Chapter 5 Methods of physical control of pathogenic microorganisms in hospital areas

Capítulo 5 Métodos de control físico de microorganismos patógenos en áreas hospitalarias

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Abstract

Hospitals are establishments that are open 24 hours a day, 365 days a year, and are responsible for providing the necessary care to patients, there are hospitals of different levels and each one of them fulfills its mandate with different equipment and materials. Cleaning and disinfection are important issues to address, so this paper explains under reliable information, the different physical methods that have been implemented to improve the cleaning process every day and to control the levels of viable pathogen microorganisms installed on surfaces or equipment, there are also chemicals that damage health, the above is distributed in different hospital areas where there is contact between health personnel, patient, administrative workers, family members, and others. The administration of physical disinfection methods such as sterilization by dry or wet methods, radiation, filtration, electricity, have shown to be effective over the years and have been reflected in the controls carried out by Mexico's Secretary of Health or various institutions responsible for implementing cleaning protocols and that these are applied. Within a hospital, everything must be planned for good work performance and that the impact is favorable, with the information provided by this research is expected to achieve a social impact especially in health centers or hospitals, so that the problems that occur every day are decreasing.

Hospital areas, Pathogens, Physical methods of control

Resumen

Los hospitales son establecimientos que están abiertos las 24 horas del día, los 365 días del año, y son los encargados de brindar la atención necesaria a los pacientes, existen hospitales de diferentes niveles y cada uno de ellos cumple su mandato con diferentes equipos y materiales. La limpieza y desinfección es un tema importante a tratar, por lo que en este trabajo se explica bajo información fidedigna, los diferentes métodos físicos que se han implementado para mejorar el proceso de limpieza cada día y controlar los niveles de microorganismos patógenos viables instalados en las superficies o equipos, también existen productos químicos que dañan la salud, lo anterior se distribuye en las diferentes áreas hospitalarias donde hay contacto entre el personal de salud, el paciente, los trabajadores administrativos, los familiares, entre otros. La administración de métodos de desinfección física como la esterilización por métodos secos o húmedos, radiación, filtración, electricidad, han demostrado ser efectivos a lo largo de los años y se han visto reflejados en los controles realizados por la Secretaría de Salud de México o diversas instituciones encargadas de implementar los protocolos de limpieza y que estos sean aplicados. Dentro de un hospital, todo debe ser planeado para un buen desempeño laboral y que el impacto sea favorable, con la información que aporta esta investigación se espera lograr un impacto social sobre todo en los centros de salud u hospitales, para que los problemas que se presentan día a día vayan disminuyendo

Áreas hospitalarias, Patógenos, Métodos físicos de control

5.1 Introduction

There are problems within a hospital that might be caused by different factors, such as lack of economic resources, lack of infrastructure, personal and union situations, and internal attention, among others. From the above, important challenges are derived in terms of public health, according to the Diagnostic Study of the Right to Health conducted by the National Council for the Evaluation of Social Development Policy (CONEVAL), in México, physical and economic access to health services must be improved, infrastructure in health institutions must be increased, health education must be promoted, and the quality and effectiveness of medical services must be improved (CONEVAL, 2014).

Cleanliness and asepsis have also been considered among the biggest challenges to overcome, since all areas need to be perfectly innocuous, considering that the hospital environment is a source of infection due to the transitory diseases that are handled in the different health centers. Hospital is a space where there are several people involved, patients, family members, and medical staff who, under any circumstance, perform their work, usually present innocuous scenarios from which derives a source of infection depending on the emergency attended, so the intrahospital areas should remain dirty as little time as possible (López, 2013).

The topic of cleaning is complex since there is a cycle in which the personnel, the materials used (wound dressing supplies, laboratory material, among others), and the disinfection methods such as chemical, physical, among others are involved, the latter have had to improve and evolve to fulfill their purpose: which is to reduce at minimum the presence and the viable number of pathogenic microorganisms in hospital areas, (Rodriguez, 2018). Therefore, to provide information to health personnel, regarding physical disinfection, this work presents a review regarding the types of physical methods that are used in different health facilities, hospitals, clinics, and offices involved in health care.

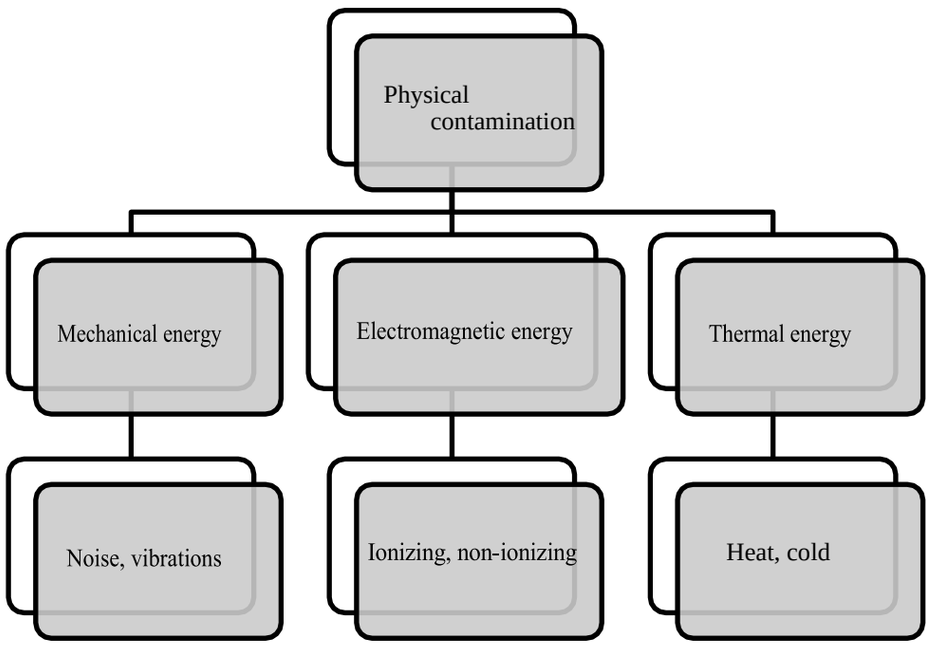
5.2 Contaminants in hospital areas

According to the World Health Organization (WHO), a hospital is a medical and social organization whose mission is to provide the population with complete medical-health care, both curative and preventive. It is also a center for medical-health personnel training and biosocial research (WHO Guide, 2002). Due to these activities, hospitals generate multiple types of waste, which derive from the care provided to patients in different areas. (Puchau, 2018).

5.2.1 Physical contaminants

Physical contaminants refer to the different forms of energy present in the work environment, by which workers can be affected, they are depicted in Figure 5.1 (Puchau, 2018).

