Journal of Bioengineering and Medical Technology

Editorial

Organ-on-Chip Toxicology Models: Redefining Preclinical Safety Testing

Dr. Daniel H. Fraser*

Dept. of Biofabrication, Pacific Coast Biomedical University, Canada

*Corresponding author: Dr. Daniel H. Fraser, Dept. of Biofabrication, Pacific Coast Biomedical University, Canada, Email: d.fraser@pcbu.ca

Introduction

Assessing the safety of pharmaceuticals, chemicals, and consumer products is a critical step in protecting human health. Traditional toxicology testing has relied heavily on two-dimensional cell cultures and animal models. While these approaches have provided valuable insights, they often fail to accurately replicate human physiology and may not reliably predict human-specific responses. Ethical concerns, high costs, and lengthy testing timelines further highlight the need for alternative strategies. Organ-on-chip toxicology models have emerged as a promising solution, combining microengineering and cell biology to create more physiologically relevant testing platforms [1,2].

Organ-on-chip systems are microfluidic devices that simulate the structure and function of human organs using living cells arranged in three-dimensional architectures. By mimicking tissue–tissue interfaces, fluid flow, and mechanical forces, these platforms provide a more accurate representation of in vivo conditions. Their application in toxicology is transforming how researchers evaluate drug safety and chemical toxicity.

Discussion

Organ-on-chip devices typically consist of transparent polymer chips containing microchannels lined with human cells. These channels allow precise control of fluid flow, nutrient delivery, and waste removal, closely resembling the dynamic microenvironment of real tissues. For toxicology studies, organ-specific chips—such as liver-on-chip, lung-on-chip, heart-on-chip, or kidney-on-chip—are used to evaluate how substances affect different organ systems [3,4].

The liver-on-chip model, for instance, is particularly valuable because the liver is the primary site of drug metabolism. By incorporating hepatocytes and supporting cells within a microfluidic system, researchers can assess drug-induced liver injury, metabolic byproducts, and dose-dependent toxicity. Similarly, heart-on-chip platforms enable measurement of electrical activity and contractility, providing early detection of cardiotoxic effects that might otherwise go unnoticed in conventional cell cultures.

One of the most significant advantages of organ-on-chip toxicology models is their potential to reduce reliance on animal testing. These systems can be constructed using human-derived cells, including induced pluripotent stem cells, improving the relevance of toxicity predictions. Multi-organ chips, sometimes referred to as "body-on-chip" systems, connect several organ models to simulate systemic interactions, offering insights into how compounds are absorbed, distributed, metabolized, and excreted [5].

Despite their promise, challenges remain in standardization, scalability, and regulatory acceptance. Ensuring reproducibility across laboratories and validating predictive accuracy against clinical data are ongoing priorities. Integration with computational modeling and artificial intelligence may further enhance data interpretation and predictive power.

Conclusion

Organ-on-chip toxicology models represent a transformative advancement in preclinical safety assessment. By closely mimicking human organ function and physiological dynamics, these platforms provide more accurate and ethical alternatives to traditional testing methods. Although technical and regulatory hurdles persist, continued innovation and validation are driving their adoption. In the future, organ-on-chip systems are poised to play a central role in safer drug development and more reliable chemical risk evaluation.

References

1. Pandey S, Gupta K, Mukherjee AK (2007) Impact of cadmium and lead on Catharanthus roseus - A phytoremediation study. Journal of Environmental Biology 28: 655-662.

2. Ahmad NH, Rahim RA, Mat I (2010) Catharanthus roseus aqueous extract is cytotoxic to Jurkat leukemic T-cells but induces the proliferation of normal peripheral blood mononuclear cells. Tropical Life Science Research 21: 101-113.

3. Subhashini V, Swamy AVVS (2013) Phytoremediation of Pb and Ni Contaminated Soils Using Catharanthus roseus (L.). Universal Journal of Enviromental Research and Technology 3:465-472.

4. Nayak BS (2007) Evaluation of woundhealing potential of Catharanthus roseus leaf extract in rats. Phytotherapies 78.7-8: 540-544.

5. SV, Sain M (2013) Catharanthus roseus (An Anticancerous Drug Yielding Plant) - A Review Of Potential Therapeutic Properties. International Journal of Pure and Applied Bioscience 139-42.