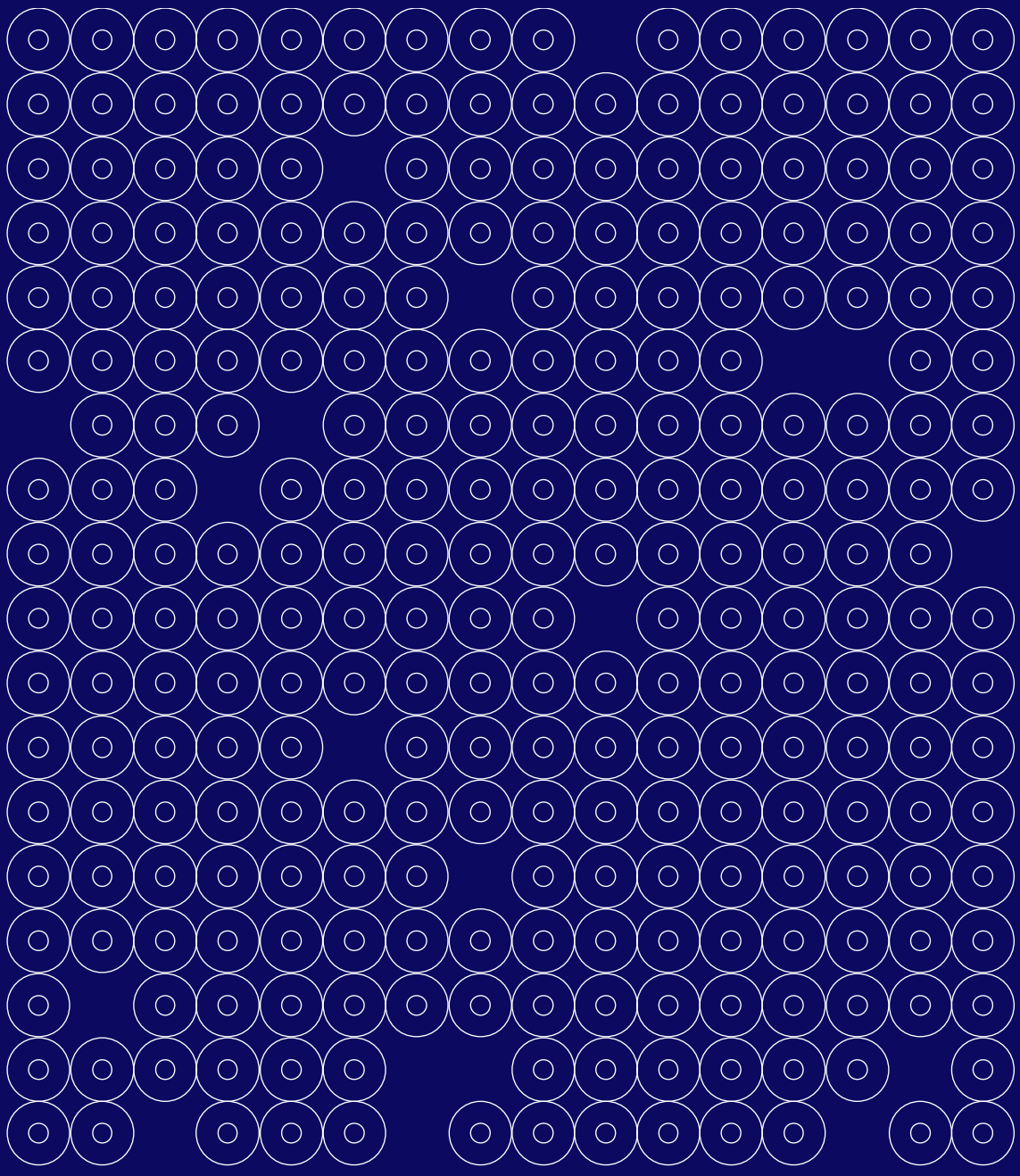
Vaccination as a strategy to combat antimicrobial resistance

Live webinar 17 June 2022

CSA DESIGN OH AMR



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Background and Objectives

Summary

The following report provides an overview of the consultation regarding the role of vaccination as a tool to tackle the growing problem of antimicrobial resistance, organised by the Coordination and Support Action (CSA) DESIGN One Health AntiMicrobial Resistance (DESIGN OH AMR). The consultation was carried out by JPIAMR together with UK Medical Research Council (MRC) and the BactiVac Network.