Figure 5.1 *Most common physical contaminants*



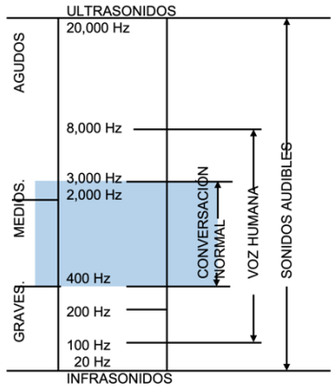
Source: Adapted from "Manual Básico de Seguridad y Salud en el trabajo "Puchau. 2018, Basic Handbook of Safety and Health at Work

5.2.1.1 Mechanical energy: Noise

It is defined as a sequence of uncoordinated sounds, unpleasant to the human ear, sound it as energy generated from an emitter, and move through space through a physical medium, to reach the receiver (passing through a transmission medium) (Puchau, 2018). The main characteristics of sound (noise) are acoustic pressure level, which refers to the intensity of the sound, it is measured in decibels (dB); and frequency, which is the number of times the sound is repeated with the same or different acoustic pressure and is measured in hertz (Hz).

Humans can only hear sounds in a certain range of frequencies, namely those between 20 and 20,000 Hz, a range known as “audible frequency spectrum”, this is depicted in Figure 5.2, normal conversations are typically between 400 and 3000 Hz (Puchau, 2018).

Figure 5.2 Audible frequency spectrum



Source: Taken from "Manual Básico de Seguridad y Salud en el trabajo" Puchau. 2018, Basic Handbook of Safety and Health at Work

A vibration can be defined as the oscillation of a particle around a point in any physical medium, if the medium is the air we get the sound, if the medium is solid, we have what is meant by the vibration ofthe material (Forteza, 2010). Vibrations are characterized by both frequency, those between 1 and 1500 Hz are of interest; and amplitude, characterized by the acceleration of the movement, measured in m/s^2. Vibrations are measured by an accelerometer, which is only sensitive to movement in one direction in space.

5.2.1.2 Radiations

There is electromagnetic energy, these are physical phenomena consisting of the emission, propagation, and absorption of energy by matter, both in the form of waves (electromagnetic radiations) and subatomic particles (corpuscular radiations) (Puchau, 2018). Radiations are divided into non-ionizing and ionizing, non-ionizing radiations, non-ionizing radiations are differentiated by the type of frequency at which itis expressed, which are given different names, such as ultraviolet, visible, infrared, microwave and radio wave radiations, as shown in Table 5.1. Therefore, it is said that non-ionizing radiation is incapable of causing an ionization effect in the body cells and c) ionizing radiation, unlike the previous radiation, we have ionizing radiation, this type of energy becomes ionizing when there is a "shock" so that it results in electrically charged particles (ions).

Ionizing radiation can be electromagnetic, such as X-rays and gamma rays, or corpuscular, such as α andβ particles, which are components of the atoms that are emitted. Exposure to ionizing radiation can causevery serious and irreversible damage to health, even provoking cancer) (Regulation on health protection againstionizing radiation, 2001).

The effect produced by ionizing radiation has only a "cause-effect" relationship, it will depend on the dose ofwhich there are levels, called "threshold dose". Below this level, there might not be direct effects depending onthe dose received, but the probability of long-term effects increases. For this reason, ionizing radiation does have an impact on the body's cells, as it is more energetic (Forteza, 2010).

Table 5.1 Non-ionizing radiation classification

	Source	Effects
Ultraviolet	Sun, Hg vapor lamps, germicidal lamps, photocopiers, others.	Skin: erythema, burns, and cancer. Eyes: conjunctivitis.
Infrared	Sun, ovens, incandescentlamps, others.	Heat shock and delayed effects on the crystallinelens.
Radiofrequency microwave	Ovens, microwaves, radio, TV broadcasts.	Possible affectation of biological membranes and alterationsin gene transmission.
Laser	Devices capable of emitting visible, infrared, or UV	Skin and eyes.

Source: Adapted from "Reglamento sobre protección sanitaria contra radiaciones ionizantes" by Boletín official del estado, number 178. 2001, Reglamento sobre protección sanitaria contra radiaciones ionizantes

5.2.1.3 Thermal energy

Human beings need a 37°C temperature to survive and keeping their homeostasis, human body has self-regulation of temperature, regardless of the surrounding conditions so physical and physiological mechanisms can be performed correctly (Puchau, 2018).

The effect of an imbalance in thermoregulation leads to consequences that could be serious and have a high impact on the human body, such as those depicted in Table 5.2.

Table 5.2 Imbalance of thermoregulation

	Description	Effects
Thermal stress(heat)	A thermal destabilization, manifested by blood vasodilatation, the opening of sweatglands, and loss of mineral salts.	Cramps, effects on the skin, exhaustion, heat stroke (death)
Cold stress	It can cause blood vasoconstriction, deactivation of sweat glands, and poorcirculation.	Hypothermia, resulting in frostbite of limbs and death (<28ºC).

Source: Adapted from: "Prevención de riesgos laborales" Francisco José Forteza Oliver; María de las NievesPiña Capó. 2010, Prevention of occupational hazards.

Finally, it is considered that, for the good development of physiological mechanisms of the human being,it is necessary to have a good relationship with the thermal environment, having a comfortable zone,which has the characteristics of the most suitable temperature being this same pleasant It is worth mentioning that not all humans will have the same thermoregulatory response, either due topersonal susceptibility or poor adaptation to new spaces, whether hot or cold. (Puchau, 2018)

5.2.1.4 Pathogenic microorganisms

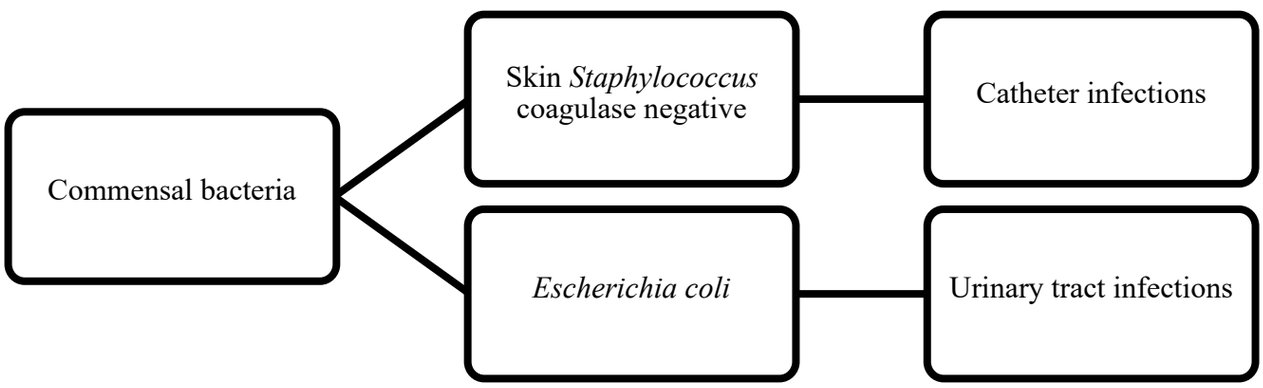
Biological agents are understood as microorganisms, including genetically modified microorganisms, cell cultures, and human endoparasites, susceptible to cause any type of infection, allergy, or toxicity. Microorganisms are any microbiological entity, cellular or not, capable of reproducingor transferring genetic material (Law. 664/1997, 1997).

