, approximately 90% of the cell phones of health professionals were colonized by some microorganism, where 14% represented pathogenic and infection-causing bacteria. The dissemination of knowledge about hygiene and daily care is fundamental in controlling the transmission and spread of multidrug-resistant microorganisms. This action is capable of saving lives and helping the health system to develop more effective treatments, thus, research in the field of bacteriology is essential to improve academic and community knowledge.

Keywords: Bacterial Resistance, Contamination, Food, Surface.

1 INTRODUCTION

The constant race to find ways to prevent the spread of resistant bacteria is increasing, the spread of resistant genes and strains represents a risk to public health, raising the rates of infections and consequently influencing the fine line of mortality and morbidity. The evolutionary process of microorganisms favors their survival in hyspid environments and provides the selection of resistant strains. The main routes are through direct or indirect contact, aerosols, food and water (PALME-BENGTSSON *et al* , 2018).

Annually thousands of lives are claimed as a result of resistant bacteria, pathogens previously restricted to the hospital environment can now be easily found in the community. Resistance is the pathogen that has the genetic characteristic of surviving a high concentration of antibiotic. The spread of bacteria in the environment or community results in the final colonization of humans, the entire pathway assists in

selection and exerts selective pressure on the bacterial community. The exchange of information between bacteria is facilitated due to the environmental movement carried out by these pathogens (PALME-BENGTSSON *et al* , 2018).

Monitoring and screening the bacterial species present in the community allows the development of a critical eye to recognize when a bacterial population is capable of acquiring resistance to a drug (ELLABAAN *et al* , 2021). Conjugation, a form of sexual reproduction of bacteria, allows the exchange of genetic material and plasmid fragments that are capable of modifying bacterial characteristics, including virulence, biofilm formation and antibiotic resistance (VIROLLE *et al* , 2020).

The environment shared by a high number of people is more likely to present a greater number of resistant bacterial species. Environments such as subways, public restrooms, food areas and so on, are places of socializing and intense bacterial interaction. The interaction between similar or different bacterial species demonstrates a risk, as it increases the chances of the spread of genes that provide resistance to one or more antibiotics (Klasert *et al* , 2021).

The countries with the highest rates of antibiotic consumption also represent the places with the highest numbers of multidrug-resistant bacteria. The arrival of these pathogens in the community is the result of incorrect use of antibiotics, failure in biosafety protocols and genetic alterations. The formation of biofilms also favors bacterial propagation and survival both in hospital and community settings (MARTINA *et al* , 2019).

The bacteria previously restricted to the hospital environment, are now also found in the community. The escape of these microorganisms to the general population is a result of the traffic of patients hospitalized or treated at the units, as well as the failure of hospital biosafety practices among health professionals. Another factor is the genetic mutation in bacteria already associated with the community, making them resistant to antimicrobials. Hands are one of the main means of transport for these microorganisms (MARTINA *et al* , 2019).

Human skin contains its own microbiota, where some sites are more susceptible to transmission and colonization. However, the specific microbiota or flora of each patient undergoes changes over the course of a few days inside the hospital, and colonization by multidrug-resistant pathogens is possible. In view of this, hospitals, clinical and laboratory environments must contain policies and measures for the prevention and control of infection. These measures require training of professionals regarding biosecurity, adequate infrastructure, patient/visitor awareness and PPE supplies as tools to prevent and minimize the spread of microorganisms (STRICH; PALMORE, 2017).

The use of antibiotics has contributed to a dramatic reduction in morbidity and mortality due to infectious diseases worldwide. Global antibiotic consumption increased by 65% between 2000 and 2015 worldwide, which is inversely correlated with decreasing deaths from infectious diseases. The massive use of antibiotics has also led to the selection of resistant bacterial strains (OUMOU *et al* , 2020).

Data on the frequency of nosocomial infections (NI) and antibiotic use are important indicators of quality, and the growing problem of antibiotic resistance has important consequences: it reduces treatment options for infected patients and results in morbidity, mortality, and costs. additional. Rational use of antibiotics can reduce the selective pressure for the development of antibiotic resistance (BEHNKE *et al* , 2017).