Within this consultation, the following activities were carried out:

- Bibliographic analysis to inform development of the webinar.
- Live webinar on the 17th of June 2022 to discuss the potential for human vaccination as a tool to tackle antimicrobial resistance. Due to time constraints, this webinar focussed on human health aspects of vaccination.
- Brief stakeholder consultation.

Scientific rationale

Multiple factors contribute to the development and persistence of antimicrobial resistance (AMR). Among these, overprescribing, environmental use and over the counter availability of antimicrobials are among the main drivers of the development of AMR. The rise in resistant infections is often associated with hospital acquired infections, such as ventilator acquired pneumonia and surgical site infections, however, a growing number of resistant pathogens have been shown to be initially prevalent in the community, suggesting that a community wide approach, such as preventative vaccination, could help to curb transmission of these pathogens.[1]

In the field of bacterial resistance, there is a significant association between the level of consumption of specific antibiotics, unregulated use of these drugs and incidence of resistance.[2] [3] Under National Action Plans, several policy recommendations around stewardship for antimicrobials have already been made and implemented.[4] Vaccines can prevent and reduce the level of resistant infections, by reducing the number of pathogens and by preventing their transmission. This impacts both hospital environments and the community, leading to health and economic benefits and could potentially lead to a decrease in the emergence of resistance.[5] [6]

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[1] Prosperi M, Veras N, Azarian T, et al. Molecular epidemiology of community-associated methicillin-resistant Staphylococcus aureus in the genomic era: a cross-sectional study. Sci Rep. 2013;3:1902. doi:10.1038/srep01902

[2] Pouwels KB, Butler CC, Robotham JV. Comment on 'The distribution of antibiotic use and its association with antibiotic resistance' Elife. 2019;8:e46561

[3] Ayukekbong, J. A., Ntemgwa, M. & Atabe, A. N. The threat of antimicrobial resistance in developing countries: causes and control strategies. Antimicrob. Resist. Infect. Control. 6, 47 (2017).

[4] Organization for Economic Cooperation and Development. Stemming the Superbug Tide OECD Publishing; 2018. Available from: https://www.oecd-ilibrary.org/social-issues-migration-health/stemming-the-superbug-tide_9789264307599-en.

[5] Mishra, R. P., Oviedo-Orta, E., Prachi, P., Rappuoli, R. & Bagnoli, F. Vaccines and antibiotic resistance. Curr. Opin. Microbiol. 15, 596–602 (2012).

[6] Micoli, F., Bagnoli, F., Rappuoli, R. et al. The role of vaccines in combatting antimicrobial resistance. Nat Rev Microbiol 19, 287–302 (2021). https://doi.org/10.1038/s41579-020-00506-3

Vaccination programs are also known to be effective to promote the prudent use of antibiotics.[7] Vaccination programs may also reduce the need for antibiotic prescriptions and indirectly affect the development of new resistant strains by reducing selective pressure.[8]

Limitations to vaccination include coverage and efficacy: vaccinations often only exist for a limited number of infections and for a limited number of serotypes within a single species of pathogen.

Strategic rationale

Recent studies suggest that bacterial antimicrobial resistant infections alone were wholly responsible for 1.27 million deaths in 2019.[9] The issue of drug resistance in bacteria, fungi, viruses, and parasites is pressing, and drug design alone will not solve the problem; other approaches including behavioural change, stewardship and vaccination programmes are required.

To date, JPIAMR has not run a consultation focussed on the vaccination as a tool to curb AMR. This is a timely topic as society is aware of the impacts of vaccination on transmission following the COVID-19 pandemic. In order to prepare the SRIA of the One-Health AMR Partnership, we must develop an integrated strategy that includes vaccines together with novel therapeutic agents, diagnostic tools, behavioural interventions, and stewardship to combat AMR effectively.

Aims

The aim of the webinar was to identify opportunities and priorities for vaccine research from an immunological perspective to a wider translational context, in the field of antimicrobial resistance (AMR).

