Rapid Processor for Methicillin-Resistant
Staphylococcus aureus Identification in the
Operating Room

Jake Trahan III1, Taehyun Park2, Junseo Choi2, Bahador Farshchian2,
Jeffery A. Hobden1, Vinod Dasa1, Michael C. Murphy2
1 LSU Health Sciences Center New Orleans 2 LSU Department of Mechanical Engineering

Abstract

Introduction & Significance: Timely identification of potential bacterial infections in the operating room (OR) is essential for safer surgery. Current standards in testing for infection include bacterial detection techniques and host response measures that are time consuming and delay proper treatment.

Hypothesis & Objectives: A polymethyl methacrylate (PMMA) chip was fabricated to selectively capture Methicillin-Resistant Staphylococcus aureus (MRSA) from dilute synovial fluid samples. While laboratory-based methods may take from hours to days to produce conclusive results, this approach should detect bacteria within minutes.

Experimental Methods & Design: Using hot embossing and nanoimprint lithography, uncovered, prototype PMMA chips of desired thicknesses were produced. Several techniques for sealing the chips using nanopattern cover slips were evaluated, including spin coating with a PMMA solution and heating under pressure in a forced convection oven.

Results: Although the bonding tests were unsuccessful to date, chips were successfully tested by using a suction pump to provide a sufficient seal between the cover slips and chips allowing fluid samples to be tested. Under these conditions, the flow rate exceeds the optimal velocity for bacteria capture, so alternatives are being investigated.

Conclusions: Bonding nanometer polymer channels in the fashion necessary for bacteria capture is highly difficult and requires great precision beyond what is currently available. While the use of a suction pump for sealing is not conducive to providing a portable bacteria capture device, it allows us to continue testing the chip until a sealing technique is discovered. We demonstrated that the chip supports fluid flow and is prepared for further testing with antibody immobilization and bacteria capture through an antibody-antigen reaction.

Introduction

- Timely identification of potential bacterial infections in the operating room (OR) is essential for safer surgery
- For example, periprosthetic joint infection (PJI) can lead to:
  - Implant failure
  - Multiple operations including revision arthroplasty
  - Extended disability
  - Potential morbidity
- Most common organisms in PJI are Staphylococcus aureus and Staphylococcus epidermidis with varying degrees of Methicillin-resistance and Methicillin-sensitivity
- Current standards for bacterial detection in synovial fluid include:
  - Tissue culture
  - PCR
  - Host response measures (ESR, CRP, IL-6, and SF WBC count)
- All require time-consuming laboratory protocols, leading to:
  - Delays in the application of effective countermeasures
  - Overuse of broad spectrum antibiotics
- Early identification and treatment are necessary due to the economic and psychological burden
  - Initial treatment, with a 33.3% success rate, includes:
    - Debridement and irrigation
    - Polyethylene liner exchange
    - Intravenous antibiotics for a minimum of 6 weeks
    - Persistent infections require, with an 88% success rate:
      - Prosthesis removal
      - Insertion of cement spacer impregnated with antibiotics
    - Both physically and emotionally demanding for the patient and medical staff
- Micro-nano-fabricated chips offer faster, more accurate detection
  - PMMA chip functionalized with specific bacterial antibodies
  - MRSA antigens within dilute synovial fluid can be detected
  - Binding depends on the intrinsic rate of reaction and the encounter duration
  - Nanolayer barriers used to trap MRSA cells in the capture zone

Sealing Techniques

Fluorescence Microscopy

Conclusions and Future Work

- Continue development of bonding techniques including the use of pressure-assisted bonding point control thermal fusion bonding
- Determine the optimal velocity of capture for MRSA
- Capture tests with simulated and real synovial fluid