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Review

Infections associated with mesh repairs of abdominal wall hernias: Are antimicrobial biomaterials the longed-for solution?

O. Guillaume [a, *], R. Pérez-Tanoira [b, c], R. Fortelny [d, e, f], H. Redl [e, g], T.F. Moriarty [a], R.G. Richards [a], D. Eglin [a], A. Petter Puchner [d, e]

[a] AO Research Institute Davos, Clavadelerstrasse 8, CH 7270, Davos, Switzerland
[b] Division of Infectious Diseases, IIS-Fundación Jiménez Díaz, Madrid, Spain
[c] Department of Otorhinolaryngology - Head and Neck Surgery, Helsinki University Hospital and University of Helsinki, Finland
[d] Department of General, Visceral and Oncologic Surgery, Wilhelminen Hospital, Montleartstrasse 37, 1160, Vienna, Austria
[e] Ludwig Boltzmann Institute for Experimental and Clinical Traumatology, Donaueschingenstraße 13, A-1200, Vienna, Austria
[f] Sigmund Freud University, Medical Faculty, Kelsenstraße 2, A-1030, Vienna, Austria
[g] Austrian Cluster for Tissue Regeneration, Donaueschingenstrasse 13, A-1200, Vienna, Austria

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ABSTRACT

The incidence of mesh-related infection after abdominal wall hernia repair is low, generally between 1 and 4%; however, worldwide, this corresponds to tens of thousands of difficult cases to treat annually. Adopting best practices in prevention is one of the keys to reduce the incidence of mesh-related infection. Once the infection is established, however, only a limited number of options are available that provides an efficient and successful treatment outcome. Over the past few years, there has been a tremendous amount of research dedicated to the functionalization of prosthetic meshes with antimicrobial properties, with some receiving regulatory approval and are currently available for clinical use. In this context, it is important to review the clinical importance of mesh infection, its risk factors, prophylaxis and pathogenicity. In addition, we give an overview of the main functionalization approaches that have been applied on meshes to confer anti-bacterial protection, the respective benefits and limitations, and finally some relevant future directions.

1. Introduction to mesh-associated infection after hernia repair

Abdominal wall hernia is a common surgical problem affecting patient populations across the world. The main causes of abdominal wall hernia are related to collagen disorders and/or insufficient suture closing techniques after laparotomies (called incisional hernia). The surgical repair of abdominal wall hernia, involves repositioning the contents of the hernia sac (protruded organs) into the abdominal cavity, and consequently the closure and reinforcement of the defect using either a suture (known as herniorrhaphy) or a net-like prosthesis (called mesh, known as hernioplasty). The utilization of mesh materials over the last five decades has brought clear advantages compared to direct suturing, which was the previous standard protocol. Indeed, the mesh approach is generally associated with reduced recurrence rates, a quicker recovery, and lower risk of post-operative chronic pain [1].

Nevertheless, hernia repair using either suture or mesh technique can result in infectious complications [1,2], with incidence rates between 1 and 4% of all patients. Hernia mesh-related infection is "*a surgical disaster*" [3], with dramatic effects for the patients and incurs significant healthcare costs. Considering that more than 1 million hernia repair operations using mesh are performed annually in the USA, it is estimated that approximately 60 000 inguinal and ventral hernia (corresponding to protrusion through the inguinal canal or through the muscles of the abdominal wall respectively) repairs become infected annually, with similar numbers in Europe [4].

In the 2004 publication entitled "Post mesh herniorrhaphy infection control: Are we doing all we can?" [5], Pr. Deysine suggested that philosophical changes must be considered since surgical site infection (SSI) in herniatology was still unacceptably high. He compared the situation to the orthopaedic community, who achieved a tremendous reduction of SSI within the last decades (*e.g.*

* Corresponding author.
E-mail address: olivier.guillaume@aofoundation.org (O. Guillaume).

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by using filtered incoming air in theatres, local antibiotherapy, three pairs of gloves, *etc.*) [5]. Among the possible routes for progress, judicious surgical approaches but also technologies and innovative techniques dedicated to the prevention of mesh infection are seen to play crucial role; and have already brought promises in this challenging field [5]. As illustrated Fig. 1, the hernia community is showing increasing interest in this field, with a continuous augmentation of published reports dealing with mesh-related infection and innovative strategies aiming to prevent hernia surgical site infection (SSI).

In order to facilitate the development of innovative strategies dedicated to tackle mesh related infection, we need to fully comprehend the clinical problem. Therefore, the following review will focus on biomaterials strategies used to fight against infection, but will also include the pathogenesis of mesh-related infection, the clinical solutions currently available and the recent advances in anti-infective meshes.