Specific aims included:

- To identify ways in which vaccination could be used to curb AMR
- To examine the remaining gaps in the vaccines for AMR research portfolio and discuss how to tackle these
- To break down silos between researchers, policymakers, and industry
- To involve a wider range of stakeholders and policymakers in identifying gaps in our knowledge, in particular bringing together the animal and human health perspectives
- To better understand current attitudes to vaccination programmes, following the COVID-19 pandemic

To scope gaps and priorities for the Strategic Research and Innovations Agenda of the candidate One-Health AMR Partnership.

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[7] Lipsitch, M. & Siber, G. R. How can vaccines contribute to solving the antimicrobial resistance problem? mBio 7, e00428-16 (2016).
[8] John, T. J., Cherian, T. & Raghupathy, P. Haemophilus influenzae disease in children in India: a hospital perspective. Pediatr. Infect. Dis. J. 17, S169–S171 (1998).
[9] Antimicrobial Resistance Collaborators. "Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis." Lancet (London, England), S0140-6736(21)02724-0. 18 Jan. 2022, doi:10.1016/S0140-6736(21)02724-0

Webinar Attendees

A total of 241 people registered for the webinar, from as far afield as South Korea, North America, and Australia. Of these, 133 joined the meeting on the day, with a similar global distribution (see Figure 1). Following the event, a recording of the talks was made available on YouTube. The recording achieved 126 views in 2 weeks.

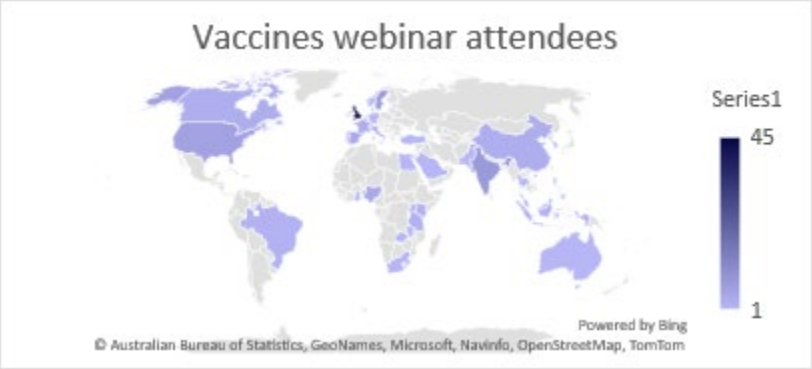

Figure 1. Global distribution of webinar attendees.

Webinar registrants came from a wide range of professional background, and while a university/academic background was one of the most represented areas, industry, SMEs, and those with clinical background were also well represented.