The main objective of the present study is to provide information on the routes of microbiological dissemination in the community, focusing on food and surfaces and in the hospital environment. In addition to presenting an overview of the risks of contamination in the community and potential infections, showing the serious situation in relation to public health. Emphasizing the danger represented by the presence of multidrug-resistant bacteria in the community as well as reporting the incidence of infections related to the hospital service. The systematic review demonstrates the importance of disseminating microbiological knowledge about contamination in civilization, preventing recurrences of infections, transmission of pathologies and resistant bacterial species.

2 METHODOLOGY

The study is a systematic review, in which several studies published in journals originally in English were analyzed and evaluated, during the period from 2017 to 2022. The databases used as reference were MEDLINE, PubMed , BVSalud and ScienceDirect . In order to select the studies with the greatest scientific evidence, favoring controlled and randomized clinical trials, in addition to systematic and bibliographic reviews. The search used the following keyword combinations: *Bacterial Resistance; Hospital* ; *Food; surface* . To identify the study designs, the following terms were used: *Bacterial resistance ; Hospital; Food; Surfaces.*

The terms were attached to the respective platforms individually and then together with the Boolean operator *and* . The inclusion and exclusion criteria were applied following the inclusion basis between the period from 2017 to 2022. With an emphasis on controlled, randomized clinical studies, systematic and bibliographic reviews.

3 THEORETICAL FRAMEWORK

3.1.1 Contamination of food by resistant bacteria

Multidrug-resistant bacteria represent a great risk to public health, since they have the ability to resist several antibiotics. Bacterial infections are denoted in all countries, being one of the main causes of community-acquired infections. An example to consider is methicillin - resistant *Staphylococcus aureus* (MRSA) which can be found colonizing objects, surfaces, human skin, food and public places. Food is essential for human survival, however, it also acts as a potential vector (RODRÍGUEZ *et al* , 2019).

Contamination can occur during food handling, favoring product and handler contamination. Contact with the skin, meat, secretions and other exudates of slaughtered animals poses a major risk of

MRSA contamination associated with livestock. Ingestion of contaminated food can result in severe intestinal infections, extra-intestinal infection and transmission (RODRÍGUEZ *et al* , 2019).

The lack of biosecurity when handling products of animal origin is a great risk to public health, these failures involve not washing hands after handling, using the same container for preparing or storing raw meat to ingest the cooked meat, without due prior cleaning. Another mistake is to use the same board for preparing raw meats for preparing ready-to-eat foods, such as vegetables, fruits and vegetables. These flaws favor cross-contamination by pathogenic species of bacteria (RODRÍGUEZ *et al* , 2019).

The spread of resistant bacteria between foods, whether raw or ready-to-eat, results in an increase in serious intestinal infections. Cross-contamination by MRSA or other pathogens acts indirectly and recurrently, through recontamination (RODRÍGUEZ *et al* , 2019).

In cross-contamination (indirect) the transfer of bacteria from a contaminated food to an uncontaminated product is observed, through manipulation or utensils, while in recontamination , food contamination is observed after its preparation and potential inactivation of microorganisms. Careless handling of these foods also results in contamination of the handler, which in turn may act as a vector in the propagation of these bacteria in other environments (RODRÍGUEZ *et al* , 2019).

Food preparation must be careful, failures such as not washing hands before, during and after handling the product help in the vector transmission of microorganisms; The use of the same kitchen appliances and objects for raw meats and ready-to-eat foods; Ineffective cleaning of the utensils used. This view highlights that the actions taken in the preparation of food products are directly related to bacterial transfer and the high number of recurrent gastrointestinal infections. Mishandling and faulty food, whether contaminated or not, can lead to greater consumer exposure to resistant microorganisms (RODRÍGUEZ *et al* , 2019).