Infectious microorganisms vary in different patient populations, different health care facilities, differentfacilities, and different countries (WHO Guideline, 2002).

In the case of working with this type of biological agent in a hospital, it is the protocol to use measures suchas personal protective equipment (PPE) or take sanitary measures on handwashing (Law. 664/1997, 1997).

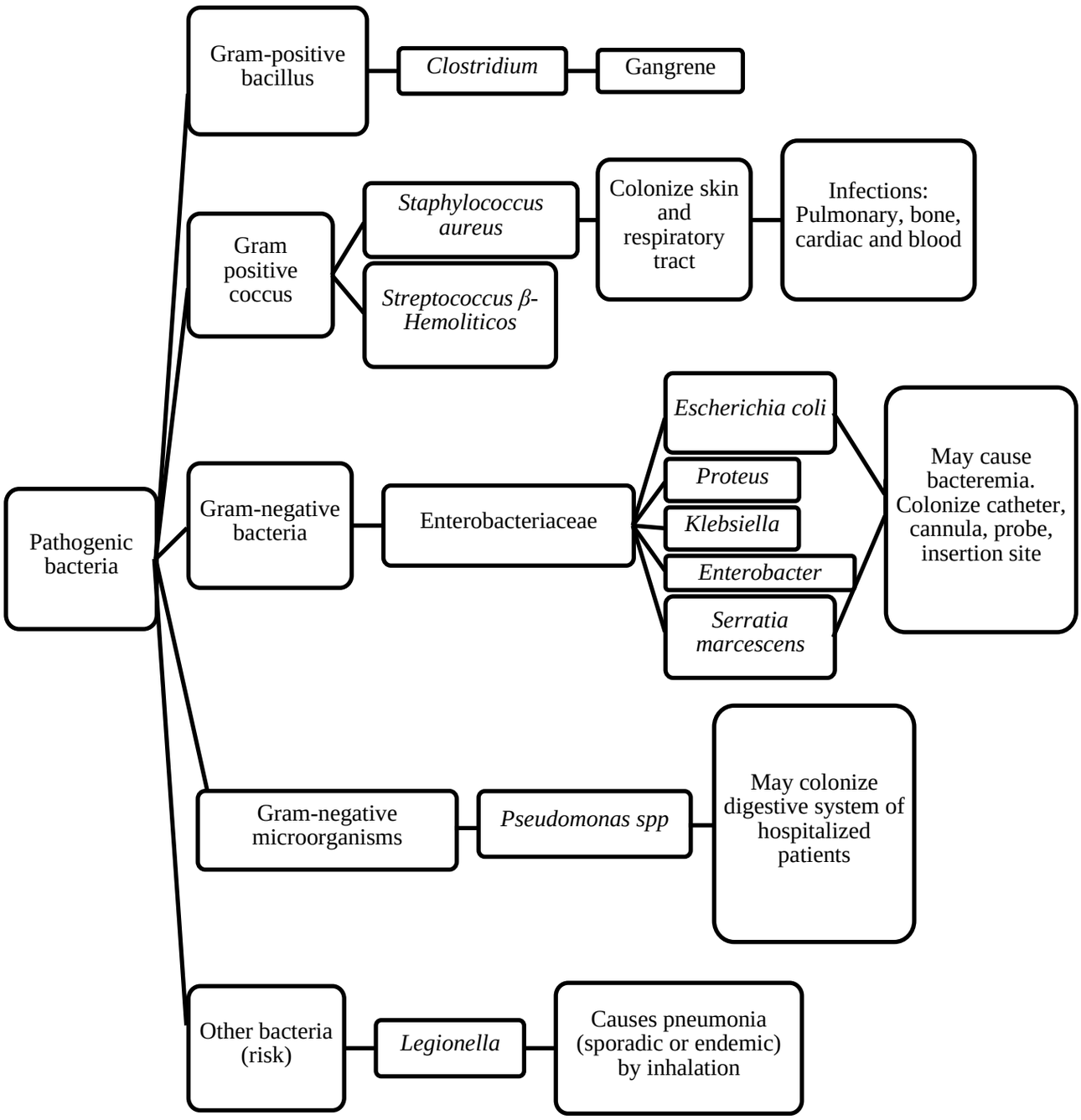
As a result of the above, under different and numerous studies it has been possible to identify the microorganisms that contribute to hospital contamination, as shown in Figures 5.3 and 5.4.

Figure 5.3 Most common commensal bacteria in hospitals causing infections



Source: Adapted from "On the protection of workers against risks related to exposure to biological agents at work" by State Official Gazette, number 124. 1997, On the protection of workers against risks relatedto exposure to biological agents during work

Figure 5.4 Most common pathogenic bacteria in hospital areas



Adapted from: Prevention of nosocomial infections by World Health Organization. 2002, Practicalguide Prevention of nosocomial infections

5.2.2.1 Nosocomial or in-hospital illnesses

Nosocomial infections (NI) are infections acquired by patients admitted to a hospital for a reason other than admission, therefore it is understood that a hospital can be a focus of these nosocomial infections, and this represents a major health and economic problem today (Leralta, 2017).

Infections occurring more than 48 hours after hospitalization are considered nosocomial. According to NOM-045-SSA2-2005 for epidemiological surveillance, prevention, and control of nosocomial infections, infections acquired by neonates who become infected by passage through the birth canal, those that develop within 30 days following a surgical intervention or that occur in the year following the performance of a surgery in which an implant was placed are also considered nosocomial, as shownin Table 5.7.

Table 5.3 Relationship of microorganisms with the focus of infection

	Respiratory infection	Urinary tract infection	Bacteremia	SurgicalWound
Escherichia coli	X	XXXX	XX	XXXX
Staphylococcus aureus	XXXX	----	XXXXX	XXXXXXXX
Pseudomona aerugiosa	XXX	XXX	X	XX
Enterococcus faecalis	----	X	XXXX	XXX
Klebsiella. pneumonie	XX	XX	XXX	X
Staphylococcus epidermidis	----	----	XXXXXXXX	XXXXX

Note: The "X" relates the nosocomial microorganism with the type of infection it produces to a greater or lesser extent, depending on the translocation of the microorganisms from their usual location to a new sterile location, they can produce some infections or others