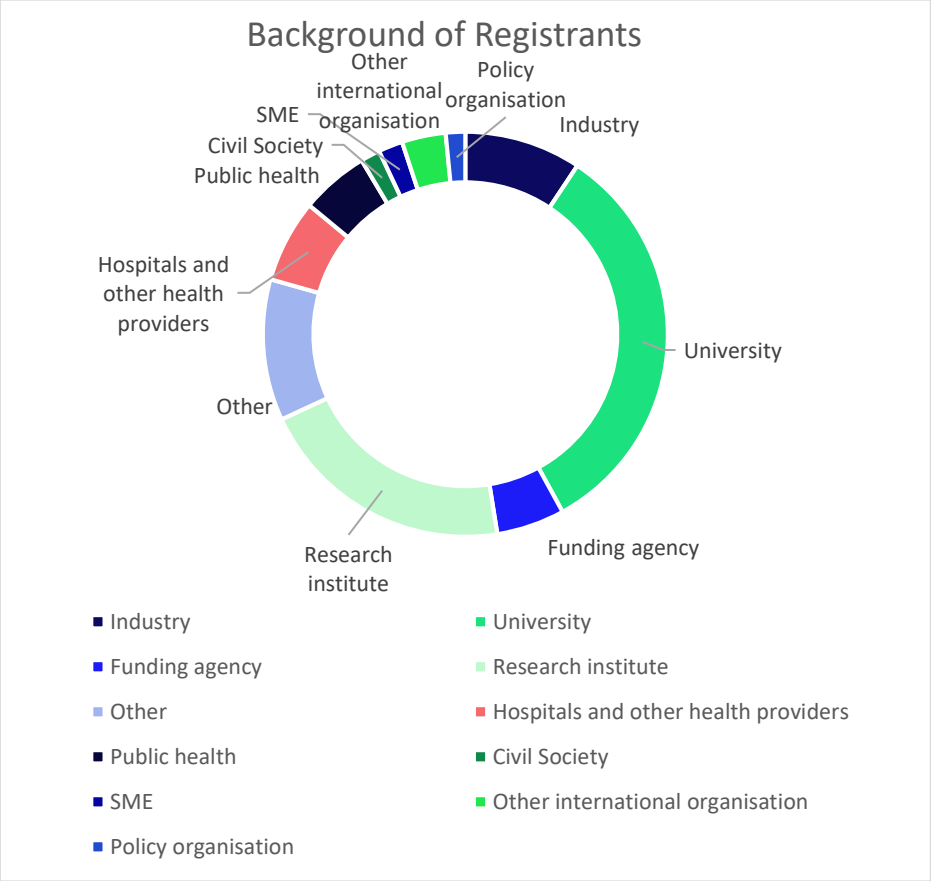

Figure 2. Background of webinar registrants.

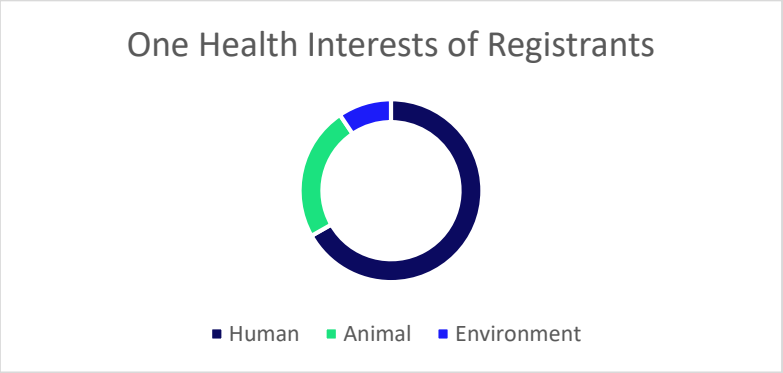

Figure 3. One Health interests of registrants.

As a part of the registration process, potential participants were asked to specify the area(s) of One Health that most interested them. Despite the overall focus on human health, registrants came from three main one health sectors: human, animal and environment (see Figure 3).

Stakeholder Consultation

As a part of the registration process, potential attendees were also asked to define where they felt the most important gaps in research for antimicrobial resistance research were.

The most common theme among answers was vaccines or vaccination (67/241), in particular the development of novel vaccines, themes that were reiterated in the webinar session (for more comments from registrants, see Box 1).

Box 1: Common themes regarding Vaccination to tackle AMR

- Investing in young researchers to add more vaccines development platforms to our toolbox
- Gaps in identifying vaccine targets for bacterial diseases
- Opportunities in exploring novel vaccine platforms
- Vaccine development for humans and animals, with a focus on neglected bacterial diseases
- Need to understand the mechanisms of immune protection and pathogen biology. An opportunity - develop new adjuvants. to increase vaccine efficacy
- Vaccine impact on antibiotic use and AMR development needs to be evaluated in a more systematic way

Additional comments focussed on improving accessibility, stewardship, diagnosis and testing, increasing surveillance, further developing our understanding of drivers, transmission of resistance and developing new drugs, including monoclonal antibody therapeutics and potentially repurposing existing drugs.

Steering Group, Chair, Panellists and Speakers

Professor Calman A. MacLennan
Senior Program Officer, Bacterial Vaccines, Global Health - Enteric & Diarrheal Diseases, Bill & Melinda Gates Foundation, USA

Senior Clinical Fellow, Jenner Institute, University of Oxford, UK

Director, BactiVac, the Bacterial Vaccines Network & Professor of Vaccine Immunology, University of Birmingham, UK

Professor MacLennan is the Senior Program Officer for Bacterial Vaccines in the Enteric and Diarrheal Diseases team at the Bill and Melinda Gates Foundation, responsible for *Shigella* and *Salmonella* vaccine product development. Following his medical degree and DPhil from Oxford, and during specialist training in clinical immunology, he spent time in Kenya and Malawi investigating immunity to invasive *Salmonella* disease. From 2010, he was Head of the Exploratory Programme at the Novartis Vaccines Institute for Global Health, Italy, developing vaccines against *Salmonella*, *Shigella* and meningococcus. He returned to Oxford, in 2015 to the Jenner Institute, before moving to the Gates Foundation in 2017. His work at the Jenner Institute focuses on gonorrhoea vaccine development. Professor MacLennan is an honorary consultant immunologist, Professor of Vaccine Immunology and Director of the MRC/GCRF BactiVac Bacterial Vaccinology Network.