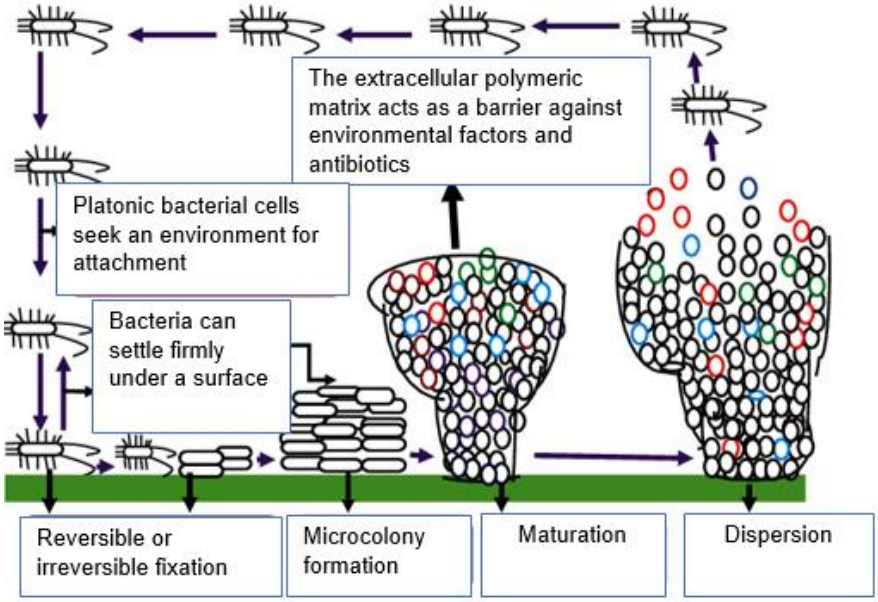
Contamination of food with bacteria results in approximately 600 million sick people annually. The contaminating process can occur during food production, distribution, storage and consumer handling. Biofilm formation is a serious problem when observed in food and collective environments, this bacterial community is able to develop on biotic and abiotic surfaces (ABEBE, 2020).

Pathogenic microorganisms are able to colonize, proliferate and form a biofilm on the surface of food products, increasing the risk of infections and food poisoning. Ineffective cleaning practices allow the survival of microorganisms and particles that aid in the colonization process. The biofilm (Figure 1) acts as a protective base for adhered microorganisms, being resistant, persistent and insensitive to hygiene chemicals (ABEBE, 2020).

Multi-resistant antibiotic-resistant pathogens adhered to a biofilm matrix become resistant to adverse and extreme environmental conditions, thus infectious processes are more difficult to regress in antibiotic therapy. It is estimated that 80% of chronic infections are related to the presence of biofilm (ABEBE, 2020).

Bacterial cells inserted in the biofilm are found in a high proximity to each other, this proximity facilitates communication between them through chemical signals, favoring the response to environmental stimuli. The formation of the protective capsule increases resistance, restricting drug entry; action of enzymes that inhibit the drug; alteration of bacterial metabolism; use of efflux pumps. The environment in the biofilm allows for a higher rate of genetic mutations, favoring the formation of inactivating enzymes . In addition, within the community, there is a horizontal transfer of plasmids and genes that encode resistance to new antibiotics between one cell and another (ABEBE, 2020).

Figure 1. Biofilm formation process



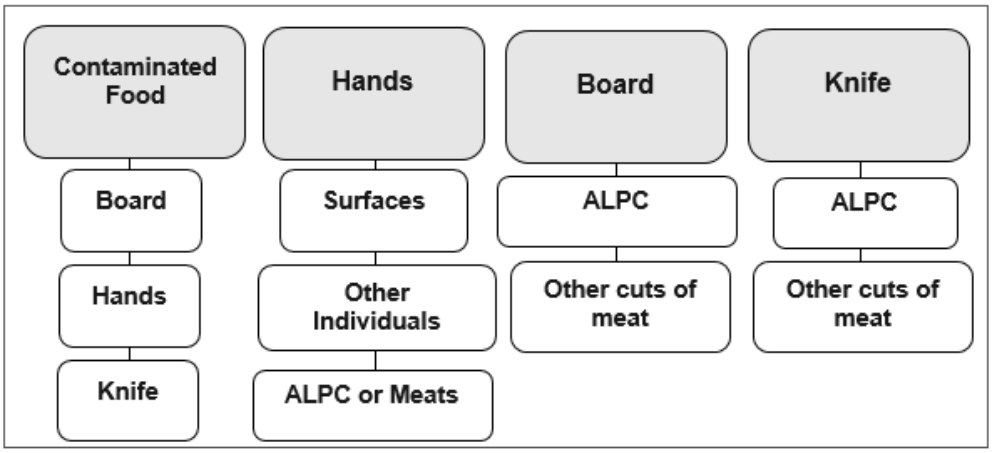
Source: Adapted from ABEBE, 2020.