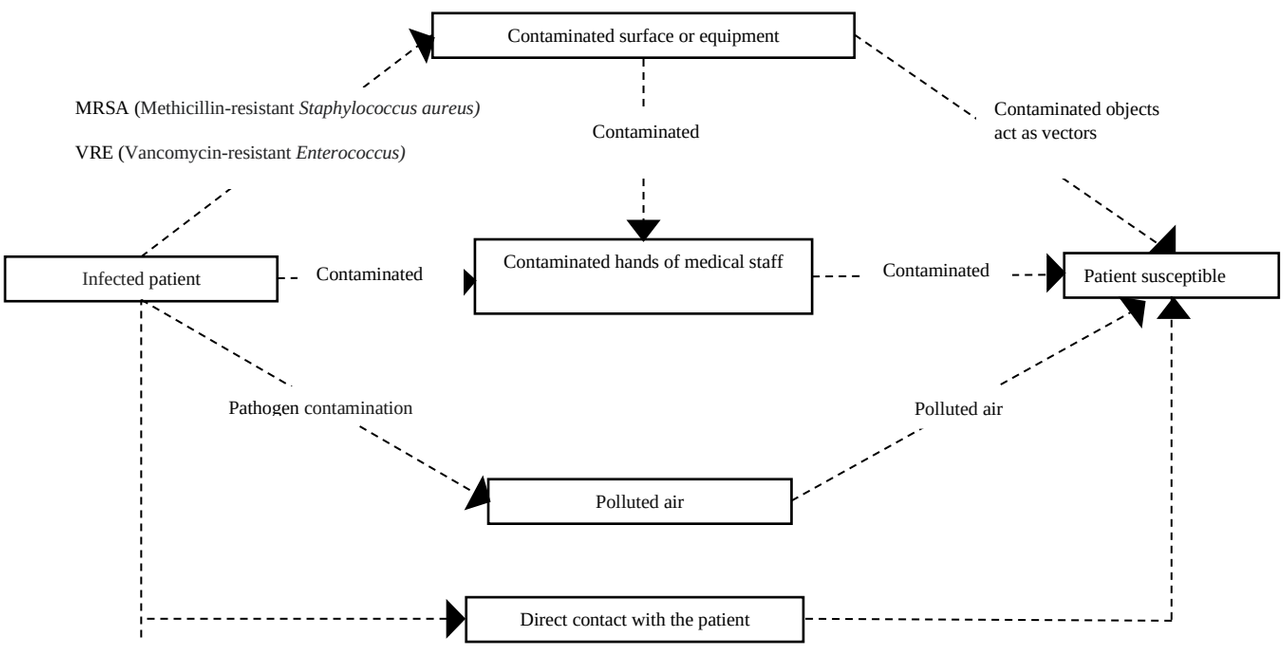
Source: Adapted from "Nosocomial infections, importance of Pseudomona aeruginosa" by Claudia Leralta Gonzales. 2017, Nosocomial infections, importance of Pseudomona aeruginosa

5.2.3 Hospital equipment

5.2.3.1 Personal computers as sources of infection

Patient-to-patient transmission of nosocomial pathogens has been associated with transient colonization of healthcare workers, and studies have suggested that contamination of healthcare workers' clothing is an important part (Treakle *et al*., 2009), as is the use of medical equipment and instruments, as well as technological equipment such as cell phones or watches. Most studies have identified various types of pathogenic germs, and some objects, being in close contact with patients and other individuals, could serve as reservoirs of bacteria easily transmitted and disseminated both within the hospital and in external homes (Magdaleno *et al*., 2011). Under the analysis of the presence of nosocomial infections, the consequences are the impact on the patient's health and life, the consequent increase in health care costs, and lawsuits against the medical practice. There is sufficient evidence to explain the sequence of events that occur in the possible role ofsurfaces of medical accessories and devices in the chain of NIs, as shown in Figure 5.5 Pathogens are shedfrom infected or colonized patients (sometimes from staff) in the hospital environment (General, S., 2016).

Figure 5.5 Nosocomial infection acquisition route



Source: Adapted from "Stethoscope, gown and tie, and the risk of nosocomial infections" Baptista and Zamorano 201.

5.2.3.2 Shared diagnostic hospital equipment

For the formation of a hospital, assets are needed to ensure the optimal functioning of the hospital, which include: a)medical equipment, which includes devices that are used for specific purposes of prevention, diagnosis, treatment, or rehabilitation of an illness or injury; it can be used alone or in combination with some accessories, consumables, or other medical equipment, b)furniture, which is designed to keep patients in a comfortable position during a process of exploration or medical care; of safeguarding, holding, organizing, and mobilizing medical supplies, the above items are shown in Appendix 1, c)communication and information systems and industrial equipment, for example, electric generators, heaters, water pumps, refrigeration, and air conditioning systems, elevators, laundry, kitchen, and other similar equipment (Secretaría de Salud, 2016).

5.2.4 Cleaning procedure in hospital areas

The cleanliness of the patient's environment is an important factor in their early recovery from illness. The hospital environment, as mentioned above, is predisposed to harboring potential pathogens, the main reasons being the volume of sick patients and the pace of patient care activities performed by healthcare workers. The complexity of the hospital is the reason for all medical surfaces and equipment to require dailycleaning. The ability of certain pathogens to remain viable for long periods on inert surfaces (some microorganisms can survive weeks or months in the hospital environment), make careful sanitization of areas difficult and even more important (Pimienta, 2017).

There is a classification with concerning the risk of transmission of infections based on the activities performed in each one. This classification helps in some strategies against the transmission of nosocomialinfections. The purpose of this classification is to guide on the complexity, timeliness, and detail of the sanitation services in the areas in question so that the cleaning and disinfection process is appropriate to the risk, in addition to facilitating the development of procedures for cleaning and disinfection of intrahospital surfaces (Pimienta, 2017).

A) High-risk areas (critical): space where delicate patients are located, who has undergone surgery or suffer from a chronic degenerative disease, where immunosuppressed patients can be found, for example operating room, toco-surgical unit, intensive therapy unit, dialysis, hemodynamics, burns, transplants, isolation units, analysis laboratory, blood bank, nursery, materials, and sterilization center, milk bank, among the most important ones. B) Intermediate risk areas (semi-critical): here patients who have undergone a disease with a low level of transmissibility or diseases that do not generate direct contagion share space, examples of this type of areas are nurses' stations, consulting rooms, bathrooms, elevators, and corridors. C) Low-risk areas (non-critical): these are areas that are generally used by health personnel or other hospital workers, for example dressing rooms, bedrooms, offices, administrative areas, warehouses, library, among others (Pimienta, 2017).

Cleaning is the mechanical removal of all foreign matter in the environment, on surfaces and objects, using manual or mechanical washing. The purpose of cleaning is to reduce the bioburden (number of microorganisms) through mechanical removal. Usually, water and detergent are used for this process. It is recommended that a detergent be used to ensure the effectiveness of the cleaning process (Molina, 2003). Cleaning generally comprises 3 types of action:

1) Mechanical action such as scrubbing, brushing, or pressure washing, 2) Chemical action refers to the use of detergents, enzymatic detergents, and water, necessary to inhibit and diminish bioburden and dustparticles and 3) Thermal action specifically refers to the use of heat (hot water) from mechanized washingmachines where they exist (Molina, 2003).

