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Commentary: Go with the flow: The biophysical aspects of tracheal reconstructions

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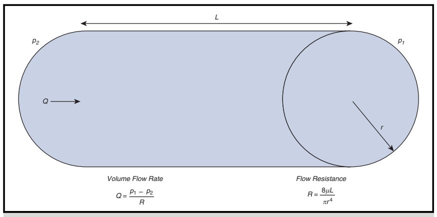

Hagen–Poiseuille equation (Δp = pressure gradient, μ = viscosity, L = length, r = radius, Q = flow).

CENTRAL MESSAGE

Toenail grafts should be suitable for tracheal reconstruction due to physiologic and anatomic structures, maintaining respiratory tract's flexibility and patency according to Hagen—Poiseuille's law.

Tracheal resection is, fortunately, a relatively infrequent procedure that requires a thorough multidisciplinary approach. Collaboration with the anaesthesia team is of utmost importance for critical airway management. A careful and precise surgical technique is crucial for successful results. For instance, it is critical to understand the principles underlying the process of reducing anastomotic tension. Postoperative care significantly affects outcomes.[1]

In most cases, the adult trachea can be reconstructed employing a primary anastomosis. However, more extended resections increase the risk of anastomotic complications. Despite numerous attempts with different grafts, replacing the tracheal defect remains a challenge. The characteristics of an ideal tracheal replacement include rigidity and stiffness in the lateral direction, flexibility along the longitudinal axis, and an utterly airtight lumen.[2] In addition, the graft should avoid growth factors contraindicated in patients with cancer. The literature describes 3 powerful techniques for tracheal reconstruction: synthetic matrix graft, free-tissue transfer, and allotransplantation.[2]

In their paper, Huang and colleagues[3] described 4 tracheal reconstructions with nail grafts. The indications varied from stenosis to oncologic. Toenail grafts should be suitable for tracheal reconstruction due to their natural physiologic and anatomic structures, maintaining the respiratory tract's flexibility and lumen patency. Even if biased by the single-center retrospective design, this study shows promising results for tracheal reconstruction with autologous graft for closure of minor tracheal defects.[3] The nail plate is a keratinized laminated structure that lies on top of the nail matrix. The eponychium is a layer of epidermis that extends from the proximal nail fold and adheres to the nail plate's dorsal aspect.[4]

From a biophysical point of view, resistance to gas flow in the airways is a combination of resistance to lung and chest wall tissue deformation, inertia of those tissues, inertia of the gas, and gas compression. Bernoulli's principle states mathematically that as the diameter of a tube decreases, the velocity of the gas must increase:

$$\frac{v^2}{2}+\int_{p_2}^{p_1}\frac{d\overline{p}}{\rho(\overline{p})}+\Psi=constant$$

p is the pressure, ρ is the density, v is the flow speed, and Ψ is the potential associated with the conservative force field. The pressure must fall to the level of the primary

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volumetric flow (of course, the other factors such as temperature and air density remain constant). In a normal physiological state, the airway divides and narrows. To maintain volumetric flow, the velocity of the airway will increase with each additional division. Increased velocity increases turbulent flow, resulting in increased airflow resistance, which is critical when treating a patient whose airways have collapsed or constricted.[5] The Hagen–Poiseuille equation is a physical law in fluid dynamics, which governs the pressure gradient Δp, in a fluid with a viscosity μ, flowing through a rigid cylindrical pipe of length L, and radius r, at volumetric flow rate Q:

$$\Delta p = \frac{8\mu QL}{\pi r^4}$$

Hagen–Poiseuille's law states that airflow is directly proportional to the radius to the fourth power, highlighting the potential detriment of even a tiny decrease in tracheal lumen diameter.[6]

In conclusion, the nail graft could be a reconstruction technique since it provides rigid support with a physiological airflow.

References

1. Mathisen D. Distal tracheal resection and reconstruction: state of the art and lessons learned. *Thorac Surg Clin*. 2018;28:199-210.
2. Etienne H, Fabre D, Gomez Caro A, Kolb F, Mussot S, Mercier O, et al. Tracheal replacement. *Eur Respir J*. 2018;51:1702211.
3. Huang H-F, Hwang J-J, Huang P-M. Tracheal reconstruction with nail grafts: a novel approach. *J Thorac Cardiovasc Surg Tech*. 2021;10:554-60.
4. de Berker D. Nail anatomy. *Clin Dermatol*. 2013;31:509-15.
5. Sapra A, Campbell M. *Physiology, Airflow Resistance*. Treasure Island (FL): StatPearls Publishing; 2021. StatPearls [Internet].
6. