The problem of infections associated with implants – an overview

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Abstract

Implant-associated infections are serious and relatively common complication that leads to implant loss. The purpose of this paper is to gather knowledge about this issue. A literature review of the epidemiology, risk factors and pathogenesis of infections related to implants was carried out. This position collects data on commonly used implants and infections associated with them from various fields of medicine and contains classifications of the main factors that predispose to this infection, frequency hierarchy and categorization of bacteria strain that cause them. The risk factors are grouped into four basic groups dependent on: the implant, the patient, the local environment and the surgical technique. It was found that this infections are the most common in the case of: ventricular assist devices, catheters, bone substitutes, dental and breast implants. The conclusion was made that implant-associated infections are usually caused by multiple strains of bacterial species, mainly by *Staphylococci*, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*. The most important aspect of minimizing implant-associated infections is prevention. Summarize, besides of perioperative antibiotic prophylaxis, sterility of treatment and hygiene, the crucial aspect is also the design of implants.

Key words:

Implant-associated infection, biomaterials infection, Staphylococci, bioactive biomaterials, Prophylaxis

Introduction

Implants and biomedical devices play an important role in treating diseases, restoring health and saving human life. In recent years, they have become an extremely common, valid and inseparable part of medicine [1]. Despite their benefits, their usage involves certain problems. The major ones are: inflammatory reaction, lack of integration with the surrounding tissue, total rejection and infection [2,3]. Generally, it is assumed that infections are one of the main reasons for removal of implants [3]. However, it is implants themselves that contribute to infection. Opening the body's layers and tissue damage by surgery, as well as implementation of foreign body into the interior allows bacteria to colonize in the body [1-3]. It is estimated that most of these infections occur in the form of biofilms, hence they are extremely resistant to host defences and therapy [2-4].

It is important in the aspect of prevention and therapy to have knowledge about a given issue. Hence, the aim of this paper is collecting data on implant-associated infections. The position contains the following classifications: frequency of infections related to implants, factors predisposing to their occurrence and the bacteria strains that cause them.

Methods

Studies were searched in electronic databases according to article titles, abstract contents, and relevance in the field of implant-associated infection. The databases used in this research were: ScienceDirect, PubMed and Academic Google. The main terms applied were: implant infection, biomaterials infection, biofilm, risk factor implant infection and infections related to specific implants (e.g. orthopedic implant infection or dental implant infection). Articles were sought that provided knowledge about factors affecting the infection, the epidemiology of implant-associated infections and types of bacteria that cause these infections.

Results

Common factors influencing implant-associated infections

The pathogenesis of implant-associated infections is an extremely complex issue and a constant challenge for modern science. Generally, there are four groups of factors that can contribute to infection after implant placement (Fig. 1). These are factors related to: implant properties, patient's individual characteristics, environment properties and surgery technique.

Nowadays, designing implants is important for combating infections. Crucial aspects include: biomaterial selection, production quality, surface treatment, geometry optimization and sterilization process. Furthermore, the current trend involves the application of bioactive coatings to implants that fight bacteria (e.g. releasing antibiotic or nanometals particles) [5-9].

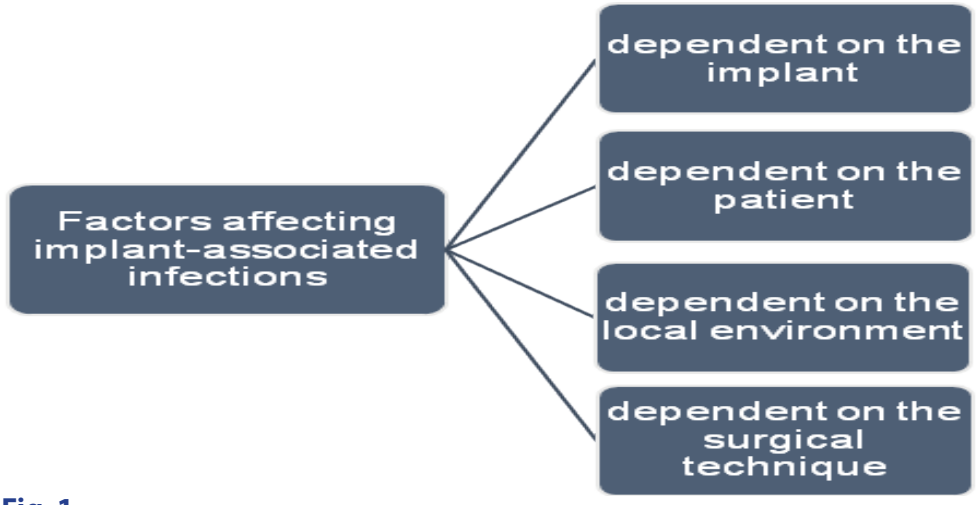

Fig. 1.
Classification of factors affecting the risk of implant-associated infections

Other factors that can increase the risk of implant-associated infections are individual features of the patient, i.e. age, health status, BMI, coexisting diseases, using of stimulants, taking drugs, as well as hygiene [10-16].

Furthermore, the properties of the local environment where the implant will be placed can affect the infection. These include: nature of the body fluid (i.e. pH, ion composition, viscosity and circulation rate), quality of tissue, blood supply and vascular integrity, as well as adjacent inflammation or infection. However, if the implant is not biocompatible or the tissue is hypersensitive, it also will increase the risk of infection. Attention should be paid also to the aspect of bacterial contamination at various intensities depending on the place of implantation [3,15,17-20].

The surgery technique also affects the risk of implant-associated infections. The following factors can be distinguished: placement of the implant, its anatomic location, degree of opening the body surface, surgical trauma and degree of damage to surrounding tissues, advancement of perioperative bacterial contamination, reoperation, as well as experience and skills of surgeon [15,20-22].

All common factors related to implant-associated infections were collected in Tab. 1. It can be observed how complicated the character of these infections is. Four groups of factors are dependent on three different people: the implant designer, the surgeon and the patient.

Table 1.
Common factors affecting implant-associated infections

Factors affecting implant-associated infections:	
Properties of the implant **[6-9]**	• implant material • geometry and shape of implant • surface topography and roughness • hydrophilic surface with high surface free energy • surface purity and sterility

Individual features of the patient **[10-16]**	• age
	• obesity
	• co-morbidities:
	  • diabetes
	  • malnutrition
	  • anemia
	  • renal failure
	  • HIV
	• drugs (e.g. anticoagulants or corticosteroids)
	• systemic illness
	• smoking
	• alcoholism
	• radiotherapy or/and chemotherapy
	• hygiene

Local environment properties **[3,15,17-20]**	• nature of the fluid • bone quality • adjacent inflammation or infection • soft tissue viability • vascular integrity • hypersensitivity of tissue to implant components
Surgical technique **[15,20-22]**	• surgical trauma • anatomic location of the implant • degree of opening the body surface • previous failure • perioperative bacterial contamination • experience and skills of surgeon

Frequency of implant--associated infections

The factors described above contribute to the fact that implant-associated infections have numerous risk of occurrence. Literature analysis of the frequency of these infections was collected in Fig. 2. However, these data are estimated because they come from various sources in which different criteria have been adopted. The aspect of defining the infection, adopting the time of its occurrence, as well as the number of data analyzed from the unit were particularly important. However, the collection allows to determine which implants are particularly predisposed to infection. It is also necessary to take into account the differences between the occurrence of bacterial contamination on the implant surface and the occurrence of implant-associated infections. Most implants will be covered during use with bacteria, this mainly applies to dental implants, catheters or contact lenses. Hence, the key aspect is the proper use of implants. For example, frequent changes of catheters or proper hygiene of contact lenses during use or general oral hygiene in the case of dental implants [23-44].

The greatest risk of implant-associated infections occurs in the case of: ventricular assist devices, catheters, bone substitutes, dental and breast implants. However, the smallest frequency occurs in the case of orthopedic implants, such as: prosthetic joints or fracture stabilizing equipment (plates and screws).

