Spectroscopic signature of ZnO NP-induced cell death modalities assessed by non-negative PCA

Abstract

Selective cytotoxicity of ZnO nanoparticles among different cell types and cancer and non-cancerous cells has been demonstrated earlier. In the view of anticancer potential of ZnO nanoparticles and their presence in numerous industrial products, it is of great importance to carefully evaluate their effects and mechanisms of action in both cancerous and healthy cells. In this paper, the effects of ZnO nanoparticles on cancerous HeLa and non-cancerous MRC-5 cells are investigated by studying the changes in the vibrational properties of the cells using Raman spectroscopy. Both types of cells were incubated with ZnO nanoparticles of average size 40 nm in the doses from the range 10-40 μg/ml for the period of 48 h, after which Raman spectra were collected. Raman modes' intensity ratios I_{1659}/I_{1444}, I_{2855}/I_{2933} and I_{1337}/I_{1305} were determined as spectral markers of the cytotoxic effect of ZnO in both cell types. Non-negative principal component analysis was used instead of standard one for analysis and detection of spectral features characteristic for nanoparticle-treated cells. The first several non-negative loading vectors obtained in this analysis coincided remarkably well with the Raman spectra of particular biomolecules, showing increase of lipid and decrease of nucleic acids and protein content. Our study pointed out that Raman spectral markers of lipid unsaturation, especially I_{1270}/I_{1300}, are relevant for tracing the cytotoxic effect of ZnO nanoparticles on both cancerous and non-cancerous cells. The change of these spectral markers is correlated to the dose of applied nanoparticles and to the degree of cellular damage. Furthermore, great similarity of spectral features of increasing lipids to spectral features of phosphatidylserine, one of the main apoptotic markers, was recognized in treated cells. Finally, the results strongly indicated that the degree of lipid saturation, presented in the cells, plays an important role in the interaction of cells with nanoparticles.