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Commentary

Antimicrobial coating innovations to prevent infectious disease: a consensus view from the AMiCI COST Action

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The European Cooperation in Science and Technology (COST) is the longest-running European framework supporting transnational co-operation among researchers, engineers, scholars and industry across Europe. These networks, called 'COST Actions', promote international coordination of nationally funded research (https://www.cost.eu). This COST Action 'AMiCI – Anti-Microbial Coating Innovations to prevent infectious diseases' (http://www.amici-consortium.eu) aimed to evaluate the impact of antimicrobial coatings (AMCs), specifically for surfaces in healthcare, but excluding AMCs used in medical implants.

In 2016, when AMiCI was established, there was clear evidence that antimicrobial drug resistance (AMR), including multi-drug-resistant organism outbreaks [1], had emerged as global health risks. While effective hand hygiene combined with efficient cleaning and prudent stewardship of antimicrobial products were being promoted as necessary for management and potential mitigation of such risk, there was increasing recognition of the possibilities that antimicrobial coatings (AMCs) presented [2,3].

AMCs and some associated technologies were not necessarily new. For instance, antimicrobial properties of copper and silver ions were well-known at the time of AMiCI launch, and

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had been utilized extensively in a variety of settings including, e.g., biofilm retardation in the marine industry, in textiles and medical devices. Both then (and now), real-world studies were scarce, although researchers were developing promising results in the reduction of healthcare-acquired infections (HCAIs) [4–7].

However, the AMiCI COST Action represented a cohesive gathering of expertise from across Europe (33 countries in total including the USA) that allowed a holistic perspective across the spectrum of activities associated with AMC innovation leading, hopefully, to new effective products suitable for implementation in healthcare environments for the benefit of staff and patients, and indeed industry. In particular, this large COST Action involved more than 300 experts from 80 partner organizations across academic, clinical, regulatory, active ingredient and coating manufacturing and hygiene sectors.

However, in the four years in which the AMiCI COST Action has been pursued, the AMR and outbreak risk has not diminished. In fact, potential risk to global public health due to microorganisms has become even more high profile, with consistent statements by credible, qualified experts regarding the need for new antibiotics and careful management of existing antimicrobials. Indeed, in the context of the current COVID-19 pandemic, and lack of therapies specific for the causative agent, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), antimicrobial coatings in healthcare settings could potentially lower the risk of transmission inside healthcare settings and protect both healthcare personnel and patients. Studies with SARS-CoV-2 and the closely related human coronavirus 229E have shown survival for four to five days on various surface materials including stainless steel, glass, plastics and ceramics but demonstrate rapid inactivation on copper alloys [8,9].

Despite this evident need, AMC technologies and products have not accelerated at a rate that might have been anticipated. Indeed, the current 2019/2020 WHO guidance regarding management of HCAIs does not refer to AMCs at all [10]. The reasons are evident and have, to a considerable extent, been highlighted in the AMiCI Consortium outputs [3,11–14]. While there are thousands of patents and associated inventions relating to AMCs, the majority relate to settings divorced from healthcare. Such settings require less stringent development, regulation and testing. Furthermore, the potential impact for failure of their antimicrobial properties are less catastrophic.

In its outputs, AMiCI has outlined clearly the state-of-the-art regarding AMC technology, manufacturing challenges and limitations, the chemistry and biological activity mediating their effects, how they may be incorporated into real-world clinical settings and tested, their incremental benefits, their potential environmental impact, their potential for promotion of antimicrobial resistance, and even how they may be evaluated economically.

However, it is readily apparent that a gap exists between innovation and availability of AMCs in the market. Within the EU, REACH [15] and the Biocidal Products Regulation [16] impose safeguards for public, environmental and agricultural safety that are necessary but none the less represent considerable compliance challenges for commercial product development and launch. Similar regulatory constraints are present elsewhere in the world.

The potential of AMCs for healthcare settings use is, in fact, hindered most by a credibility threshold. While, AMiCI represented a network of experts covering a wide scope of AMC development, from invention to clinical use, it has done so arguably preceding availability of necessary proof of AMC efficacy. Some of the most pertinent outcomes from this Consortium include recognition that:

- For hygiene professionals, AMCs are undefined, mysterious, and incomprehensible. And for their employees, the cleaners, they are entirely ignorable.
- For healthcare managers, the cost/benefit ratios are all-consuming and there is a paucity of evidence regarding AMC benefits. Do AMCs cost more (they are unlikely to cost less)? Are AMC effects durable and do they persist? Are there training implications for hospital staff? Does cleaning have an effect on the AMCs? Does the presence of an AMC have an effect on the effectiveness of cleaning solutions? What environmental monitoring is needed? Do AMCs work? Do AMCs prevent infections? Is the cost of their use less than the cost of treatment? Do AMCs contribute to AMR?
- For industry, the cost of bringing an AMC successfully to market successfully is significant. To fail to reach the market, or simply to not be successful in the market, can result in commercial disaster.
- For regulators, credible blinded, controlled proof of use *in situ* is scarce, and the impact (positive and negative) on AMR remains undefined. In addition, the data generated to date are not convincing; indeed many claims made currently can not be substantiated.

Outbreaks of bacterial, fungal or viral pathogens, increasing AMR and HCAIs are real and imminent threats to public health. Therefore, if technologies such as AMCs are to benefit public health, it will be necessary to provide testing capabilities (i.e. so-called 'test beds') for proof of concept clinical studies using protocols that reflect safe end-use, with regulatory guidance and are accessible to academic, clinical and commercial stakeholders who are invested in bringing AMC products to market widely. To fail to provide these will hinder availability of AMCs for use in healthcare and public places. However, to some degree, this need will now be met through 2020 CIG-15114: "ePlatform for a 'test bed' tool across the EU for antimicrobial coating solutions in health care entering to the market". The AMiCI network will also continue to expand, including further expertise and differing perspectives across life sciences, clinical application and systems thinking.

Conflict of interest statement

The authors declare no conflict of interest.

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