Acta Biomaterialia 50 (2017) 20–40

Contents lists available at ScienceDirect

Acta Biomaterialia

journal homepage: www.elsevier.com/locate/actabiomat

Review article

A review of the recent advances in antimicrobial coatings for urinary catheters

Priyadarshini Singha [a], Jason Locklin [a,b,*], Hitesh Handa [a,*]

[a] School of Materials, Chemical and Biomedical Engineering, College of Engineering, University of Georgia, Athens, GA, USA
[b] Department of Chemistry, University of Georgia, Athens, GA, USA

ARTICLE INFO

Article history:
Received 4 August 2016
Received in revised form 30 November 2016
Accepted 30 November 2016
Available online 1 December 2016

Keywords:
Catheter-associated urinary tract infections
Antimicrobial coatings
Antifouling coatings
Urinary catheters
Urinary catheter coatings
Biocides

ABSTRACT

More than 75% of hospital-acquired or nosocomial urinary tract infections are initiated by urinary catheters, which are used during the treatment of 15–25% of hospitalized patients. Among other purposes, urinary catheters are primarily used for draining urine after surgeries and for urinary incontinence. During catheter-associated urinary tract infections, bacteria travel up to the bladder and cause infection. A major cause of catheter-associated urinary tract infection is attributed to the use of non-ideal materials in the fabrication of urinary catheters. Such materials allow for the colonization of microorganisms, leading to bacteriuria and infection, depending on the severity of symptoms. The ideal urinary catheter is made out of materials that are biocompatible, antimicrobial, and antifouling. Although an abundance of research has been conducted over the last forty-five years on the subject, the ideal biomaterial, especially for long-term catheterization of more than a month, has yet to be developed. The aim of this review is to highlight the recent advances (over the past 10 years) in developing antimicrobial materials for urinary catheters and to outline future requirements and prospects that guide catheter materials selection and design.

Statement of Significance

This review article intends to provide an expansive insight into the various antimicrobial agents currently being researched for urinary catheter coatings. According to CDC, approximately 75% of urinary tract infections are caused by urinary catheters and 15–25% of hospitalized patients undergo catheterization. In addition to these alarming statistics, the increasing cost and health related complications associated with catheter associated UTIs make the research for antimicrobial urinary catheter coatings even more pertinent. This review provides a comprehensive summary of the history, the latest progress in development of the coatings and a brief conjecture on what the future entails for each of the antimicrobial agents discussed.

© 2016 Acta Materialia Inc. Published by Elsevier Ltd. All rights reserved.

Contents

1. Introduction 21
1.1. Urinary catheter 21

Abbreviations: catheter-associated urinary tract infection(s), CAUTI(s); urinary tract infection, UTI; colony forming unit, CFU; Healthcare Infection Control Practices Advisory Committee, HICPAC; extracellular polymeric substances, EPS; scanning electron microscopy, SEM; serial plate transfer test, SPTT; polytetrafluoroethylene, PTFE; polyethylene glycol, PEG; polyurethane, PU; 5,5-dimethylhydantoin, DMH; trimethoprim, TMP; sulfamethoxazole, SMZ; polyvinyl chlorine, PVC; ethylene vinyl acetate, EVA; 4-amide-piperidine-C12, 4AP12; enoyl-acyl carrier protein reductase, ENR; food and drug administration, FDA; antimicrobial peptides, AMP(s); polydimethylsiloxane, PDMS; allyl glycidyl ether, AGE; attenuated total reflectance-Fourier transform infrared spectroscopy, ATR-FTIR; X-ray photoelectron spectroscopy, XPS; atomic force microscopy, AFM; fluorescein isothiocyanate, FITC; bovine serum albumin, BSA; nitric oxide, NO; *S*-nitroso-N-acetyl-DL-penicillamine, SNAP; *S*-nitrosoglutathione, GSNO.

* Corresponding authors at: Department of Chemistry, College of Engineering, University of Georgia, 220 Riverbend Road, Athens 30602, GA, USA (J. Locklin). College of Engineering, University of Georgia, 220 Riverbend Road, Athens 30602, GA, USA (H. Handa).

E-mail addresses: jlocklin@uga.edu (J. Locklin), hhanda@uga.edu (H. Handa).

http://dx.doi.org/10.1016/j.actbio.2016.11.070
1742-7061/© 2016 Acta Materialia Inc. Published by Elsevier Ltd. All rights reserved.