2. Surgical site infection in herniatology

The Centers for Disease Control (CDC) in the US distinguishes between incisional surgical site infections (SSI) occurring superficially and deeper within the body. By definition, a superficial incisional SSI is an infection involving only the skin or subcutaneous tissues, requiring relatively simple treatment based on wound drainage accompanied by antibiotics administered systematically. Mesh-related infection occurring after hernia surgery is, in contrast, considered a deep incisional SSI, and more elaborate treatment protocols may be required. In addition, because the mesh is considered an implant, the duration of surveillance and diagnosis is extended to 1 year post-operatively (instead of only 30 days for superficial SSI not involving implants), and it involves deep soft tissues (*e.g.* fascia and muscle layers) [6,7].

2.1. Pathogenesis of mesh-related contamination

There are a small number of cases reporting non-sterile, counterfeit meshes [8] or inappropriately re-sterilized meshes resulting in sepsis and post-operative mesh infection [9]. Those clinical cases are relatively rare, and, in fact, the main origin of microorganisms remain the patient's skin or mucosa and the surgical environment (*e.g.* flora of the caregiver) [2]. Generally, contamination is believed to occur at the moment of the surgical insertion of the biomaterial prosthesis into the abdominal cavity, caused by a small number of adhering microorganisms.

Staphylococcus aureus and *S. epidermidis* are the leading causative microorganisms, responsible for approximately 90% of mesh-related infection, with Methicillin-resistant *Staphylococcus aureus* (MRSA) [10], responsible for up to 63% of mesh-related SSI [11,12]) [13]. Other bacteria have been isolated from infected meshes, including Gram-positive species such as *Streptococcus pyogenes* [14] and *Enterococcus faecalis* [15,16] and Gram-negative species such as *Pseudomonas sp.* [14] and *Enterobacteriaceae* (such as *Escherichia coli* and *Klebsiella pneumonia* [17,18]). Additionally, some reports describe infection by other microorganisms such as *Propionibacterium acnes*, mycoplasma, rapidly growing mycobacteria and *Candida albicans* [19–21].

A critically important point to highlight is that biofilms formed on medical devices are usually composed of several bacterial strains, and mesh-related infections can also involve polymicrobial infection [16,22]. In those complicated cases, the isolation, cultivation and identification of every causative agents still remains challenging and numerous pathogens may remain underestimated depending of the exact practices in the clinical microbiology lab [16,23]. The utilization of modern biotechnological tools such as gene sequencing has been recently employed as alternative to conventional cultivation methods to analyse the microbial population of explanted mesh following hernia recurrence [24]. The authors of this work have demonstrated for the first time that hernia meshes could be reached by bacteria, not only originating from the skin and the gut of the patient, but also from oral site (due to periodontal diseases) [24]. This study suggests as well that bacterial biofilm settled on the meshes in patients without clinical signs of infection could *a priori* also promote recurrence [24].

2.2. Incidence of SSI in herniatology

It is known that the insertion of a medical device increases the susceptibility of infection by a factor 10 000 up to 100 000 [25]. In the field of hernia repair, bacterial contamination occurs in 1/3 [19,26] up to 2/3 [24] of the implanted meshes either during mesh insertion or even after years of implantation in cases where healing is disturbed. Of those meshes colonized by microorganisms, relatively few will develop infection with clinical symptoms of SSI, but this risk persists for many decades after the surgical procedure [10]. Conventionally, the incidence of SSI in hernia surgery ranges between 1 and 4% in most of the literature reported over the last decades [5], but it depends on numerous factors. Among the risk factors of SSI, the nature of the hernia has been relatively well documented. For instance, SSI incidence is around 2–4% in open surgery for inguinal repair, but reach 6–10% in case of incisional hernia operations [27]. The surgical approach has also a direct influence on SSI, *e.g.* using laparoscopic route is usually correlated with lower SSI (compared to open surgeries) as it corresponds to a minimal invasive act, with no need of large dissection [28]. With the laparoscopic approach, SSI has be reduced to as low as 0.1% [29].

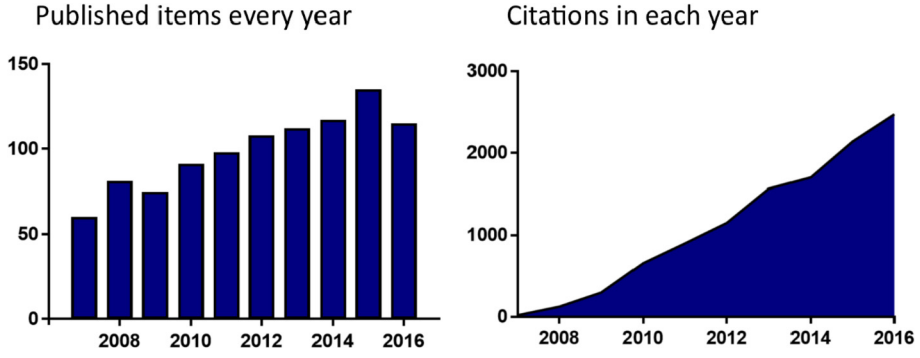

Fig. 1. Increasing awareness of mesh-related infections is reflected by the steady increase in scientific reports published every year. Search was done on the 8th of August 2017 on "isi web of knowledge" with key words "Mesh" + "Hernia" + "Infection".