The constant circulation of these pathogens directly affect human health and lifestyle. The fixation of the biofilm on food products or production equipment is worrying, as it becomes a reservoir of contamination (ABEBE, 2020).

Bacteria present on the surface of the food may migrate to the interior of the meat during the slicing performed by the consumer, this fact must be taken into account since the bacteria present inside the meat will face a different heat regime from those on the surface. The knife contaminated with the microorganism may act as a vector of dissemination by transferring these pathogens to other successive cuts of meat (IULIETTO & EVERS, 2020).

Route lines for cross-contamination can occur from contaminated hand food; from the food to the cutting board; from food to knife and other possibilities (Figure 2). The contamination cycle can reach any surface and generate a greater spread (IULIETTO & EVERS, 2020).

Figure 2. Schematic of the main routes of cross-contamination in the home



Source: Personal archive, 2022. Caption: Ready-to-eat foods (ALPC).

Contaminated hands can help spread resistant bacteria to surfaces or objects that can be colonized and serve as a reservoir of contamination. Contamination of the environment with these pathogens increases the possibility of contamination, where the contaminated surface will have direct contact with several individuals, favoring the route of hand-to-mouth contamination (IULIETTO & EVERS, 2020).

A survey evaluated 201 samples of sandwiches prepared in public food establishments, so that 36 of the samples were contaminated with *Salmonella sp* ., characterization revealed the presence of 16 different serotypes capable of causing serious food infections in humans and animals. The 36 positive samples were submitted to antimicrobial susceptibility analysis, where six showed resistance to four or more antibiotics, revealing a multi-resistance (NIKIEMA *et al* , 2021).

It is notable that there are several means of transport for microbiological contamination, such as surfaces, food, hands, cell phones and other shareable devices. Bacterial transit between environments is a risk for immunosuppressed or immunocompromised people, increasing cases of community-associated infections. Most bacterial infections present with resistance to one or more antibiotics, compromising treatment (MARTENA *et al* , 2019).

3.1.2 Contamination of surfaces, objects and hands

The lack of awareness spreads the false knowledge that microorganisms only exist in places with poor hygiene. However, one of the main vehicles of transmission of bacteria is the hands, where the habit of washing and hygiene is often careless, helping the spread of pathogens. Transmission can occur directly, that is, skin-to-skin, or indirectly, through inanimate means such as money, telephone, surfaces and food (MARTINA *et al* , 2019) .

According to a survey, approximately 90% of the cell phones of healthcare professionals were colonized by some microorganism, of which 14% represented pathogenic and infection-causing bacteria. As a device for personal use, cell phones transport bacteria from one environment to another, especially when biosecurity standards are not applied (MARTINA *et al* , 2019).

A study evaluated the contamination present in the hands of 538 volunteers, of these 531 tested positive for contamination with bacteria. In addition, the analysis of cell phones was performed, so that 238 of the 256 cell phones were contaminated by pathogenic bacteria. The antimicrobial susceptibility showed that most of the bacterial species identified had some type of resistance to one or more drugs. The study results suggest that cell phones represent one of the main vehicles for the dissemination of resistant bacteria in the community. Hand hygiene is effective in controlling bacterial colonization (MARTINA *et al* , 2019).

Bacteria are able to survive in the most different environments, contaminated surfaces act as a contaminating store which many people come into contact with daily, easily acquiring these pathogens. Hands can transmit infectious bacteria to yourself or to other people and environments (MOMANI *et al* , 2019).

A survey carried out with university students verified the presence of contamination on individual hands and cell phones. Of the 220 samples, eight bacterial species were identified and isolated: *Staphylococcus epidermidis , Streptococcus pneumoniae , Staphylococcus aureus, Streptococcus pyogenes , Enterococcus faecalis , Bacillus cereus , Micrococcus ssp* and *Escherichia coli.* In summary, 41% of hands were contaminated with one or more of the aforementioned pathogens and 18% of phones had positive growth. The species showed high resistance to the tested antimicrobials, generating a public health alert (MOMANI *et al* , 2019).