Professor Adam Cunningham
Co-director of BactiVac, the Bacterial Vaccines Network &
Professor of Functional Immunity, University of Birmingham, UK

Professor Cunningham gained his PhD from Southampton University for studies on antibody responses to Chlamydia pneumoniae. After a short-term position in The Gambia, funded by the WHO, he had his first post-doctoral position in Birmingham studying the cell wall of Mycobacterium tuberculosis. From here, he started work in Prof Ian MacLennan's group examining how antibody responses develop and are regulated. During this time, he incorporated the use of Salmonella and its component antigens into this work, leading to an independent position as a RCUK Roberts Academic Fellow, studying how immune responses develop to pathogens and vaccines. He was made Professor of Functional Immunity in August 2011 and his research is focused on how adaptive immunity to pathogens and their component antigens are induced, maintained and function. These studies help us understand why some responses are protective, whilst others are not or can even be harmful.

Professor Kathleen Neuzil
Myron M. Levine Professor in Vaccinology, University of Maryland School of Medicine, Maryland, US

Professor Neuzil directs the Center for Vaccine Development and Global Health at the University of Maryland School of Medicine. An internationally recognized vaccinologist, her work has spanned dozens of low-resource countries with multiple vaccines, including influenza, rotavirus, human papillomavirus, Japanese encephalitis, typhoid conjugate, and COVID-19 vaccines. Dr Neuzil directs TyVAC, the Typhoid Vaccine Acceleration Consortium, with the goal to accelerate the introduction of typhoid conjugate vaccines into low-resource countries. She is a member of the World Health Organization Strategic Advisory Group of Experts on Immunization, and the National Academy of Medicine.

Dr Annaliesa Anderson PhD, FAAM
Senior Vice President and the Chief Scientific Officer for both the Bacterial Vaccines, Pfizer, US

Dr Anderson has over 30 years of pharmaceutical research experience and is currently a Senior Vice President and the Chief Scientific Officer for both the Bacterial Vaccines and Hospital. Her responsibilities include infectious disease vaccine research and development as well as the development and implementation of Pfizer's anti-infective portfolio strategy. Dr Anderson's experience includes leadership roles for bacterial vaccine programs directed at the prevention of diseases due to *Streptococcus pneumoniae*, *Neisseria meningitidis, Staphylococcus aureus*, *Closteroides difficile,* Lyme disease, *Escherichia coli* and Group B Streptococcus and the development of PAXLOVID® the first authorized oral COVID-19 antiviral treatment.

Professor Gordon Dougan F Med Sci FRS
Professor in the Department of Medicine at Cambridge University and Director of the Infection Health Challenge area at Wellcome, UK

Professor Dougan is an internationally recognised expert in vaccinology, global health, and infections. He was Head of Pathogens at The Wellcome Sanger Institute (WTSI) and worked in the pharmaceutical industry. He studies the molecular basis of infection with a strong emphasis on pathogenic mechanisms/immunity, genomics, disease tracking and antibiotic resistance.

Before moving to the WTSI he was the founding Director of the Centre for Molecular Microbiology and Infection at Imperial College London and a Professor of Biochemistry. He is a member of EMBO, a Fellow of the Academy of Medical Sciences and a Fellow of the Royal Society. He has received awards nationally and internationally for his work, including the Albert B Sabin Gold Medal for his work on Affordable Vaccines. He received his B Sc and Ph.D. from the University of Sussex and conducted postdoctoral studies at the University of Washington (Seattle) in the

laboratory of the Lasker Prize winner Stanley Falkow. During his work in industry developing novel vaccines at an internationally renowned multi-national company now part of GSK and is a founder of VHSquared and Microbiotica.

Professor William Hausdorff
Lead, Vaccines Public Health Value Proposition, PATH's Center for Vaccine Innovation and Access, Washington D.C., US

Professor Hausdorff has worked on the design, development, clinical evaluation, registration, and post-marketing assessment of vaccines against major infectious diseases. Originally trained as a biochemist at the Johns Hopkins University and the US NIH, he worked with the US CDC on USAID's Children's Vaccine Initiative project, followed by two decades at Wyeth Vaccines and GSK Vaccines in the Scientific Affairs & Research Strategy and Epidemiology groups, and as a Vaccine Development Leader. He is recognized for helping articulate the epidemiological rationale for pneumococcal conjugate vaccines and catalyze their development at each company. He currently works with PATH, the international health NGO.

