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Carbon-based Antimicrobial Nanoweapons to Fight COVID-19

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In a recent review article published in the journal ACS Nano, interdisciplinary researchers from across the world evaluated the role of carbon-based nanomaterials (CBNs), such as fullerene, carbon dots, graphene, and their derivatives as promising alternatives to combat COVID-19 (coronavirus disease 2019) and other microbial infections. Due to the mainly physical mode of action of CBNs, there is a low risk of antimicrobial resistance and a wide spectrum of antimicrobial activity.

In this review, the researchers presented CBNs with antiviral activity against 13 enveloped positive-sense single-stranded RNA viruses, including severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the etiological agent of COVID-19.

CBNs show low or no toxicity to humans and are therefore promising therapeutics against the COVID-19 pneumonia complex and other viruses, bacteria, and fungi, including those that are multidrug-resistant, the researchers highlight.

"Alternative materials such as CBNs with intrinsic broad-spectrum antimicrobial activity represent a promising option that would probably overcome the microbial resistance problem due to their differential antimicrobial mechanisms."

The recent pandemic outbreak of SARS-CoV-2 has caused over 176 million infections and over 3.8 million deaths globally. With no successful therapeutic options, the pandemic continues to cause significant morbidity and mortality. COVID-19 disease is associated with viral pneumonia and acute respiratory distress syndrome (ARDS).

While the researchers noted the infliction of the virus by causing moderate and severe COVID-19, they also highlighted the rapid spread and coexistence of SARS-CoV-2 with a broad range of other types of clinically relevant microorganisms, including those which are multidrug-resistant. Pneumonia is rampant with antibiotic resistance.

With antibiotic resistance in bacterial pneumonia treatment, the present scenario constitutes a life-threatening situation to humans. It is reported that CBNs are emerging as promising options that have shown potent antiviral activity against a broad range of enveloped positive-sense single-stranded RNA viruses, including the SARS-CoV-2.

"Also, they exert an effective biocidal action against a broad spectrum of bacteria, viruses, and fungi, including multidrug-resistant strains," the researchers added.

They proposed the CBNs as the next generation of antimicrobials. Although other nanomaterials such as silver, copper, titanium, or zinc nanoparticles show potent broad-spectrum antimicrobial properties, there exists microbial resistance to these nanomaterials and high toxicity to the mammalian cells.

CBNs have unique properties: very high surface area, excellent electrical and thermal conductivity, biocompatibility, and also the possibility to be combined with engineered polymers to develop advanced antimicrobial biomaterial composites. These render the CBNs to be potential candidates for long-term therapeutics.

In a schematic, the researchers also presented how the CBNs in combination with MSCs (mesenchymal stem cells) have the potential to target the pathophysiological events (during a SARS-CoV-2 infection), acting as an alternative strategy for treating COVID-19 patients. They proposed the use of CBNs in combination with stem cell therapies for tissue regeneration as well.

The researchers analyzed the antiviral properties of CBNs individually, with each different carbon-based structure, such as fullerene (a zero-dimensional allotrope), carbon dots (or carbon quantum dots), graphene (two-dimensional CBNs), and the derivatives against 13 enveloped positive-sense single-stranded RNA viruses, such as SARS-CoV-2. The researchers have summarized the list of studies in a tabulated form.

While the CBNs are promising nanomaterials as alternative antiviral agents, their mechanism of action is still not understood completely. The researchers discussed the possible mechanism of each CBNs in the review, mentioning the immunostimulatory properties and followed by the toxicological aspects.

"CBNs could work directly against the virus particle by distorting the envelope or the capsid organization; additionally, they may exert a steric hindrance effect by physically occupying a catalytic site of an essential viral enzyme or a receptor cavity," observed the researchers.

In conclusion, the researchers highlighted the promising antiviral activity of CBNs against the 13 enveloped viruses (HCoV, PRRSV, PEDV, HIV-1, HIV-2, FCoV, JEV, SIV, M-MuLV, ZIKV, DENV, HCV, and SARS-CoV-2), all single-stranded positive-sense RNA viruses belonging to the Baltimore group IV. They call these CBNs 'antimicrobial nanoweapons' that can be employed to combat SARS-CoV-2 and other types of viruses, bacteria, or fungi causing pneumonia, emphasizing the multidrug-resistant strains.

"As a revolutionary technology approach to treat COVID-19, these carbon-based therapeutics can provide a significant breakthrough, as these nanomaterials allow the targeting of microbial resistance issues and can potentially induce tissue regeneration at the same time."

Read the original article on News Medical.