The greater the handling or contact of a piece of equipment, surface or object with several people, the greater the rates of colonization of the product by resistant bacteria. This sharing and lack of hygiene results in the spread of different microorganisms among users (ROZARIO *et al* , 2020).

Contamination of environments is a serious problem as it helps in the spread of resistant strains in the community, surfaces are areas with easy colonization, acting as a reservoir for multiresistant bacteria, in addition to facilitating the spread by contact with the hands. Horizontal transmission can happen quickly when repeated people touch the same surface (OH *et al* , 2021).

In everyday life, contact categories can be divided into items used exclusively by the individual, items used especially by the individual, but shared with others on some occasions and items of general or public use. Items such as furniture, doorknobs and other general contact surfaces represent a higher concentration of resistant bacteria compared to individual items. However, these categories can suffer from cross-contamination through direct contact and a vector, the hands. In this way, the need to apply strict hygiene practices to avoid the transmission of potentially infectious pathogens is highlighted, these measures must be regular especially in public places (OH *et al* , 2021).

An example is the currency of exchange, that is, money. Money acts as a potential vector in the transmission of bacteria between people, as it is passed from hand to hand. One way to avoid contamination of individuals and other individuals would be the application of hand hygiene after handling money (OH *et al* , 2021).

The skin provides protection against several pathogens harmful to human health, however, it also has several commensal and pathogenic microorganisms on its surface. Microorganisms colonizing the epidermis can spread through direct contact or by desquamation. The cycle of epidermal dissemination occurs between individuals who live together or frequent the same environment, consequently environmental contamination also plays a role as a vector of resistant pathogens (BAQUERO *et al* , 2021).

The whole scenario of bacterial dissemination and the growing phenomenon of multidrug resistant, characterizes a worrisome world canary. Therapeutic options are weakened daily. Population awareness about the importance of hygiene and the human role in the spread of these microorganisms is fundamental to reduce the rates of serious gastrointestinal, epithelial and systemic infections in the community (BAQUERO *et al* , 2021).

The controlled and conscious use of antimicrobials is essential for the control of pathogens resistant to several drugs, exerting control over the selective pressure suffered by the unconscious use of antibiotics and maintaining the hygiene of environments and hands, are ways to circumvent the growing increase of these pathogenic pathogens in the community (BAQUERO *et al* , 2021).

3.1.3 Hospital contamination

The increase in healthcare-associated infections is a reflection of a heterogeneous chain of factors, including the lack of biosecurity among the various professionals who provide patient care (BAYRAKTAR, M et al, 2021). The hospital environment has several means for the propagation of multidrug-resistant bacterial strains. High and low contact surfaces can be potential targets for contamination by bacteria, the contact of health professionals with these surfaces and the neglect of biosafety favors nosocomial transmission to patients with possible serious conditions (FRICKMANN *et al* , 2018).

A qualitative study carried out in 2017 evaluated the presence of multidrug resistant bacteria on low and high contact surfaces, and in the hands of health professionals, noting that all samples were contaminated with a multidrug resistant pathogen, such as *S. aureus* , *Streptococcus spp* , *Bacillus* spp , *Lactococcus spp , Micrococcus spp , Corynebacterium spp , Enterobacteriaceae and Enterococcus spp* . The surfaces verified as contaminated in the study went through the disinfection process and subsequent analysis, demonstrating that although the disinfection kept the colonies under control, the microorganisms did not disappear completely, emphasizing the importance of correct hygiene of the hands of health professionals and patients before and after treatment. after contact (FRICKMANN *et al* , 2018).

Analyzes and observations of biosafety failures, violations and errors are alarming, involving entry into patient rooms with isolation notice without some or all of personal protective equipment (PPE), errors in the sequence of PPE removal, touching areas of the body or objects with contaminated gloves or aprons. Despite seeming simple or unimportant failures, each of these can result in contamination of surfaces, patients, self -contamination or other health professionals (KREIN *et al* , 2018).

The observations carried out in the hospital environment were able to identify the main mistakes made by health professionals during patient care, favoring the spread of multidrug-resistant bacterial strains. The need for attention to biosafety standards must be individual and collective, care and precautions must be taken both with potentially infected patients with contact precautions, droplets or contact enteric, and with potentially contaminated patients (KREIN *et al* , 2018).