Dr Padmini Srikantiah, MD MPH
Deputy Director Global Health, Bill & Melinda Gates Foundation, US

Dr Srikantiah is a Deputy Director in Global Health at the Bill & Melinda Gates Foundation. Dr Srikantiah serves as the lead for the foundation's cross-cutting Antimicrobial Resistance (AMR) strategy, which is focused on preventing mortality due to high AMR risk pathogens in low and middle-income country populations, including efforts to prevent neonatal sepsis by developing a vaccine against *Klebsiella pneumoniae.* Padmini also leads the foundation's initiative to address respiratory syncytial virus, the leading cause of pneumonia in young infants globally, through the development of effective maternal and infant immunization strategies. Prior to joining the foundation, Padmini was with the U.S. Centers for Disease Control and Prevention as a Senior Medical Epidemiologist, where she led CDC's AMR platform in India, which encompassed efforts to strengthen AMR surveillance and reduce healthcare associated infections. She also led CDC-India's infectious disease surveillance activities. Padmini has previously served as medical officer for HIV treatment in the WHO South East Asia Regional Office where she led the HIV Drug Resistance Surveillance and Prevention program and provided extensive technical assistance on antiretroviral therapy scale-up and evaluation. Padmini is board certified in infectious diseases and served in the CDC's Epidemic Intelligence Service.

Professor Birgitta Henriques Normark
Professor of Medical Microbial Pathogenesis Department of Microbiology, Tumor and Cell Biology, Karolinska Intitutet, SE

Professor Henriques-Normark is professor and senior consultant physician in clinical microbiology at Karolinska Institutet and

Karolinska University Hospital. Her research focuses on respiratory tract infections with a focus on pneumococcal diseases. The approach is translational going from basic mechanisms of pathogenesis to epidemiological and clinical studies. New antimicrobial therapies and novel vaccine candidates are being identified. She has had several leadership appointments at the Swedish Institute for Infectious Disease Control and at Karolinska Institutet such as vice dean for recruitments and as academic vice president for research. She has previously been a member of the scientific board of JPIAMR.

Dr Isabel Frost
Consultant, Immunization, Vaccines and Biologicals, World Health Organization Headquarters, Geneva, CH

Dr Frost is a consultant for the Immunization, Vaccines and Biologicals Department of the World Health Organization. Her work focuses on understanding how we can best use vaccines to combat antimicrobial resistance (AMR). Prior to this she was a research fellow working on multiple projects relating to AMR, at the Center for Disease Dynamics, Economics & Policy, based in Delhi, India. She also had Honorary Research Fellow appointments at both Imperial College, London and Amity University, Delhi. Isabel completed her doctorate at the University of Oxford on the evolution of antibiotic resistance in bacterial colonies.

BactiVac, the Bacterial Vaccines Network

The BactiVac Network was established in August 2017, bringing together academic, industrial and other partners involved in vaccine research against human and animal bacterial infections from the UK and LMICs.

The BactiVac Network fosters partnership, disseminates relevant information and provides catalyst project and training support with the aim of accelerating vaccine development for bacterial infections relevant to LMICs. The BactiVac Network delivers this through catalyst project and training awards to encourage cross-collaboration between academic and industrial partners in developed and developing nations.

The Network is directed by Professor Cal MacLennan and Professor Adam Cunningham and is hosted at the University of Birmingham.

The BactiVac Network is supported by the GCRF Networks in Vaccines Research and Development, which is co-funded by the Medical Research Council (MRC) and the Biotechnology and Biological Sciences Research Council (BBSRC).

