Antibacterial Scrubs for Healthcare Workers

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Abstract

Scrubs for healthcare workers have provided protection from bodily fluids and various different bacterium in a high-risk environment for contamination such as a hospital. Unfortunately, the rise of gram-negative, highly contagious, and antibiotic-resistant bacterial infections have limited the ability of the current scrub design to properly prevent infections to both healthcare workers and their patients. The number of healthcare associated infections is increasing every year, with almost 100,000 people dying from them in the U.S. alone, costing the healthcare system roughly $35 billion per year.[1,2] The development of bacteria-resistant scrubs is essential to reduce healthcare costs and prevent the spread of bacteria within hospitals due to healthcare associated infections. We tested the antibacterial properties of various fabrics and coatings using standard bacteria testing to try and create a scrub that reduces bacterial colony count on the scrub by 10^4 colony forming units/mL or more.

Background

4% — % of people who get a Healthcare Associated Infection per year. This equates to ~100,000 deaths per year.

HAIs are spread from patient-to-patient via the Healthcare Worker, who carries pathogens on their personal protective equipment.

HAIs cost the healthcare system over $35 billion a year and the cost continues to rise with the increase in instances of MRSA/bacterial resistant infections.

Healthcare associated infections (HAIs)

- ➔ Infections acquired by a patient in a healthcare setting during treatment for another condition
- ➔ Particularly high risk for patients with compromised immune systems (ex. patients in an intensive care unit)
- ➔ Caused by exchange of bodily fluids, air borne pathogens, or physical contact[1]

Transmission

- ➔ Occurs as doctors, nurses, and other health care workers (HCWs) travel from patient to patient while carrying bacteria on their scrubs
- ➔ When entering a patient's room, health care professionals will pick up antibiotic resistant bacteria from patients about 18% of the time[3]

Methods

2cm x 2cm swatches of each type of fabric were placed in a flask containing Lysogeny broth (LB) of a known concentration of *E coli*. The flasks were allowed to sit in a 37℃ incubator (with 5% CO_2) for 4 hours. The swatches were quickly dipped in PBS and then placed in centrifuge tubes with 30 mL of PBS. The tubes were vortexed for 3 minutes and the resulting PBS solutions were serially diluted and plated onto agar plates. The plates were allowed to grow for 24 hours at 37℃ (with 5% CO_2) before the individual colonies were counted and the colony forming units (CFUs) per mL were calculated.

For the flasks containing treated fabrics, the bacterial reduction percentage was calculated using the following equation:

$$R = \frac{B - A}{A} * 100$$

where R is the percent reduction of bacteria, A represents the number of bacteria colonies in the control, and B represents the number of bacteria colonies in each of the treated fabrics (both measured in CFUs/mL).

Proposed Solution

A two-pronged approach was used for the antibacterial scrub, combining the material properties of a textile with the varied properties of a chemical coating.

- Bamboo rayon was chosen for optimal comfort and sustainability. The fabric is moisture-wicking, takes coatings well, and is available in abundance[4,5]
- Silver nanoparticle fabric was chosen due to its intrinsically antibacterial properties[6]
- The silver nanoparticle fabric purchased also contained strong hydrophobic properties, further protecting healthcare workers from bacteria growth on their personal protective equipment
- The alginate coating was chosen since it is non-toxic, sustainably sourced, and has antibacterial properties[7]

Results

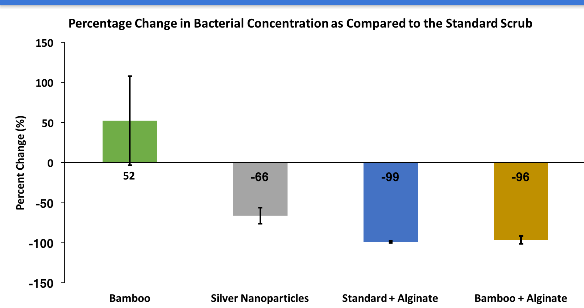

Figure 1: Graph of bacterial percent change (CFUs/mL) of each swatch of fabric as compared to the standard scrub swatch. N=3.