Classification of common bacterial strains related to implant-associated infections

Implant-associated infections also have a various bacterial background. The analysis of bacterial strains causing these infections was collected in Tab. 2. In the vast majority infections associated with implants are

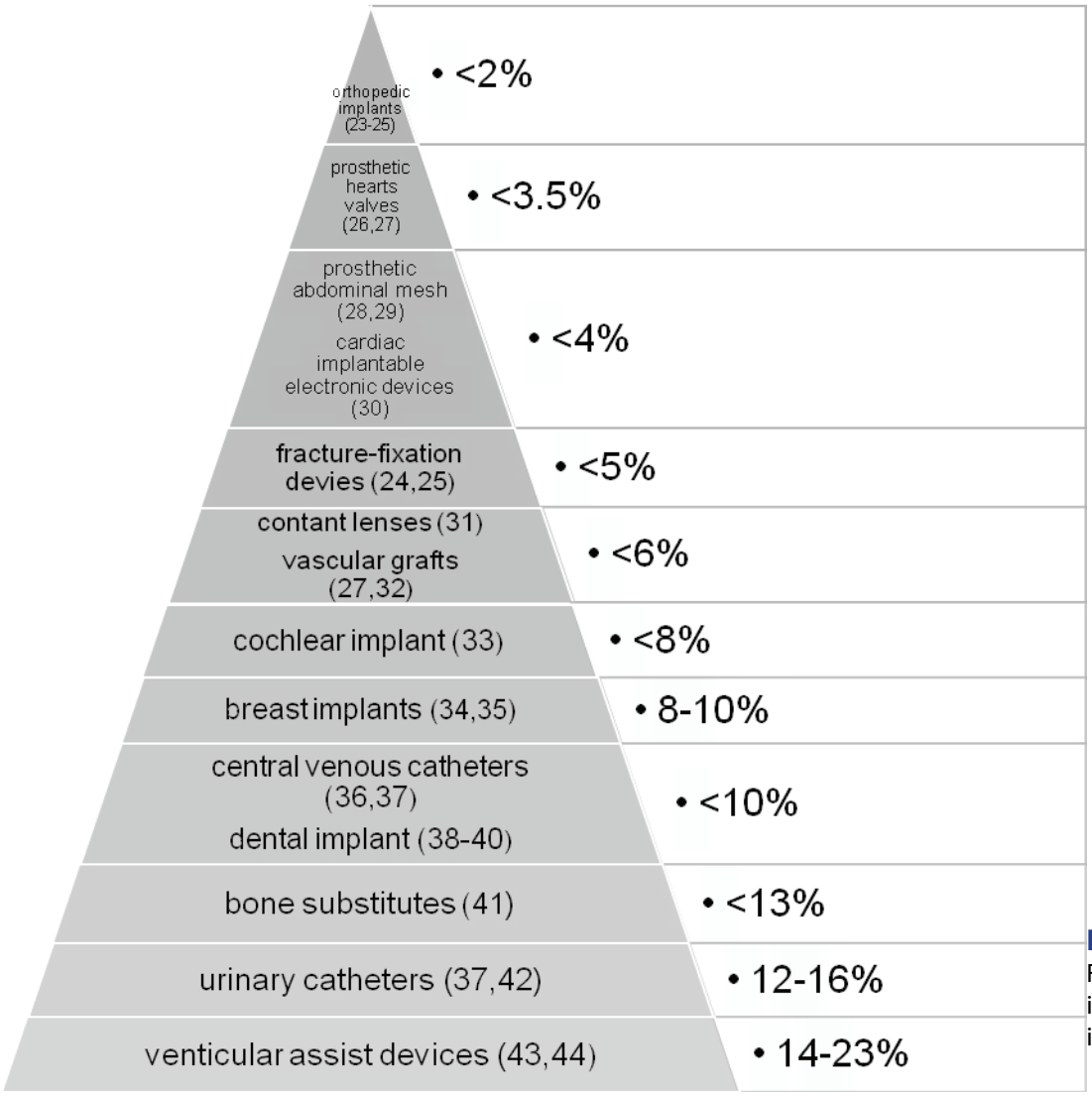

Fig. 2. Frequency of implant-associated infections

Table 2.
Common bacterial strains causing implant-associated infections

Orthopedic implant-associated infections [23-25,41]:
• Staphylococcus aureus • Staphylococcus epidermidis • Escherichia coli
Cardiovascular implant-associated infections [26,27,30]:
• Staphylococcus aureus • Escherichia coli • Staphylococcus epidermidis • Pseudomonas aeruginosa • Enterococcus faecalis
Visceral implant-associated infections [28,29]:
• Staphylococcus aureus • Staphylococcus epidermidis
Ophtalmic implant-associated infections [31]:
• Escherichia coli • Staphylococcus aureus • Staphylococcus epidermidis • Pseudomonas aeruginosa • Serratia spp • Staphylocccus spp
Breast implant-associated infections [34,35]:
• Staphylococcus aureus • Pseudomonas aeruginosa • Staphylococcus epidermidis
Dental implant-associated infections [38-40]:
• Prevotella intermedia • Prevotella nigrescens • Candida spp • Porphyromonas gingivali • Actinobacillus actinomycetemcomitans • Treponema denticola • Bacteroides spp • Streptococcus spp • Staphylococcus spp
Central venous catheter-associated infections [36,37]:
• Staphylococcus aureus • Staphylococcus spp
Urinary catheters-associated infections [37,42]:
• Escherichia coli • Klebsiella pneumoniae • Proteus mirabilis • Pseudomonas aeruginosa
Venticular assist device-associated infections [43,44]:
• Staphylococcus aureus • Enterobacteriaceae • Pseudomonas aeruginosa • Corynebacterium spp
Genital prostheses-associated infections [45]:
• Staphylococcus epidermidis
Hearing implant-associated infections [46]:
• Staphylococcus aureus • Streptococcus pneumoniae • Haemophilus influenzae • Pseudomonas aeruginosa