Webinar Discussions and Outcomes

The growing threat of drug resistance in bacteria, fungi, viruses, and parasites is known,[10] and development of effective vaccines against pathogens with the potential to develop drug resistance is a critical step in prevention of disease development and transmission of resistance, both in the hospital setting and the wider community. Development of vaccines can impact drug resistance both through reducing infection (a direct impact) but also through prevention of empiric treatment decisions and inappropriate use of drugs.[11]

During the webinar, Professor Kathleen Neuzil discussed complementary approaches to tackle AMR and the role of vaccines in that context. Prof Neuzil focussed on two themes: vaccines to target common infections for which antibiotics are commonly used, and vaccines for pathogens that often develop resistance to drugs. Professor Neuzil pointed out that deaths due to resistant infections are highest in LMICs, in particular sub-Saharan Africa, and commented that both inappropriate use of antibiotics and lack of access to antibiotics are important public health problems and that lack of access or delayed access to treatment is an important contributing factor to high mortality due to resistant infections in LMICs. Following a discussion of the Typhoid Vaccine initiative, Professor Neuzil noted that vaccines reduce both morbidity and mortality and complement other approaches, such as improved hygiene and stewardship. Professor Neuzil concluded that in order to ensure the benefit of vaccination, efforts must be made to ensure optimal use of existing vaccines and increase investment in the development of new vaccines.

Professor Adam Cunningham discussed the immune response to vaccination, and the importance of understanding this when developing effective vaccines. Professor Cunningham pointed out that vaccines are active at the time of pathogen encounter, whilst antibiotics and other drugs are usually used later in the course of infection, leading to the possibility of onward transmission and development of drug resistance. Professor Cunningham discussed the sustained level of protection against infection offered by vaccines in comparison to the broader, more short-term protection from antibiotic therapy. Professor Cunningham underlined the importance of understanding the mechanism of action of vaccines and correlates of protection. Professor Cunningham also discussed the formulation of vaccines (and adjuvants) and how to make vaccines work in different at-risk groups.

Dr Annaliesa Anderson discussed the development of vaccines that contribute to AMR reduction- in particular the pneumococcal vaccine. Dr Anderson noted that vaccination has a direct impact on antibiotic prescriptions, illness and spread to vulnerable populations. The talk provided an overview of vaccines available and in the pipeline including RSV, *E. coli*, meningococcal and pneumococcal vaccines, as well as for Lyme disease, Group B streptococcus and a discussion of the development process for a *C. difficile* vaccine. Dr Anderson concluded by emphasising the urgent global health

[10] O'Neill, J. Tackling drug-resistant infections globally: final report and recommendations. https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf

[11] Klugman KP, Black S. Impact of existing vaccines in reducing antibiotic resistance: Primary and secondary effects. Proc Natl Acad Sci U S A. 2018 Dec 18;115(51):12896-12901. doi: 10.1073/pnas.1721095115. PMID: 30559195; PMCID: PMC6304973.

problem posed by drug resistant pathogens and the potential of vaccination as a strategy to combat this issue. Dr Anderson also underlined the fact that many vaccines that have potential to tackle AMR are under development, and include both viral and bacterial targets. Finally, Dr Anderson noted the importance of both national and international cooperation to maximise the utilization of existing, licensed vaccines.

Professor Gordon Dougan pointed out the inequitable access to vaccines, which really became evident during the COVID-19 pandemic. Many vaccines that target bacterial and viral pathogens have anti-AMR potential, but more work needs to be done to properly understand the impact of vaccination on AMR transmission. Professor Dougan discussed initiatives put in place to improve access to vaccines, from GAVI, through the Gates Foundation, the Wellcome Hilleman Labs and CEPI. Professor Dougan discussed the negative impact of a failure to ensure that all communities have access to vaccines, noting the challenge posed by typhoid, rotavirus and pneumococcal vaccines. Professor Dougan noted that as economies mature, they lose GAVI coverage – the largest gap in access to vaccine development is in Africa. Professor Dougan commented that the diseases with the highest burden in LMICs are those of least interest to developers. Professor Dougan concluded by underlining the importance of influencing policy and ensuring vaccines can be developed at a reasonable cost and the importance of sharing know-how, as evidenced by the Wellcome Hilleman Lab.