The *E. coli* bacteria was grown overnight in a 37℃ incubated shaker to ensure that a sufficient concentration of bacteria was present for measurements. The swatches were each placed in the bacterial solution and allowed to sit in a 37℃ and 5% CO_2 incubator. The concentration of bacteria on each swatch was measured after the swatches had 4 hours of stationary contact with the bacteria. The experiment was conducted 3 times.

The percent change in bacteria concentration was calculated (see Methods). The bamboo fabric increased the bacterial concentration by 52% as compared to the standard scrub. On the other hand, the silver nanoparticle fabric (with hydrophobic coating) reduced the bacterial concentration by 66%, and both the standard scrub and the bamboo scrub with the alginate coating saw reductions of over 95%.

With the exception of the bamboo fabric, the standard deviation for all samples was within 11% over the 3 trials. The bamboo fabric had a standard deviation of 55%, indicating the necessity for a larger sample size.

Conclusions

Nanoparticle Fabric Efficacy

- ➢ Not sufficient for antibacterial scrubs due to reduction percentage of only 66% (approximately 10x less bacteria)

Bamboo Fabric Efficacy

- ➢ Increased bacterial concentration by an average of 52%
- ➢ Although comfort and sustainability is important, the fabric did not demonstrate antibacterial properties and is therefore deemed inappropriate for use

Alginate Coating Efficacy

- ➢ For the coating on a standard scrub, the alginate coating provided a 99% reduction (approximately 1000x less bacteria)
- ➢ For the coating on a bamboo scrub, the alginate coating provide 96% reduction (approximately 100x less bacteria)

Major Conclusions

- ➢ None of the proposed solutions provided a bacterial reduction of more than 10^4 CFUs/mL (approximately 10000x less bacteria)
- ➢ The alginate coating showed the most potential
- ➢ The bamboo fabric appears to facilitate bacteria adhesion and/or growth

Future Work

While the initial results of our work are promising, there still exist several issues that must be addressed before this technology can enter mass markets. These future directions include:

➢ *Fine tuning of alginate coating*
Currently, the alginate coating makes the fabric brittle and is therefore deemed unwearable. The cross-linking agent requires changes.

➢ *Washing durability tests*
The durability of the coatings and their respective properties has yet to be investigated and may impact recommendations moving forward.

➢ *Scaling up the coating and treatment processes*
Industrial scale production of scrubs varies greatly from lab scale, therefore more research needs to be conducted in regards to scale up.

➢ *Investigating the antibacterial properties of the fabrics with other bacteria such as Staphylococcus aureus (MRSA)*
Although E. coli is a good start, other common and dangerous bacteria strains such as MRSA exist in the hospital setting and should not be exceptions to the scrub's antibacterial properties

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References

[1] Klevens R. M., Edwards J. R., Richards C. L., et al. (2007). Estimating Health Care-Associated Infections and Deaths in U.S. Hospitals, 2002. *Public Health Reports, 122*(2), 160-166.
[2] Scott, R. D. (2009). The Direct Medical Costs of Healthcare-Associated Infections in U.S. Hospitals and the Benefits of Prevention. *CDC*.
[3] Hardy, Susan, and Anthony Corones. "Dressed to Heal: The Changing Semiotics of Surgical Dress." *Fashion Theory* 20.1 (2015): 27-49. Web.
[4] Mahish, Sudipta S. "Functional Properties of Bamboo/polyester Blended Knitted Apparel Fabrics." NISCAIR-CSIR, India, n.d. Web. 21 Nov. 2016.
[5] Teli, M.D., and Javed Sheikh. "Modified Bamboo Rayon-copper Nanoparticle Composites as Antibacterial Textiles." *International Journal of Biological Macromolecules* 61 (n.d.): 302–7.
[6] Zhang, Feng, Xiaolan Wu, Yuyue Chen, and Hong Lin. "Application of Silver Nanoparticles to Cotton Fabric as an Antibacterial Textile Finish." *Fibers and Polymers* 10.4 (2009): 496-501. Web. 6 Nov. 2016
[7] Grace, Mary; Chand, Navin; Bajpai, Sunil Kumar. "Copper Alginate-Cotton Cellulose (CACC) Fibers with Excellent Antibacterial Properties." *Journal of Engineered Fibers and Fabrics*. 2009. 4(3): 24-35.