Shaping Tomorrow's Nephrology: Insight-Driven Kidney Care
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Carbon Quantum Dot Mediated DNA Scavenging of Cytosolic DNA Suppresses cGAS-STING Signaling in Lupus Nephritis

BAEK GEONWOO[1], Jee-Yeon Ryu[2], Hyun Kim[2], Sehoon Park[2], Dong Ki Kim[2]
[1]Department of Translational Medicine, Seoul National University College of Medicine, Korea, Republic of
[2]Department of Internal Medicine-Nephrology, Seoul National University Hospital, Korea, Republic of

Objectives : Lupus nephritis (LN) is characterized by immune complex deposition in the glomeruli, where pathogenic autoantibodies directly interact with podocytes and induce structural injury. In these damaged podocytes, cytosolic DNA accumulates and aberrantly activates the cGAS–STING pathway, leading to innate immune signaling. To counter this accumulation, positively charged carbon quantum dots (CQDs) were engineered to bind nucleic acids via electrostatic interactions and applied as DNA scavengers. They were designed to reduced cytosolic DNA accumulation and attenuated cGAS–STING activation, suggesting a potential therapeutic strategy in LN.
Methods : Human podocytes were treated with IgG isolated from LN patients. Cytosolic DNA accumulation was evaluated by immunofluorescence and biochemical quantification. Activation of the cGAS–STING pathway was assessed by western blot and qPCR, measuring cGAS, STING, and downstream signaling molecules including TBK1, IRF3, and IFN-β. DNase1 expression was analyzed by western blot and qPCR, and DNA damage was assessed by TUNEL assay. DNA-binding assays were performed to confirm the scavenging capacity of CQD. To evaluate its functional effect under LN conditions, CQD was administered to IgG-treated podocytes, and cytosolic DNA levels and cGAS–STING activation were assessed.
Results : LN-derived IgG treatment significantly increased cytosolic DNA accumulation in human podocytes. Reduced DNase1 expression and increased DNA damage were observed, suggesting impaired cytosolic DNA clearance. Activation of the STING-TBK1-IRF3 axis was detected following immunoglobulin exposure. CQD treatment reduced cytosolic DNA levels and attenuated activation of the cGAS–STING signaling pathway in LN-derived IgG–treated podocytes.
Conclusions : Our study demonstrates that cytosolic DNA accumulation driven by pathogenic immunoglobulin contributes to cGAS–STING activation in LN. Carbon quantum dot–mediated DNA scavenging suppresses innate DNA sensing signaling, suggesting a potential therapeutic strategy for modulating immune activation in LN.

CQD-LN_Figure (2).png

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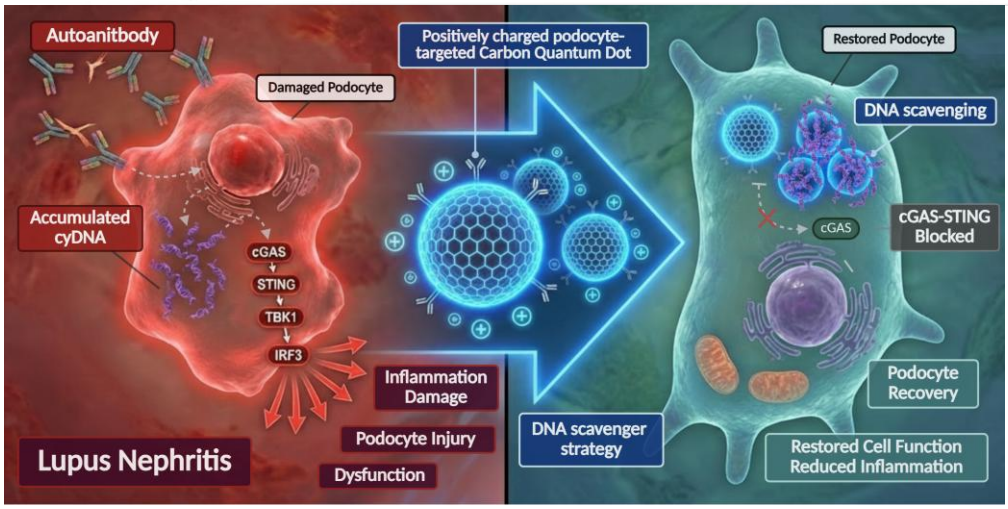
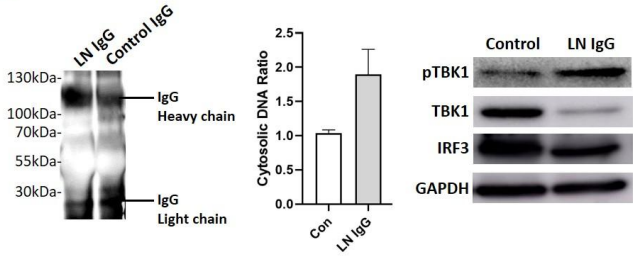


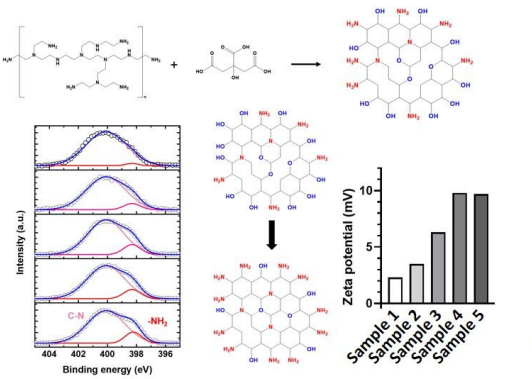
CQD-LN_Figure (2).png

1. LN-derived IgG–induced cGAS–STING activation

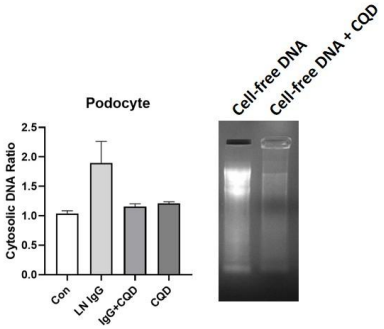


LN-derived IgG induces cytosolic DNA accumulation and activates cGAS–STING signaling in human podocytes.

2. Characterization and DNA-scavenging efficiency of carbon quantum dots (CQDs)



Chemical characterization of amine-functionalized CQDs.



DNA-binding and scavenging capacity of CQDs.