The webinar concluded with a lively panel discussion, involving Dr Padmini Srikantiah, Professor Bill Hausdorff, Professor Birgitta Henriques Normark, Dr Isabel Frost and webinar speakers. The panel tackled some of the remaining questions, including discussion of the funding priorities in relation to vaccination for drug resistant pathogens. The panel raised some important points, including:

- What is the synergism between vaccines and other antimicrobial interventions?
- How do we overcome vaccine hesitancy?
- Even in the antimicrobial space, vaccines are often not recognized as being important.
- A holistic view of vaccination in the broader context of disease and other interventions is required.
- Effective communication on the value of vaccination is necessary.
- Separation of evaluation of existing vaccines, vaccines in development and the really challenging pathogens that are difficult to target (WHO Framework for Vaccines) can help to prioritize future actions.
- Improving global coverage of vaccines, in particular in LMICs, is essential.
- Measuring the impact of vaccines on AMR and antimicrobial use can help to guide future actions.
- It is necessary to target both less common but highly resistant infections and less resistant common infections.
- Consideration of the method of administration of vaccines is required to improve uptake, in particular oral formulation, low-cost vaccines or locally applied vaccines.
- Inclusion of vaccination in National Action Plans to tackle AMR should be considered.
- AMR champions, with an understanding of the importance of vaccination are required at the national level.

- There is a need to move from data generation to action and policy in this area.
- There are funding gaps in R&D of new vaccines to target potentially resistant pathogens, in particular for fungal pathogens.

In conclusion, the panel noted that we should consider vaccines as a central pillar in our efforts to tackle AMR.

Links and abbreviations

Relevant Links

The BactiVac Network: https://birmingham.ac.uk/bactivac

Centers for Disease Control: https://www.cdc.gov/drugresistance/index.html

CEPI: https://cepi.net/about/whyweexist/

Gates Foundation: https://www.gatesfoundation.org/

GAVI: https://www.gavi.org/

Hilleman Labs: https://hilleman-labs.org/

Joint programming initiative on Antimicrobial Resistance: https://www.jpiamr.eu/

UK Medical Research Council: https://www.ukri.org/councils/mrc/

Wellcome Trust: https://wellcome.org/

World Health Organisation: https://www.who.int/health-topics/antimicrobial-resistance

Abbreviations Used

AMR Antimicrobial Resistance

CDC: Centers for Disease Control

CEPI: Coalition for Epidemic Preparedness Innovation

EMBO: European Molecular Biology Organization

GAVI: Global Alliance for Vaccines and Immunisation

HIV: Human Immunodeficiency Virus

JPIAMR: Joint programming initiative on Antimicrobial Resistance

LMIC: Lower- and Middle-income Countries

SME: Small and Medium Enterprises

TyVAC: Typhoid Vaccine Acceleration Consortium

WTSI: The Wellcome Sanger Institute

WHO: World Health Organisation

Annex I. Webinar Agenda

Agenda: JPIAMR-BactiVac Network Webinar
Vaccination as a strategy to combat Antimicrobial Resistance

Date: 17th June 2022 12:00 BST-14:00 BST
Location: Online - Zoom

Purpose: To identify key priorities, challenges, and opportunities for research in order to define priorities for funding bodies.

To achieve this the webinar aims are:

- To identify our existing knowledge regarding vaccines for AMR
- To identify areas of further research required
- To consider the policy implications of vaccination for AMR
- To identify future funding priorities for AMR related vaccine research

Webinar Start: 12:00 BST

12:00 Welcome and introduction (5 minutes)
JPIAMR and Professor Calman MacLennan (BactiVac Network Director, UK)

12:05 Keynote: Vaccination to combat AMR (15 mins talk)
Speaker: *Professor Kathleen Neuzil (University of Maryland, USA)*

12:20 Presentation: Immune response to vaccination (20 mins talk + 5 mins questions)
Speaker: *Professor Adam Cunningham (BactiVac Network Co-Director, UK)*

12:45 Presentation: Vaccine R+D (20 mins talk +5 mins questions)
Speaker: *Dr Annaliesa Anderson (Pfizer, USA)*

13:10 Presentation: Equitable access to vaccines (20 mins talk + 5 mins questions)
Speaker: *Professor Gordon Dougan (Wellcome Trust, UK)*

13:35 Panel Discussion: Future funding priorities (20 mins)
Panellists: *Dr Isabel Frost (WHO, CH)*
Professor Bill Hausdorff (PATH, USA)
Dr Padmini Srikantiah (Gates Foundation, USA)
Professor Birgitta Henriques Normark (Karolinska Institutet, SE)

13:55 Closing remarks (5 mins)
Speaker: *Professor Calman MacLennan (BactiVac Network Director, UK)*

Webinar Close 14:00 BST