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From benign airway lesions to bioengineered solutions: 3D bioprinting in tracheobronchopathia osteochondroplastica

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Abstract

Tracheobronchopathia osteochondroplastica is a rare benign lesion of the airways often managed conservatively. However, advanced obstruction requires reconstruction. This brief commentary explores the emerging role of 3D bioprinting as a curative solution, analyzing recent findings regarding mesenchymal stem cell-laden grafts and identifying vascularization as the critical hurdle preventing clinical translation.

Key words: tracheobronchopathia osteochondroplastica, 3D bioprinting, airway reconstruction, mesenchymal stem cells, tissue engineering.

Introduction

Tracheobronchopathia Osteochondroplastica (TPO) is a rare benign lesion of the airways, characterized by multiple nodular proliferations of bone with or without cartilaginous tissue in the submucosa of the trachea and bronchi. These nodular proliferations frequently project into the anterior and lateral walls of the tracheobronchial lumen while rarely affecting the posterior wall. The exact pathogenesis is unclear but the most clinically related hypothesis states that it is due to chronic infection and inflammation, causing cartilaginous and osseous metaplasia of tracheobronchial submucosa [1].

To evaluate emerging therapeutic options, the existing literature on PubMed and Google Scholar was reviewed using the keywords 'Tracheobronchopathia Osteochondroplastica,' '3D Bioprinting,' and 'Airway Reconstruction. Management is usually conservative; however, 3D bio-printed tracheal grafts have the potential to deal with the advanced stage of the disease and offering a new hope to patients (Figure 1).

Discussion

Tracheal reconstruction strategies, such as 3D bioprinting, electrospinning and AI-driven scaffold design, have demonstrated significant potential to counter this formidable clinical challenge. Specifically, synthetic polymers, such as polycaprolactone and polylactic acid, provide mechanical stability and tunable degradation properties, while 3D bio-printed tracheal grafts augment biocompatibility and support cellular integration [2].

Recent experimental results reinforce the possibility of 3D bio-printed tracheal grafts in vivo. The technique involves bone marrow-derived ferret mesenchymal stem cells (f-MSCs) capable of directing musculoskeletal differentiation along with a multi-material 3D bio-printed scaffold, which results in *in vitro* cartilage regeneration as manifested by glycosaminoglycan (GAGs) production and collagen II immunohistochemical staining [3].

Furthermore, in a rabbit model of circumferential tracheal defects, implantation of a dual-layer scaffold seeded with induced pluripotent cell (iPSC)-derived mesenchymal stem cells (MSC) and chondrocytes sustained airway patency and structural integrity comparable to the native trachea. Histological sections verified low-grade inflammation and Safranin O and type II collagen staining confirmed extensive cartilage-like extracellular matrix deposition surrounding the graft. These results identify that cell-seeded, 3D-printed tracheal grafts can accomplish structural support and biologic incorporation, confirming their promising role within future clinical use for advanced airway disorders such as TPO [4].

Despite these advances, several challenges remain, such as mechanical failure and chronic inflammation. However, the most daunting and formidable challenge is effective

vascularization. This single factor determines the viability of the tracheal graft. A highly efficient microvascular anastomosis is essential to ensure adequate oxygen and nutrient supply and prevent hypoxia-induced tissue necrosis [2].

Conclusions

In conclusion, 3D bio-printed tracheal grafts present a promising future for improving Tracheobronchopathia Osteochondroplastica treatment. Translation of this promise to clinical practice will depend on future work focusing on randomized trials and the optimization of graft transplantation protocols.

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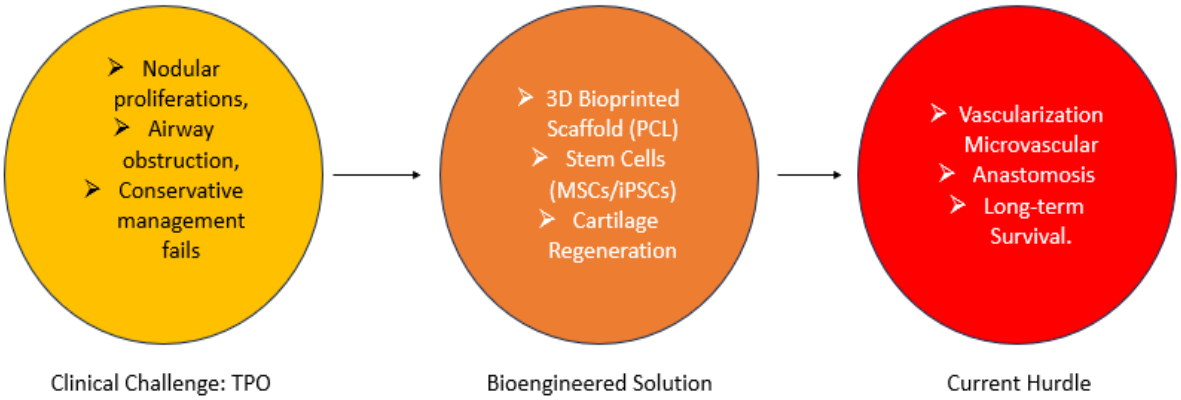

Figure 1. Schematic representation of the transition from clinical pathology to regenerative solutions. (Left) Tracheobronchopathia osteochondroplastica (TPO) presents as obstructive nodular lesions. (Middle) 3D bioprinting offers a reconstructive solution using mesenchymal stem cell (MSC)-laden scaffolds to regenerate cartilage. (Right) The critical barrier to clinical translation remains the establishment of effective graft vascularization to prevent necrosis.