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Awareness about Nanotoxicology in Medicinal Applications among Dental Students

Research Article

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Abstract

Introduction: Nanotoxicology focuses on determining the adverse effects of nanomaterials on human health and the environment. Nanotoxicology searches for establishing and identifying the harms of engineered nanomaterials and requires a multidisciplinary team approach including toxicology, biology, chemistry, physics, material science, geology, exposure assessment, pharmacokinetics, and medicine.
Aim: This survey was conducted for assessing the nanotoxicology in medicinal applications among dental students.
Materials and Method: A cross-section research was conducted with a self-administered questionnaire containing ten questions distributed amongst 100 dental students. The questionnaire assessed the awareness about nanotoxicology in medicinal applications, pro-inflammatory effects, reactive oxygen species generation, mechanism of action and toxicity effects of nanoparticles and nanotoxicity assessment assays. The responses were recorded and analysed.
Results: 8% of the respondents were aware of the nanotoxicology in medicinal applications, 5 % were aware of pro-inflammatory effects, 5% were aware of reactive oxygen species generation, 3% were aware of mechanism of action and toxicity effects of nanoparticles and, 3% were aware of nanotoxicity assessment assays.
Conclusion: There is limited awareness amongst dental students about nanotoxicology in medicinal applications. Enhanced awareness initiatives and dental educational programmes together with increased importance for curriculum improvements that further promote knowledge and awareness of nanotoxicology in medicinal applications.

Keywords: Awareness; Nanoparticles; Dental; Students; Medicinal; Reactive Oxygen Species; Nanotoxicology.

Introduction

The field of nanotoxicology studies the negative consequences of nanomaterials on human health and the environment. Nanotoxicology entails a multidisciplinary team approach that includes toxicology, biology, chemistry, physics, material science, geology, exposure assessment, pharmacokinetics, and medicine in order to establish and evaluate the risks of manufactured nanomaterials. On the one hand, while it is utilized in the field of biomedicine to diagnose and cure diseases, concerns have begun to grow that it may cause diseases. Exposure period, dose, aggregation and concentration, particle size and shape, surface area, and charge are all important factors in determining the toxicity of nanomaterials. [1].

The size of a nanoparticle can affect its toxicity in a variety of ways [2, 3]. The reduction in size of nanomaterials, for example, results in an increase in particle surface area. As a result of additional molecules binding to the surface area, the harmful effect increases. Particles of varied sizes can accumulate in different parts of the lungs and be removed at different rates [4].

Nanomaterials have a large surface area and a fine surface structure, which aid biological interaction between the microenvironment and the nanomaterial. Nanomaterials have coatings on them and can be positive or negative charged depending on their function. Topographic characterization can be performed using electron and atomic force microscopes, allowing surface chemistry to be assessed. These factors have been shown to influence the toxicity of nanoparticles in studies [5, 6].

Nanomaterials have been shown to have dose-dependent harm-

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ful effects when inhaled, and there have been numerous papers on the subject. According to recent studies, evaluating mass concentration measurements alone for the purpose of toxicological dosing produces erroneous results and does not explain the entire connection between nanoparticles and exposed tissue [7]. Our research experience has prompted us in pursuing this research [8-19]. This survey was conducted for assessing the nanotoxicology in medicinal applications among dental students.

Materials and Methods

A cross-section research was conducted with a self-administered questionnaire containing ten questions distributed amongst 100 dental students. The questionnaire assessed the awareness about nanotoxicology in medicinal applications, pro-inflammatory effects, reactive oxygen species generation, mechanism of action and toxicity effects of nanoparticles and nanotoxicity assessment assays. The responses were recorded and analysed.

Results

8% of the respondents were aware of the nanotoxicology in medicinal applications (Fig 1). 5 % were aware of nanotoxicity induced pro-inflammatory effects (Fig 2), 5% were aware of nanotoxicity induced reactive oxygen species generation (Fig 3), 3% were aware of mechanism of action and toxicity effects of nanoparticles (Fig 4) and, 3% were aware of nanotoxicity assessment assays (Fig 5).