5.2.5 Floor cleaning

5.2.5.1 Two-bucket technique

It involves cleaning with the use of floor cleaning cloths and floor dryer, using two buckets, which comes to optimize the work of the cleaning staff and the disinfection of surfaces, avoiding back and forth movements for a water change and cleaning of the cloth, in the best case, or the use of dirty water to continue cleaning, by not resorting to water change (Pimienta, 2017).

Wet Sweeping (Mopping)

1) Mopping the edges, with horizontal movements, it is important not to go over the same place twice, to reinforce the mop should be rinsed until it is clean, and go over it again. 2) Take care not to leave puddles or wet places that favor bacterial growth. 3) Verify the state of the drains and remove all dirt onthe floor such as chewing gum, stains, etc. (PAHO, 2011).

Common areas are mopped only with clean water and a well-washed and wrung-out mop. Areas with spills of body fluids should have sodium hypochlorite at a concentration of 5000 ppm, as this is used forcleaning. It is important to verify that the implements are very clean when cleaning in another area or room, to avoid cross-contamination (PAHO, 2011).

Soaping, rinsing and drying

Lathering, is the action of rubbing the surface with soap or detergent to remove all the dirt, thisstage, one of the buckets contains water and the other soap or detergent, therefore, rinsing has the purposeof removing the soap or detergent, in this last stage, the two buckets contain only water, finally, it is leftto dry (Pimienta, 2017). After finishing mopping, it is necessary to verify that the buckets used for the water change are placed upside down to avoid bacterial growth (PAHO, 2011).

Minimum frequency of floor cleaning

All cleaning should be structured in an official guide, which should be followed to the letter, these being appropriate to each need that the hospital has, some common points are: inpatient rooms should be cleaned once a day when stained and upon discharge of the patient, laboratories require daily cleaning. Floors will be cleaned with a disinfectant detergent solution, operating rooms require a special cleaning regimen and the frequency of this should be standardized (Quiroga, 2018).

5.2.6 Surface cleaning

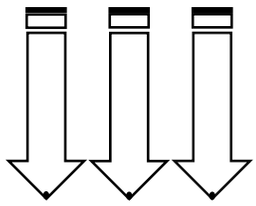
Contaminating particles are not always visible, they are distributed in various media such as air, furniture, walls, among others. Therefore, a fundamental part of cleaning is shaking; being this a common technique, a safe process is needed (Molina, 2003). There are considerations for dust cleaning, this process should be carried out in recurrent and terminal cleanings, put on personal protection elements (according to the biosafety manual), do not shake the cloth so as not to disperse the dust, start cleaning from the upper parts, continue towards the lower parts, continue with flat surfaces, sides, and supports and verify that all the spaces where dust cleaning was performed are in perfect conditions. Based on the above, cleaning techniques have been implemented:

1) Aseptic technique: It is so-called because it is a technique that can prevent contact with pathogenic microorganisms.

2) Dragging technique: perform a movement from top to bottom on vertical surfaces, from right to left or vice versa, trying not to pass the cloth through the same place, as shown in Figure 5.6.This technique is used for dust cleaning. It is important to emphasize the chipping (part in which a surface loses its coating) and cracks in which dirt can remain accumulated.

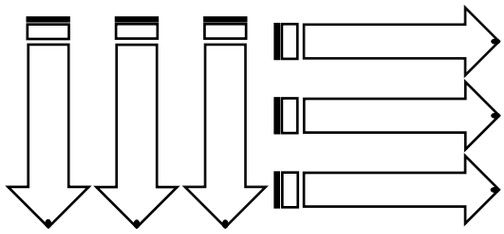
3) Grid technique, the flannel used in this procedure must be moistened in sodium hypochlorite solution (in a concentration according to the service or area), this will be used to exert friction directly in the surfaces with a downward movement, next with another clean flannel, previously moistened in water, movements are made to the right, exerting friction to remove the sodium hypochlorite, as shown in Figure 5.7. (Forteza, 2010, JaveSalud, 2017).

Figure 5.6 Dragging technique



Source: Adapted from "Protocol for cleaning and disinfection of surfaces and equipment". Quiroga, 2018

Figure 5.7 Grid technique.



Source: Adapted from "Protocol for cleaning and disinfection of surfaces and equipment". Quiroga, 2018

The techniques and activities related to cleaning and disinfection are focused on the most frequently identified critical points, in order to establish the following recommendations: Never sweep dry, use thebucket with wet syringe, to collect residues, start with clean areas and finish with the dirtiest areas, cleaning should not coincide with the distribution of food and clean clothes, the cleaning of areas with daily presence of patients, family members or health personnel should be carried out appropriately and permanently, in the same way on working days, as well as on holidays and weekends, do not create air currents that facilitate the movement of germs, cleaning will be performed in one direction only, from top to bottom or side to side, without backing up, cleaning will require friction to remove dirt and microorganisms, surfaces close to the patient should be the first to be cleaned, floors may be waxed, as long as a thorough previous cleaning has been performed (Pimienta, 2017).

5.2.7 Cleaning of hospital instruments

There are important aspects for this type of cleaning, such as the disinfectant for the processing of instruments and equipment used with the patient, disinfectants should be selected in each place considering the use, efficacy, acceptability, safety, and cost and should always be used in the dilution and manner recommended by the manufacturer (Quiroga, 2018).

The Spaulding classification of medical devices is currently accepted according to the degree of contactwith the patient, which will determine the risk of infection: a) Critical medical device: It is the material that is in contact with the vascular system and sterile areas of the organism in any intervention or hospitalization, requiring cleaning followed by sterilization. For example, surgical instruments, suction devices, nebulizers, comfort devices, among others. These instruments must be sterilized, which will bediscussed later. b) Semi-critical medical devices: These are materials that may encounter mucous membranes and non-intact skin. The processing of this material requires cleaning followed by high level disinfection. For example, Laryngoscope blade, otoscope, among others. These devices must undergo high-level disinfection and c) non-critical medical device: This material does not directly touch the patient; however, it requires cleaning processing followed by an intermediate or low level of disinfection. For example: thermometers, auxiliary tables and equipment such as electrocardiographs, ultrasound scanners, among others, should be cleaned-disinfected (Acosta-Andrade, 2008). In the case of incubators, they should be completely dismantled, washed, rinsed, dried and disinfected when disassembled and after assembly, they should be plugged in for complete drying (Quiroga, 2018).

For the cleaning and disinfection of surfaces of biomedical equipment that have electronic parts or that by manufacturer's recommendation should not be wetted with water, the detergent-disinfectant is used, the measures are as follows: Precautions should be taken such as turning off the equipment before cleaning and disinfection and not applying chemicals directly to the electrical part of the equipment and keyboards, the foam is applied directly on the surface of the biomedical equipment or a compress so that the surface of the equipment can be completely cleaned, it is allowed to dry (Acosta-Andrade, 2008).