A study carried out from the observation of 479 interactions between patients and health professionals showed that about 71 or 15% of these interactions resulted in contamination (glove, lab coat and objects) of the professional by the VRE. Thus, it was concluded that the higher the bacterial load, the greater the chances of contamination of the professionals' PPE , turning them into a strong source of transmission (JACKSON *et al,* 2018).

The dissemination routes of multidrug-resistant microorganisms in the hospital environment occurs mainly through patient contact with the environment, surfaces or colonized objects; contact of the infected/contaminated patient with the environment, surfaces or objects; contact of the health professional with the environment, surfaces or colonized objects; contact of the health professional contaminated with the environment, surfaces or objects; contact of the contaminated health professional with the patient; contact of the health professional with a contaminated/infected patient. The illustration below summarizes the main routes of transmission of microorganisms, where number 1 shows the route of transmission from the infected or contaminated patient to the health professional (PFS) and the environment; in route 2, the contagion occurs from the contaminated environment to the health professional and patient and in route 3, the transmission route from the contaminated professional to the patient and environment is observed. (BLANCO *et al* , 2020).

Surveillance in the hospital environment is essential and can lead to a reduction in the number of nosocomial infections. Surveillance, control and prevention (1) enables constant observation and facilitates early warning of outbreaks, (2) constant training and feedback for employees and health workers, encourage them to improve and improve their performance with Regarding infection control and surveillance, (3) the programs train staff to find potential risk or protective factors for fighting nosocomial infections (LI *et al* , 2017).

4 RESULTS AND DISCUSSIONS

4.1.1 Food safety

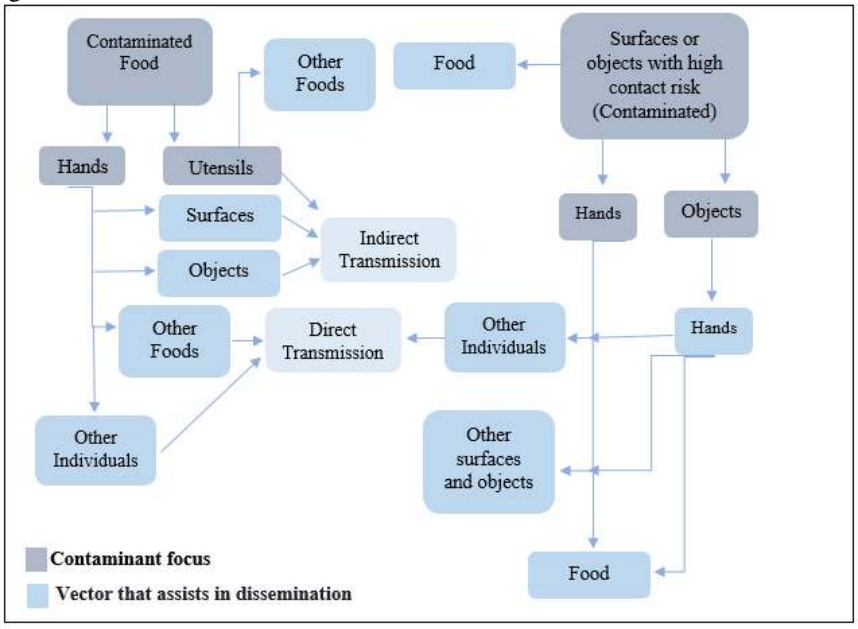
Food security is an essential phenomenon for public health, as it represents economic, physical and social access to quality and safe food. The lack of socioeconomic resources puts pressure on the consumption of foods that are not nutritious and without health monitoring, putting population health at risk. Food safety acts in the handling, preparation and storage of food products in order to prevent foodborne pathologies (BANKEFA *et al* , 2021).

Foods as carriers of bacteria and other microorganisms need parameters to define the origin, labeling, the quality of local and product hygiene, government guidelines and others. Compliance with these parameters guarantees a reduction in the risk of food poisoning and microbiological dissemination. Bacteria are the main pathogens responsible for the risk within food safety, causing poisoning. According to a survey carried out by the World Health Organization (WHO) in 2020, approximately 600 million people fall ill with foodborne pathologies, with 230,000 deaths being reported, increasing the need for care in food surveillance (BANKEFA *et al* , 2021).