Discussion

Nanoparticles (NPs) are hypothesised to play a role in the development of some diseases by interacting with the lungs and other organ systems through a variety of harmful pathways. Respiratory units can reach distal airways with particles smaller than 0.1 m. [20]. Inhaled NPs reach the respiratory epithelium, where they travel through holes in the alveoli-capillary membrane, first to the interstitium, and subsequently to the systemic circulation via blood and lymphatic circulation. It has been established experimentally in mice that NPs injected into the trachea enter into systemic circulation in this manner [21].

NPs of various characteristics were applied in various ways viz. inhalation, intratracheal, intravenous, intraperitoneal, etc. and in various doses in studies to reveal the possible toxic effects of NPs on human health, and parameters such as transition to systemic circulation in living organisms, accumulation in tissues, inflammation in tissues, other immune responses, and NP excretion were

Figure 1. Awareness of the nanotoxicology in medicinal applications.

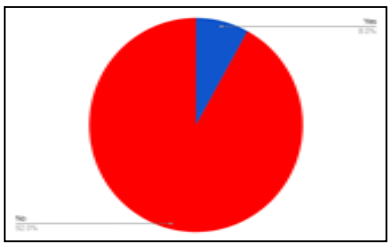


Figure 2. Awareness of the nanotoxicity induced pro-inflammatory effect.

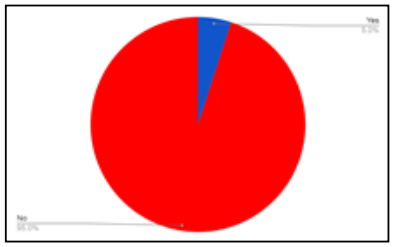


Figure 3. Awareness of the nanotoxicity induced reactive oxygen species generation.

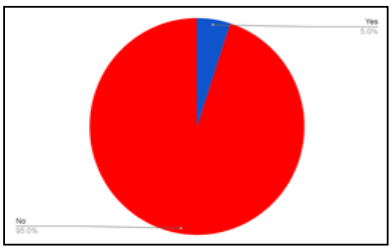


Figure 4. Awareness of the mechanism of action and toxicity effects of nanoparticles.

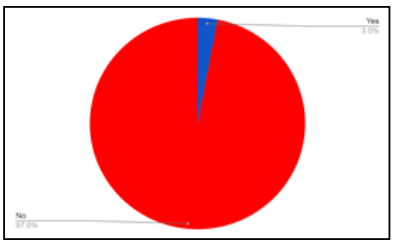
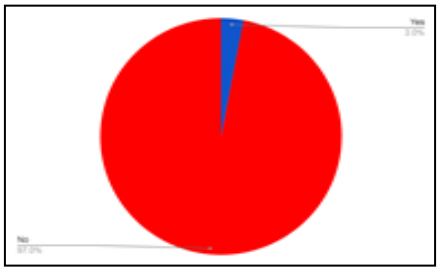


Figure 5. Awareness of the nanotoxicity assessment assays.



monitored [22]. In a mouse model study, the 60-day tissue distribution of magnetoelectric NPs of various sizes administered intravenously was investigated using electron microscopy. All NPs reached peak deposition in the lung in about one week, but large particles of 600nm were eliminated from the lung at a slower rate than small particles [23].

Macrophages destroy nanoparticles with a short size and spiral structure that enter the body. Nanotubes with a high aspect ratio, on the other hand, reach the pleura like asbestos fibres and aggregate around the pores. Because these fibrous particles are not phagocytosed, mesothelial cells release proinflammatory, genotoxic mitogenic mediators. As a result, a process of inflammation and damage begins [24]. This pulmonary inflammation induces pulmonary endothelial dysfunction and stimulation of pulmonary reflexes on the one hand, and activates platelets and enhances thrombotic activity on the other. Inflammation in the vascular system can also produce vascular endothelial dysfunction, which can lead to cardiovascular problems like irregular heartbeat and rhythm, as well as the creation and rupture of atherosclerotic plaques [20].