5.3 Physical antimicrobial control

5.3.1 Sterilization

It is the set of operations intended to eliminate or kill all forms of living beings contained in an object or substance. Any material used in hospital areas that is called a critical article must undergo a sterilization process according to its properties. The standard establishes that the theoretical probability of a viable microorganism being present in the product must be equal to or less than 1 in 1,000,000. This expression is what is internationally known as SAL Level (Security Assurance Level) (Sanchez, 2017). But to rely on the sterility of a product, it is necessary to have internal control, which, is going to count on different factors, among which is the initial microbial load, in addition to the subsequent storage of the sterile product. As mentioned above, cleaning and disinfection (high, medium, or low level) must be carried out; to then move on to the sterilization process, although these decontamination processes are variable in terms of antimicrobial effectiveness (Sanchez, 2017).

Some factors affect the efficiency of these processes; therefore, some criteria have been implemented that must be followed to obtain adequate sterilization:

The number of microorganisms (Co). This is a fundamental factor since the sterilization effect of thematerials will depend on it. Organic matter (S) The presence of organic matter impedes the elimination of microorganisms, but it is one of the easily modifiable factors. These two factors Co and S highlight the importance of cleaning before sterilization. Time: An important factor for the correct sterilization process as it is taken as an indicative criterion. The F value is the time necessary for a suspension at a temperature of 121ºC to eliminate all bacterial spores. It is also used as a reference valuein the evaluation of sterilization methods (De Salud, 2010).

Temperature. The temperature is fundamental during this specific sterilization process because when thetemperature is higher than indicated, the better effect there is on the microorganisms and generally causestheir death. Relative humidity (RH). It is defined as the fraction of water vapor pressure in a system concerning another system with the maximum pressure (100% saturated) and at the same temperature. There is a direct relationship, higher relative humidity - higher water content in the cells or spores and better final sterilization result, which makes the process faster. Standardization of the load, the packages should have the measures (28 x 28 x 47 cm.) and wrappings internationally standardized. The load to be sterilized is very variable, it can change with respect to the number of instruments, load volume, size of the instruments and contents of the packages. It is important to standardize sterilization processes according to the different items in the load as the effectiveness of the method may vary depending on the items (De Salud, 2010).

5.3.2 Dry heat

It is characterized by the absence of water in the heating environment. This method has been less used due to the introduction of disposable materials such as needles or syringes, which are sterilized by radiation or ethylene oxide. However, the method is used to sterilize all materials that are reused, such as glass syringes, delicate cutting instruments, surgical instruments, stainless steel items, and oily materials, mostly dry sterilization is used in laboratories to sterilize glassware (Robilotti and Couso, 2011).

All microorganisms, according to their characteristics and components, are susceptible to the action of heat, this reaches the entire mass, even in places of the material that may be unreachable by other agents. The mechanism of heat as a sterilizing agent involves protein denaturation, fusion and disorganization of membranes and/or the occurrence of irreversible oxidative processes (Jimenez, 2018).

The duration of exposure to heat to saturate all the materials, due to the slowness of dry heat, was determined by experimental tests and it was concluded that: 1) The larger the volume of the material (flasks, instruments, etc.), the longer the pre-sterilization time, 2) The lower the conductivity of the material (talc, kaolin, oils, etc.) the longer the pre-sterilization time and 3) If the greater the thickness and lower the conductivity of the jar walls, the longer the pre-sterilization time (Jimenez, 2018).

The main variables of a heat sterilization process are temperature and exposure time, because the destruction of microorganisms by heat does not occur instantaneously, there is a time-temperature-general conditions relationship between the product to be sterilized, by the above criteria, microorganisms are classified into two groups, based on heat resistance: (a) Vegetative cells, whose thermal resistance is relatively small, being sufficient as a general rule to an exposure to 80°C for 1 minute for their destruction and (b) Sporulated bacteria, capable of surviving being subjected to temperatures of 100°C and higher for relatively long times. [29]

Depending on the amount of water contained in the microbial cell is its resistance to destruction by dry heat, although it was accepted that in states of extreme dryness microbial cells better-resisted inactivationby dry heat, later research showed that the influence of moisture on dry heating processes is much morecomplicated than previously anticipated (Jimenez, 2018).

The major advantage of this method is that it penetrates solids, non-aqueous liquids, and closed cavities.There is no corrosion of the materials involved and the disadvantages are that it requires high temperatures and very long periods. Dry heat is the method of choice for the sterilization of anhydrous oils and powders, due to its high penetrating power. There are two types of hot air sterilizers(as they are often called) commonly used in laboratories and hospitals: A) gravity convection and B) mechanical convection. For both types, the electrical heating method is used. The usual workingtemperature is 160ºC to 168ºC. The regulator is adjusted (Robilotti and Couso, 2011).

Gravity Convection

In the gravity convection sterilizer, the air circulates according to the temperature differences in the sterilizer chamber. The design of the gravity convection hot air sterilizer specifically influences its efficiency. The design features are not opposed to airflow with the flow to the corners of the chamber, bafflesor other places where obstacles to air circulation are encountered. The electric heater assembly will be placed at the bottom of the chamber, spaced by a perforated metal plate that is a uniform diffusing surfacefor the hot air over the entire vertical extent of the chamber (Robilotti and Couso, 2011).

In this type of sterilizer, there are factors such as the long heating time, therefore, more time is needed toreach the desired temperature and it is less uniform in the control of the chamber temperature, comparedto the mechanical convection sterilizer. Its use is recommended only for materials where heating is fast and precise, without the factors of chamber capacity restrictions and accelerated air circulation being decisive (Robilotti and Couso, 2011).

Mechanical Convection

The hot air mechanical convection sterilizer is of maximum functional efficiency at minimum cost. This instrument is equipped with a fan motor, which can move a large volume of hot air faster, transferring heat to the load, depending on the temperature control condition. In this case, the set of resistors is located directly in front of the fan motor, in a compartment separated from the chamber by a diffuser wall (Robilotti and Couso, 2011).

Factors such as air velocity, circulation direction, and heating intensity are moderated to achieve a stabletemperature inside the chamber, which is managed according to the type of load. It can reach temperatures of 160ºC in the chamber without a load in 30 minutes and with the chamber filledwith glassware it reaches 160ºC in 75 minutes. It has positive characteristics for the ventilation of gasesor humidity (steam) formed during the sterilization process (Pérez and Sosa, 2013).

In any procedure, there are parameters, which will vary according to the load, volume, weight, thermal resistance of the material (porcelain, glass, stainless steel, oils, among others), type and power of the stove. It is important to know A) Temperature. Sterilization temperatures fluctuate between 160ºC to 180ºC. The temperature used should not be below 160ºC for one hour, since it is the minimum condition, when the water content is 0%. Without exceeding the determined temperatures (above 180ºC), the material may be damaged. B) Time. The time needed for the air inside the chamber to reach the sterilization temperature (preheating time). 2. The time it takes for the materials to reach the sterilization temperature. 3. The sterilization time itself, as shown in Table 5.3 (Vásquez, 2001).

