Abstract Type : Oral presentation
Abstract Submission No.: A-0765
Abstract Topic : Basic Research

Graphene Quantum Dots Counteract Peritoneal Fibrosis by Binding Calcium Ions and Preventing Oxidative Stress

Kyu Hong Kim[1], Gaeun Bae[2], Kyung Don Yoo[4], Jae Wook Lee[5], Jong Bo Park[3], Byung Hee Hong[2], Yon Su Kim[6], Seung Hee Yang[7]
[1]Department of Biomedical Sciences, Seoul National University College of Medicine, Korea, Republic of
[2]Department of Chemistry, Seoul National University College of Natural Sciences, Korea, Republic of
[3]Department of R&D Center, Graphene Square Chemical Inc., Korea, Republic of
[4]Department of Internal Medicine-Nephrology, Ulsan University Hospital, Korea, Republic of
[5]Department of Internal Medicine-Nephrology, National Cancer Center, Korea, Republic of
[6]Department of Internal Medicine-Nephrology, Seoul National University Hospital, Korea, Republic of
[7]Department of Kidney Research Institute, Seoul National University Medical Research Center , Korea, Republic of

Objectives : Divalent cations, including Ca^{2+}, play a crucial role in the inflammation and fibrosis of the peritoneal membrane (PM). Accumulating evidence suggests that carbon-based nanomaterials, such as graphene quantum dots (GQDs), exhibit high affinity for calcium ions due to their surface oxygen functional groups and modulate calcium channels. In this study, we investigated the beneficial effects of GQDs in $CaCl_2$-induced oxidative stress in human peritoneal mesothelial cells (HPMCs) and chlorhexidine gluconate (CG)-induced peritoneal fibrosis in a mouse model.
Methods : The interaction between GQDs and Ca^{2+} was evaluated by photoluminescence (PL) using a spectrofluorometer with 365 nm excitation and zeta potential using Zetasizer NanoZS. The therapeutic efficacy of GQDs was evaluated in HPMCs with $CaCl_2$-induced oxidative stress and in a CG-induced peritoneal fibrosis mouse model (CG: 0.1% daily in 15% EtOH; GQDs 20 or 40 mg/kg, every other day) by assessing ROS production, with additional analysis of DEGs and histology in the CG model.
Results : Zeta potential analysis confirmed that the negatively charged surface of GQDs (-37.9±1.8 mV) facilitates their binding with Ca^{2+} and showed high selectivity for Ca^{2+} (-13.4 1.1 mV) over Na^{+} (-27.5 3.1 mV) and K^{+} (-23.8 1.2 mV). This Ca^{2+} binding leads to significant PL quenching of GQDs compared to Na^{+}, K^{+}, Mg^{2+}, also corresponds to their color changes and aggregation behavior. Transcriptomic profiling of GQDs-treated mice identified six downregulated pathways (p-value < 0.05) linked to calcium transport, endothelial apoptosis, and immune cell migration. GQDs reduced fibronectin and collagen deposition, suppressed immune infiltration, and enhanced Sod-2 activity in peritoneal tissue. In vitro, GQDs promoted oxidative degradation, correlating with Sod-2 expression. Notably, GQDs alleviated calcium abnormalities by suppressing L-type calcium channel genes (Cav 1.3 subtype; Cancnb3, Cacna1d, Cacnb1), mitigating calcium-driven fibrosis and oxidative stress.
Conclusions : GQDs inhibit peritoneal fibrosis by binding Ca^{2+}, reducing oxidative stress, and modulating calcium-dependent fibrotic and apoptotic pathways.