caused by *Staphylococci*, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*. The exceptions are dental implants, which infections in most cases are caused by anaerobic bacteria and urinary catheters, which are caused mainly by *Escherichia coli*. On the one hand, this knowledge gives a big advantage in the aspect of therapy selection, but on the other, the bacteria develop and mutate, as well as, implant-associated infections are caused by multiple strains of bacterial species. Furthermore, their resistance to drug therapy and creating biofilm structures is the growing problem. Bacteria are constantly mutating and become resistance to antibiotics, so fight against them become a crucial problem to medicine [25,35,38,42].

Prevention of implant--associated infections

Effective prevention and, as a consequence, minimizing the risk of developing implant-associated infections is possible while complying the adopted rules regarding the decontamination of the operating environment, the use of perioperative prophylaxis (the right choice of antibiotic, its dose and duration of therapy), proper hygiene, frequent changes of routine used implants, continuous training of medical personnel, as well as control and monitoring procedures are carried out.

Furthermore, bioactive implants presently become standard as well. They are designed to reduce the risk of surface contamination of bacteria or are equipped with antibacterial coating or modifiers [47-49].

Conclusions

- Implant-associated infection is a serious complication related to the use of implants in medicine.
- Four groups of factors favoring the occurrence of implant-associated infection are distinguished: dependent on the implant, dependent on the patient, dependent on the local environment and dependent on the surgical technique.
- The greatest risk of implant-associated infections occurs in the case of: ventricular assist devices, catheters, bone substitutes, dental and breast implants.
- Implant-associated infections are usually caused by multiple strains of bacterial species.
- *Staphylococci* are responsible for the majority of infections associated with implants, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*.
- A crucial problem is the resistance of bacteria to therapies. Hence, the prevention of infection seems to be the key aspect.
- Nowadays, in addition to perioperative antibiotic prophylaxis, sterility of treatment and hygiene, the crucial aspect of minimizing the risk of implant-associated infection is the design of implants.

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