Table 5.4 Time-temperature relationship for dry heat sterilization

Temperature (°C)	Exposure time
180°C	30 minutes
170°C	1 hour
160°C	2 hours
150°C	2 hours and 30 minutes
140°C	3 hours
121°C	12 hours

Source: From "Manual de esterilización para centros de salud" Acosta-Andrade, 2008

Every sterilization procedure has advantages and disadvantages, among the advantages is that it does notcause corrosive effects for metals and instruments and allows the sterilization of powdery, viscous, non-aqueous (non-volatile) substances. (On the other hand, the disadvantage is that it requires a long time forsterilization, due to the low penetration of heat (Vasquez, 2001).

5.3.3 Moist heat

Steam sterilization is the most used sterilization procedure, and the equipment used is called an autoclave. The mechanism of action of moist heat is by denaturation of proteins (De Salud, 2010), it is the most widely used method, due to the much more penetrating action of moist heat, which facilitates the coagulation of bacterial proteins, coagulation that is directly related to the degree of hydration. Thismethod should be considered as the method of choice whenever the materials allow it (De Salud, 2010).The steam can sterilize the surfaces of the material, so that it establishes its action only on these surfaces.Therefore, the materials will be positioned in particular ways so that the action of the sterilizing agent iseffective, for example open tweezers, disassembled syringes, textile material, glass, rubber, Teflon, among others. Wet materials become better conductors of heat much faster than dry materials due to theenergy released during condensation. To achieve reliable sterilization, the standard method is saturated steam autoclaving, as shown in Table 5.4. This temperature is achieved by steam at one atmosphere above atmospheric pressure (Vasquez, 2001).

Table 5.4 Time-temperature relationship for moist heat sterilization

Temperature (°C)	Minimum exposure time (minutes)
134	3
121	15

Source: From "Guía de trabajos prácticos: Cátedra de Microbiología e Inmunología" 36. Medvedeff etal., 2009

The autoclave is mostly used in laboratories to sterilize cultures and solutions that do not form emulsionswith water and that do not denature at temperatures higher than 100°C. As mentioned above, it is used to sterilize textile material (provided that the autoclave is equipped with a vacuum drying system); for tubular elements, it is practiced moistening them with distilled water, so that the steam generated expelsthe air. Glassware can be sterilized in an autoclave but must then be dried in an oven (Vásquez, 2001). As any method, it has advantages and disadvantages, it has the advantage of raising its temperaturequickly without leaving toxic residues in the material (De Salud, 2010), on the other hand, thedisadvantage we can mention the long time in which the process is carried out and that it is not applicableto thermosensitive materials (Medvedeff et al., 2009).

The efficiency of steam as a sterilizing agent depends on: humidity, heat, penetration and the mixtureof steam and pure air (and other impurities it may contain) (De Salud, 2010).

5.3.4 Radiation

Radiation is the transport or propagation of energy in the form of particles or waves; if the radiation is due to electrical or magnetic forces, it is called electromagnetic radiation (Sanz, 2011). By their biological effect, radiation can be classified into two types:

a) Ionizing or high-energy radiation, they can beelectromagnetic or particle radiation, the former are short wavelength radiation, and the latter areconstituted by high-energy electrons produced by high-voltage generators (Barrera et al., 2005)

b) Non-ionizing or low-energy radiation, which are electromagnetic rays (i.e., not particles) with a wavelength longer than visible light and which are absorbed as heat in a large proportion (Sanz, 2011).

In sterilization, radiation is lethal to microbial cells as well as to other organisms. Of the various typesof radiation, those used for sterilization purposes are differentiated by their nature and energy. It is thephenomenon of emission and propagation of energy in space or through a material medium. Theradiations with a harmful action on microorganisms are ultraviolet rays, x-rays, gamma rays and cathoderays (Sanz, 2011). Their action depends on 1. type of radiation 2. exposure time 3. dose (Vásquez, 2001)

5.3.4.1 Ultraviolet rays

There are different types of ultraviolet radiation: 1) UV-A or long or near ultraviolet radiation, whose wavelength ranges from 380 to 320 nm (380 nm is the upper limit for the visual perception of violet color). This is the radiation that we know to be very intense, so much so that it reaches the Earth and can penetrate tissues. 2) UV-B or medium ultraviolet radiation, with a wavelength of 320 to 280 nm. It is used for the application of the photochemical effect (pigmentation or vitamin D formation). It is biologically harmful. 3) UV-C or far ultraviolet radiation, short or germicidal radiation, with a wavelength of 280 to 200 nm, presents the maximum energy (Barrera et al., 2005).

UV-C radiation or far ultraviolet radiation has a germicidal function, acting on the DNA molecules (deoxyribonucleic acid) of microorganisms, with wavelengths between 240 to 280 nm (nanometers), it mainly damages the nucleic acids of microorganisms, its main damage is in distorting the shape of DNAand interfering with normal base pairing, resulting in inhibition of DNA synthesis and therefore growthand respiration. Ultraviolet radiation can be produced artificially with mercury vapor lamps (Sanz, 2011).This sterilization method is used in the microbiology laboratory to disinfect surfaces, air, water, surgicalareas and sterile rooms (González, *et al*., 2011).

5.3.4.2 X-rays

X-rays were discovered in 1895 by Roëntgen and were the first known example of ionizing radiation of electromagnetic nature, they are produced by the collision against the matter of electrons accelerated at highspeed and in any X-ray apparatus, there is a cathode emitting electrons and an anode connected to a strongly positive potential to the cathode, which attracts the electrons and serves as a targetagainst which they collide. X-rays are short-wavelength electromagnetic radiation, which propagates in astraight line at the speed of light. They have great penetration capacity and are therefore used to obtain images for diagnosis (Barrera et al., 2005).

Their germicidal function is based on the ionization of molecules with which they cross, mainly affectingtheir nuclear DNA, which is vital in every cell (González, *et al*., 2011).

5.3.4.3 Gamma Rays

It is even more energetic than X-rays and more effective, although they act in the same way, they have a shorter wavelength (10-10 to 10-12 nm), attractive for sterilizing material of high thickness or volume, glass material tends to present a brownish color. Two sources are used to generate these rays: Cobalt-60 and Cesium-137 produced by atomic reactions. Gamma radiation can penetrate through products of great thickness, regardless of the type of product, density or packaging used, does not leave toxic residues in the product so it can be used without the need for quarantine and the only parameter that must becontrolled is the exposure time (Olmo, 2018).

Its mechanism of action is based on the production of ions and free radicals that attack the bases of nucleic acids, protein and lipid structures, and essential components for the viability of microorganisms. These rays have properties such as their high penetrability used for thermolabile materials such as disposable syringes, probes, needles, prostheses, catheters, etc. They are used on an industrial scale (antibiotics, vaccines, food, etc.), since complex and expensive installations are required. They are not used for culture media or protein solutions because they produce alterations in their components (Vásquez, 2001).