Nanoparticles cause an inflammatory reaction and boost both natural and acquired immunity. Proinflammatory cytokines, lipid mediators, and free radicals are released when the macrophage/monocyte, neutrophil, dendritic, and natural killer cells responsible for natural immunity and the dendritic cells and lymphocyte responsible for acquired immunity are stimulated, resulting in neutrophilic or eosinophilic lung inflammation. Physicochemical features of NPs, such as size, surface structure, electric charge, and aggregation ratio, may influence their immunomodulatory activities [1].

Toxicity is caused by mechanical impacts caused by nanoparticles' physicochemical characteristics. The generation of reactive oxygen species (ROS), either directly or indirectly, is the primary process of hazardous effect formation. Multiple pathways in the cell make ROS production hazardous in vitro [13]. The reduction of molecular oxygen to water results in ATP generation in mitochondria. Superoxide anions and radicals carrying different oxygen are produced during this process. The hydroxyl radical, single oxygen, hydrogen peroxide, and superoxide anion radicals are among the ROS produced [25]. Overproduction of these radicals, which play a role in mitogenic response and cellular signaling and leads to disruption of physiological functions in cells [26]. Nanomaterials can induce cytotoxic and genotoxic damage to cells. Because of their small size and high surface reactivity, nanomaterials produce more ROS than larger materials [27].

Different types of nanomaterials generate toxicity via activating ROS, according to research in living tissues such as human erythrocytes and skin fibroblasts. Nano-Ag produces oxidative stress and genotoxicity in cultured live tissue, according to Kim *et al.,* [28] Hsin *et al.,* reported that nano-Ag caused cytotoxicity by activating ROS in the mitochondrial pathway [29]. According to Akhtar et al., silica nanoparticles cause cytotoxicity in cell membranes and in mouse embryonic fibroblasts by producing reactive oxygen species (ROS) and lipid peroxidation of nano-CuO [30]. It is reported that cytotoxic effect of nano-ZnO in human bronchial epithelial cells by increasing ROS production [31]. Nano-FeO was found to have a harmful effect in hepatocyte cells by increasing ROS formation and apoptosis. When the cytotoxic effects of nano-Ti02, Co3O4, ZnO, and CuO were compared in hepatocyte cells, it was discovered that nano-CuO had the highest cytotoxic effect [32].

Surface area, surface coating, molecular size, shape, oxidation status, solubility, and degree of aggregation and agglomeration are all characteristics that contribute to nanomaterials' toxicity [33]. It is determined that increasing the toxic effect of nanoparticles is directly proportional to the decrease in size. Yoshida et al. reported that amorphous nanosilica causes toxicity in the human cell, both by increasing ROS formation and by damaging DNA [34]. The size, shape, and interaction of quantum dots' surface components with nanotoxicity have all been studied. The influence of nanomaterial solubility on toxicity was investigated. According to Studer et al., ZnO nanoparticles are less hazardous than soluble copper metal [35].

Medical experts prioritise biocompatibility, biodegradability, and effectiveness of nanomaterials, whereas industrialists, marketers, and economists may focus scaling up manufacturing of innovative devices or nanomaterials while reducing prices and timeframes. This inconsistency also raises concerns regarding the potential negative impacts of nanomaterials. Governments have implemented specific institutional programmes in response to increased regulatory demands for the use of nanomaterial-based medical devices and advanced therapeutic pharmaceutical products.

The effects of nanoparticles on human health have been studied in a variety of ways as technology has progressed. Nanotoxicology research on 3D human organs, cells, and advanced genetic investigations are beginning to take the place of traditional in vitro analytical procedures [36]. Multiple difficult steps, such as physicochemical qualities of nanomaterials, the environment-target cell, cellular uptake, and epigenetic interaction, may be assessed using in vitro testing methods [37]. Omic methods, such as next-generation sequencing, transcriptomics, and proteomics, have yielded a lot more knowledge about the toxicity of the complex biological processes generated by nanomaterial interaction with the microenvironment [38]. Personalized toxicology is also an es-

sential consideration. Under this issue, any hereditary sensitivity to nanomaterial toxicity should be further investigated.

Conclusion

There is limited awareness amongst dental students about nanotoxicology in medicinal applications. Enhanced awareness initiatives and dental educational programmes together with increased importance for curriculum improvements that further promote knowledge and awareness of nanotoxicology in medicinal applications.

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