Currently, there is a great concern about the hygiene of food and environments. The incidence of community-related bacterial infections is increasing and represents a rich real for public health. Bacterial resistance has been a barrier in the application of effective therapeutic measures, the number of annual recurrent deaths from infections caused by bacteria is shocking. Surface contamination allows the transmission of pathological pathogens not only to one individual, but several, fulfilling its role as a contamination reservoir (TROPEA, 2021).

Bacterial dissemination routes (Figure 3) when known prevent contamination and help with cleaning. The different routes used for bacterial dissemination harm and jeopardize the food and physical security of the population. It is essential to pass on basic knowledge of microbiology to the population, this action allows the formation and improvement of individual conscience, where it will encourage the practices of personal and environmental hygiene. This action, applied globally, can reduce or control cross-contamination and bacterial interactions, consequently, a drop in the bacterial resistance index can be observed in different species, making the race in the production of new antimicrobials fairer (TROPEA, 2021).

Figure 3. Overview of the main routes of bacterial dissemination in the community



Caption: Contaminant foci act as reservoirs for microorganisms, especially bacteria adapted to the environment. Vectors are responsible for assisting in the dissemination of microorganisms within the community, carrying out a direct or indirect transmission. Source: Personal archive, 2022.

4.1.2 Hospital infections and biosecurity

The increasing number of nosocomial infections associated with health care encompasses not only a public health concern, but also demands a greater economic burden due to its greater severity and use of resources. Patients infected with a multidrug-resistant pathogen face longer stays in hospitals/ICUs, which consequently increases hospital costs with the use of antimicrobial therapy. Thus, the development of research becomes fundamental for the discovery and improvement of efficient methods and treatments against nosocomial infections, as well as for the creation of new means to control the spread of multidrug-resistant bacterial strains (CERCEO *et al* , 2016).

Although there is a visible sense of urgency and attention in many countries in controlling the spread of multidrug-resistant microorganisms, methicillin-resistant Staphylococcus aureus remains one of the main pathogens present in hospital-acquired infections . In addition to MRSA, bacteria such as multidrug-resistant Escherichia coli and carbapenem -resistant Enterobacteriaceae also pose a public health problem.

Healthcare professionals must play an important role in infection control. Hand decontamination is required with suitable hand sanitizers after contact with infected patients. Safe injection practices and sterile equipment are critical. The use of masks, gloves, headgear or appropriate uniform is essential for the provision of health care (KHAN, 2018).

Several hospitals adopt biosecurity measures, including precautions for contact with patients who are confirmed or suspected to be infected. During the care of these patients, it should be mandatory to use personal protective equipment or PPE, avoid the use of personal objects such as cell phones and not touch the face or clothes with gloved hands, among other precautions (JAIN *et al* , 2018).).

These standard precautions for the control of infectious outbreaks reduce the likelihood of contamination of the healthcare professional and the consequent transmission to other hospital beds and environments. The main objective of personal protective material is to reduce the chances of contamination and transmission of pathogens that can put the lives of patients at risk, however, the neglect of the correct use of these equipment favors the increasing number of infections associated with the hospital (JAIN *et al* . , 2018).

5 CONCLUSION

The high number of infections reported annually portrays a worrying picture for public health, since it represents a high value of investment and expenses in treatments. Bacterial dissemination in the community is increasing, extremely pathogenic species are easily found in the community environment and reaching immunosuppressed or immunocompetent patients, resulting in alarming deaths and chronic infections.

The lack of hygiene of food, hands and environment characterizes the main means for bacterial dissemination, since they act as vehicles of locomotion. Bacterial interaction allows the exchange of valuable genetic information to increase bacterial resistance, this scenario is worrisome from the

perspective of antibiotic therapy, as available antibiotics become increasingly insensitive to these pathogens. The result is the severe picture of numerous community-associated bacterial infections.

The dissemination of knowledge about hygiene and daily care is fundamental in controlling the transmission and spread of multidrug-resistant microorganisms. This action is capable of saving lives and helping the health system to develop more effective treatments, thus, research in the field of bacteriology is essential to improve academic and community knowledge.

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