5.3.4.4 Cathode rays

Produced by an electron accelerator, which can be linear (classical) or circular (modern). This electron beam radiation is mostly used to sterilize surgical material, medicines and other materials; its main advantage is that the material can be sterilized already packaged (since these radiations penetrate the wrappings) and at an indeterminate or ambient temperature. Sterilization by accelerated electrons, developed in the 1950s from radiotherapy, has been shown in several studies to be the state-of-the-art method for sterilization of medical-surgical, laboratory and pharmaceutical materials (González, 2011). The treatment is based on the electron beam, which causes an ionizing effect, so energetically high that it can transform the electrons of the molecules into ions, i.e., they are electrically charged, without modifying the nuclei, i.e. without making them radioactive. This process has the disadvantage of causing physical effects on materials such as plastics, these changes include change in color or changes in mechanical resistance. This phenomenon, sought after in certain applications (cross-linking of plastic materials) could be limiting inthe sterilization of single-use medical products that use these materials. Radio-stable materials are therefore required. This is not a problem since there is a wide variety of polymers and other plastic materials on the market that do not modify their physical properties during ionization (González, 2011).It has notable advantages such as its excellent penetration and utilization performance, its availability and reliability, its treatment with unitary control, its high dose performance limiting degradation risks, its harmlessness on the product and its absence of environmental impact (Gonzalez, 2011).

5.3.4.5 Filtration

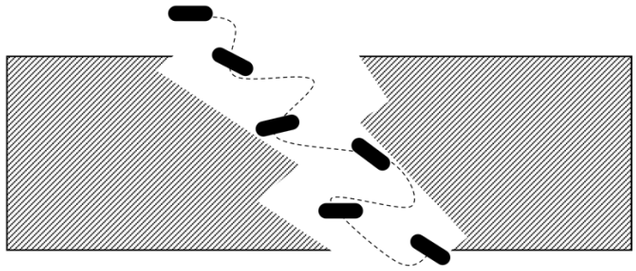
Sterilizing filtration is the process of complete removal of microorganisms (except viruses) from a fluid. A sterilizing grade filter must remove all microorganisms present in a fluid without adversely affecting the quality of the product (McBurnie, 2004). The materials that pass through this type must be fluids (gaseous or liquid), where mainly culture media are involved, in order to separate the existence of thermolabile substances, also used in vitamin solutions.

a) Operation of a sterilizing grade filter: Filters are composed of selective pores, and their mainfunction is to retain large particles that remain stagnant in the filter. This mechanism of particle arrestment or capture is known by different names, such as sieve retention, physical capture, direct interception, size exclusion, etc. Size exclusion is an important point, which is considered for sterilizingfilters the most reliable mechanism of filtering action, however, it is not the only one, as there is anothermechanism where particles small enough to enter and pass through the pores of a filter can be captured by adsorption to the pore walls. Regardless of particle size, a proper filtration process can capture even the smallest particle through the pores, as other conditions govern filtration, theseconditions are important if bacteria of smaller pore size are present (McBurnie, 2004).

As mentioned above, in the case of adsorption filtration, some conditions need to be controlled depending on the case, some of them are: applied pressure differential, flow rates, number of particles present, and the characteristics of the liquid in terms of surface tension, pH, ionic strength, among other factors. All must be monitored to have a good performance of the filtration process (Galeano, 2007).

b) Factors affecting microbial holding capacity for a sterilizing grade filter: 1) Bioburden - The total microbiological load present in a medium. In situations where not all contaminants are retained by size exclusion, the result can be said to be probabilistic. Figure 5.8 shows a bacterium (particle) smaller than the pore size entering the pore. The bacteria can either pass through the pore to exit with the flow, or stumble against the pore wall. Whichever situation prevails is the result of probabilities. Regardless of the level of challenge for a filter that is not clogged, the probability of any particle penetrating is the samefor any identical particle. The higher the number of particles (bioburden), i.e., the higher the challenge d ensity, the more likely it is that some particles will escape capture. The lower the bioburden versus thefilter, the better the filter performs (McBurnie, 2004).

Figure 5.8 Alternative pathway of bacteria through a pore



Source: Adapted from Technical Report No. 26 "Sterilizing Filtration of Liquids" PDA. 1998,

4) Pressure Differential - Another important aspect is the pressure differential, i.e., the pressure of both parts of the filtration site, where it is known that the lower the pressure differential, the higher the particlesequestration, due to the high residence time, which allows the absorption of the particle or microorganism in the pore; on the contrary, the higher the pressure differential, the lower the particle sequestration, due to the short residence time. There is, therefore, a direct relationship for adsorption capture, expressed by the inverse relationship of adsorption sequestration with the level of differential pressure (Galeano, 2007). 3) Other Affecting Factors - Several investigations have shown that propertiessuch as pH, surface tension, ionic strength and viscosity, can be factors of poor retention in filters, it is worth mentioning that filtration is also affected by the type of vehicle of the microorganisms present, bytheir change in size or morphology. Such changes can result in a non-sterile filtrate (McBurnie, 2004).

5.4 Conclusions

All the above exposed allows us to conclude that cleaning by physical methods isfundamental for intrahospital areas since everything is moderated through a cycle that has been constituted throughout the years by the sanitary emergencies that have been presented, which have given the guideline so that we can develop better control of diseases and thus improve those factors whether they are economic, infrastructure and attention.

The methods presented above have been updated and optimized for better use, through studies and research, which are important because thanks to them there is a better internal development; in the presentstudy, it was possible to compile information on the physical methods to be used in a hospital, some of them already updated, which already use computers for their management, new circuits for their operation, reduced size of the equipment and data such as time/temperature with a lower margin of error on sterilization.

The pandemic that has been experienced by COVID-19 has had a great impact on hospitals, mainly dueto the care of infected patients, but also due to the issue of ensuring the disinfection and cleaning of all areas, to take care of health personnel and other people involved.

It makes a difference to provide information in this study, which makes visible the importance of correctlyperforming the disinfection and cleaning processes concerning the material or surfaces in all hospitalareas that require it.

5.5 Appendix 1

Shared diagnostic equipment

Team	Description
Vital signs monitor	Vital signs display equipment.
Oximeter	Equipment for continuous measurement and recording of oxygen saturation in peripheralblood.
Fan	Equipment based on life support forventilatory support in adult and pediatric patients.
Nebulizer	Electric and pneumatic equipment, which generates vapor particles to provide air, under controlled humidity, temperature andoxygen conditions.
Defibrillator	Life support equipment, for electric shock and for monitoring the electrical activity ofthe heart.
Intensive care incubators	Equipment that provides life support in optimal conditions of temperature, humidity and oxygenation, in variable ranges and more similar to the intrauterineenvironment. For newborns
Stretchers	Bed specially designed for hospitalized patients or other people who need some kind of medical attention. Specialized stretchers are available by area.
Commode or urinal	The Comfortable is a medical accessorymade of very resistant plastic materials. It should be placed under the patient, at the level of his genitals to collect urine.
Table (Mayfield table, patient washingtable, surgical table)	Instrument holder, for bathing the patient and table to facilitate the surgical procedure.

Source: Adapted from "Medical equipment management glossary" by Secretary of Health. 2016

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