Which color for the light emitted by the aerosol particles?

Light4Lungs

Partners involved

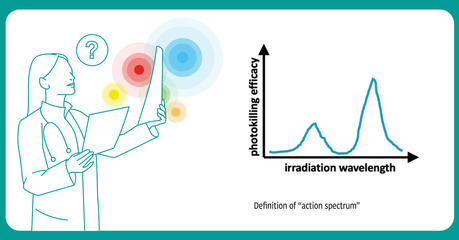
UNIFI, SU (partners directly involved) + UNIFI third party = University of Siena, Italy

Giovanni Romano, Chiara Treghini, Alfonso Dell'Accio, Giacomo Insero, Franco Fusi, Lucia Pallecchi, Maria Micieli, Eleonora Riccobono, Felice Valzano, Nelly Henry, Nidia Maldonado-Carmona, Gian Maria Rossolini

Objectives

To find which emission color(s) for the aerosol particles are predicted to maximize the antibacterial efficacy in vivo. This information will be passed on to the project partners in charge of particle synthesis, production, and characterization to make them emit these color(s). This corresponds to find the "action spectrum" of light for in vivo bacterial photokilling, in the lungs.

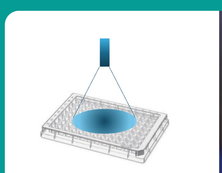
To demonstrate that visible light kills bacteria in laboratory conditions, and particularly the strains chosen in the project to be most representative of lung infections (Pseudomonas aeruginosa and Staphylococcus aureus).



Definition of "action spectrum"

Methodology

Standard light sources were used as a preliminary step prior to using the light-emitting aerosol. Laboratory-grown bacteria biofilms were illuminated by specifically made LED sources in 4 different color ranges: violet (405nm), blue (445nm), green (525nm) and red (623nm) with different light doses. A total of 4 bacterial strains were considered: 2 reference strains (PAO1 for P. aeruginosa and USA300 for S. aureus) and 2 clinical strains (LESB65 for P. aeruginosa and CF-MRSA for S. aureus).
After irradiation, the surviving bacteria % was measured by routine counting techniques and correlated with the light wavelength and dose.
The same biofilms were also analyzed with milli-fluidic and microscopy techniques, to have a deep insight into their optical properties and biological response after light irradiation.



Illumination scheme: light is shined onto a plastic "multiwell", containing the biofilm.

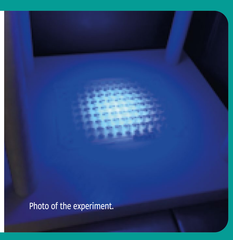
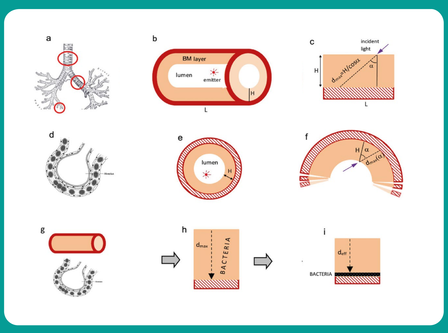


Photo of the experiment.



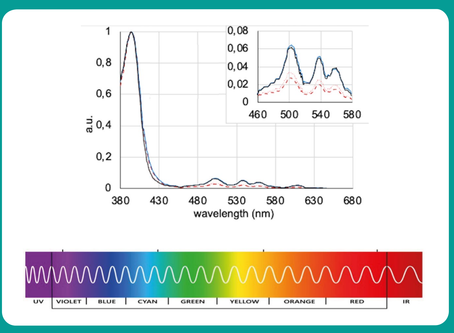
A model for light-biofilm interaction in the lungs was developed. Software simulation routines were specifically designed and used to predict the photokilling effects inside the lungs.

Results

In vitro photokilling experiments were performed against bacterial biofilm, demonstrating the efficacy of visible light in reducing the bacterial load, especially for violet-blue light (wavelength in the range 390-410 nm). The photokilling effect depends on the light color, light dose, and the specific bacterial strain. More than 99,5% bacterial load reduction was obtained in the best case.

A model to explain the action of the light was developed, considering both geometrical and physical parameters.
The predicted relative efficacy of the various light colors to kill bacteria in the lungs (action spectrum) was obtained. The results clearly show a maximum in correspondence to violet light (390-410nm wavelength), which is then predicted to be the most effective in killing bacteria. Therefore, the same colors are effective both against bacteria in vitro and in the infected organ.

A final curve depicting the relative % efficacy of the various light colors was obtained. The vertical axis reports the photokilling efficacy in terms of logarithmic decrease in the alive bacteria population.



Conclusions

Visible light can kill the chosen bacterial strains in vitro (laboratory conditions) in a way which is dependent on light color and dose, and on the specific strain.
The best predicted conditions to maximize biofilm photokilling in the lungs correspond to a violet-blue emission for the aerosol particles. The aerosol particles must then emit light especially in this color range.
The aerosol antibacterial efficacy is predicted to rise for higher emitted light intensity.

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SORBONNE UNIVERSITÉ

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