Ultrashort NSAID-conjugated Peptides as Bifunctional Nanomaterials

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Biofunctional Nanomaterials Group
Outline

1. Ultrashort peptides
2. Self-assembling peptides
3. Ultrashort self-assembling antimicrobial peptides
4. NSAID-conjugated self-assembling peptides
What are Ultrashort Peptides?

- Ultrashort = 4-7 amino acids
- Cationic = net positive charge (+2)
- Cost effective $\rightarrow$ Upscale $\rightarrow$ Translational potential $\rightarrow$ Patient
- Numerous advantages including:
  - ↑ chemical versatility
  - ↓ immunogenicity
  - Tunable biocompatibility + biodegradability
  - Tailored self-assembly/pharmacological properties
  - Antimicrobial = innate immune response
  - Nanotechnology
Self-assembling Peptides

Peptide Amphiphiles  
(Stupp)

α-helices/ Coiled coils  
(Woolfson/ Tirrell)

β-sheets  
(Agelli/ Collier)

Short Aromatics  
(Xu/ Gazit/ Ulijn)

β-haripins  
(Pochan/ Schneider)
Core Technology

Self-assembled Peptides

- Short peptide sequences
- External stimuli
- Assembly

Stimuli
- pH
- Light
- Temperature
- Ionic Strength
- Specific enzymes

Hydrophobic: Hydrophilic \(\rightarrow\) Hydrogel
(critical gelation concentration)

Peptide Hydrogels
Biofunctional Nanomaterials Utilising the Building Blocks of Life!

- Infection and Medical Devices
- Wound healing
- Drug Delivery
- Stem Cells/Regenerative medicine
Planktonic vs. Biofilm Bacteria

- Planktonic form: Free floating in liquid
- Biofilm form: sessile, composed of aggregated microcolonies of cells surrounded by a protective extracellular polymeric matrix
- Mature biofilms can resist 10-1000 times the concentrations of standard antibiotic regimens that are required to kill genetically equivalent planktonic forms

P. Dirckx, Centre for Biofilm Engineering, Montana State University, Bozeman

Biofilms in the Environment and Medicine

Biofilm growth on rocks in a stream (USGS) and within a kitchen pipe (MSU Center for Biofilm Engineering).

Biofilm formation on a voice prosthesis implant.

SEM Pseudomonas aeruginosa, shown here attached to an implant surface, is one of many resistant microorganisms.

University of Illinois researchers tested a prototype of a new device that can see biofilms behind the eardrum to better diagnose and treat chronic ear infections.
Antimicrobial Resistance

- Healthcare associated infections
- Medical devices: reservoir for “superbugs”
- Chronic wounds
- Persistent burden on:
  - Patient morbidity & mortality
  - Family and carers
  - Healthcare budgets
What are the solutions?

Antimicrobial Activity of Short, Synthetic Cationic Lipopeptides

Garry Laverty, Martin McLaughlin, Christopher Shaw, Sean P. Gorman and Brendan F. Gilmore*

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Evolution of Antimicrobial Peptides to Self-Assembled Peptides for Biomaterial Applications

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Cationic Antimicrobial Peptide Cytotoxicity

Garry Laverty* and Brendan Gilmore

Anti-biofilm activity of ultrashort cinnamic acid peptide derivatives against medical device-related pathogens

Garry Laverty, *Alice P. McCloskey, Sean P. Gorman and Brendan F. Gilmore
### Rational Design of Antimicrobial Peptide Motif vs Self-assembly

<table>
<thead>
<tr>
<th>Antimicrobial Activity</th>
<th>Propensity to Self-assemble</th>
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<tbody>
<tr>
<td>Hydrophobic/Hydrophilic (Charge) ratio (more important with regard to antimicrobial activity than size)</td>
<td>Hydrophobic/Hydrophilic balance</td>
</tr>
<tr>
<td>Interactions with microbial extracellular membranes</td>
<td>Non Covalent intermolecular interactions (e.g. Van der Waal’s, π-π stacking)</td>
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<tr>
<td>Interaction with intracellular targets/processes (DNA, RNA, enzymes, protein synthesis)</td>
<td>Ability of peptide to form hydrogen bonds with each other and with water</td>
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Self-assembled Ultrashort Peptide Gels

- Successful library of ultrashort peptides: self-assembled at physiological pH
- \((X_1\text{-FF-X}_2)\)
- Hydrophobicity: naphthalene (Nap) grouping (at \(X_1\)) and varying quantity of phenylalanine (F) in primary structure
- Minimum of 2 charged units required for antimicrobial activity
- Primary amine group provides cationic charge
- Cationic amino acids vary by number of methylene units on R-group

Dual Antimicrobial Anti-inflammatory Nanomaterials

- Hydrophobicity provided by NSAID structure
- High in aromaticity
- Display self-assembly and gelation characteristics
- Potential applications in chronic infected wounds

Self-assemble to Hydrogel Networks

NpxFFKK 0.5 %
IndFFKK 2 %
IndFFKK 1 %

Queen's University
Belfast
Confirmation of β-sheet Hydrogel Networks

Oscillatory rheology

FTIR
Dual action

Antimicrobial

Percentage reduction of mature 24h biofilm treated with 2% w/v NSAID- conjugated hydrogels utilizing an alamarBlue assay.

Anti-inflammatory

Percent inhibition of COX 1 and 2 enzyme by NSAID self-assembled hydrogels and by the model COX inhibitor DuP-697 using a COX Fluorescent Inhibitor Screening Assay Kit.
Conclusion

• Developed a library of ultrashort self-assembling bifunctional peptides
• Vast potential for use against Biomaterial/Medical Device/Implant Infections
• Wound healing/surgical gel: Increased healing as mimics natural tissues
• Platforms/vehicles to deliver existing antimicrobials, extend spectrum of activity to Gram-negatives
• Translatable and economically friendly form of nanotechnology for patient benefit

Urinary catheter encrustation
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