1.2. The problem with urinary catheters: long-term catheterization and catheter-associated urinary tract infections . . . 22
1.3. The case of antimicrobial resistance in CAUTIs . . . 24
1.4. Improving interaction between the urinary system and the urinary catheter . . . 24
2. Antimicrobial urinary catheter coating agents/materials in clinical trials and/or research . . . 26
2.1. Clinically-tested antimicrobial agents/materials . . . 26
2.1.1. Silver . . . 26
2.1.2. Antibiotics . . . 27
2.2. Antimicrobial agents/materials in research (not yet clinically tested) . . . 28
2.2.1. Chlorhexidine . . . 29
2.2.2. Triclosan . . . 29
2.2.3. Antimicrobial peptides (AMPs) . . . 30
2.2.4. Bacteriophages . . . 30
2.2.5. Enzymes . . . 31
2.2.6. Nitric oxide . . . 32
2.2.7. Polyzwitterions . . . 33
2.2.8. Polymeric coating modifications . . . 34
2.2.9. Liposomes . . . 35
3. Future perspectives and challenges . . . 35
4. Conclusion . . . 36
Acknowledgement . . . 36
References . . . 36

1. Introduction

1.1. Urinary catheter

Urinary catheters have been used since the third century B.C., by the Greeks, Egyptians and Chinese, but the first malleable urinary catheter on record was only made in 1779 by a goldsmith, Bernard [1]. Some of the first materials used to make urinary catheters were copper, tin, bronze, gold, lead, papyrus, onion stems, dried reeds and palm leaves. In recent times, materials such as gum-elastic, plastic (poly(vinylchloride), PVC), polyurethanes, silicone and latex rubbers have been used for their superior malleability [2,3]. These materials have been developed over the years to include most of the characteristics desirable in a catheter: high tensile strength, soft and pliable, inherently chemical resistant, biocompatible and able to meet flow requirements while maintaining a minimally invasive circumference or French profile. Some of the strengths and weaknesses of different urinary catheter materials have been listed in Table 1, and these characteristics have led the emergence of silicone as the material of choice for urinary catheters despite a few of its disadvantages [1,4,5]. While latex was originally used alone, or modified with either hydrogel or Teflon coatings, its unsuitable properties like poor UV and chemical resistance, poor adherence, and possible allergic reactions leave much to be desired [1]. It has also been observed using scanning electron microscopy (SEM) that the rough surface of latex can also promote biofilm formation [6]. Therefore, silicone is now more commonly used as a base catheter material since it circumvents many of the problems faced by latex catheters.

Besides the evolution of materials, catheter design has also undergone several changes over the years including the balloon used to hold the catheter onto the urinary bladder and develop-

Table 1
Comparison of strengths and weaknesses of commonly used urinary catheter materials.

Material	Advantages	Disadvantages
Latex rubber	• Can be modified by PTFE coatings • Low cost • Easily processed • High tensile strength	• Poor biocompatibility • Prone to infection and encrustation • Causes latex allergy (8–17% among medical professionals) and higher in patients with spina bifida or spinal cord injury (47%). Prevalence in general population is 1–6%
Silicone	• Long lifetime before encrustation and blockage sets in • No allergic reaction • Moderate resistance to abrasion • Enhanced surface lubrication • Biocompatible • Good chemical and thermal stability (−80 C to +230 C) • Low surface tension	• Uncomfortable for some patients due to its rigidity • Can be deflated unlike latex catheters and hence prone to premature device failure
PTFE coating	• Fairly biocompatible • Low coefficient of friction • Hydrophobic • Self-lubricating • Can be autoclaved or ethylene oxide sterilized	• Predisposed to infection and encrustation • Toxic • Stiff
Polyvinyl chloride	• Durability • Chemically stable • Inexpensive	• Less flexible without plasticizers • Public health concerns due to additives that can leach in vivo causing several problems
Polyurethane	• Larger internal diameter because of thinner wall • Excellent biocompatibility • Softens in body • Excellent tensile strength	• Sensitive to heat • Cannot be autoclaved

Download English Version:

https://daneshyari.com/en/article/6449671

Download Persian Version:

https://daneshyari.com/article/6449671

Daneshyari.com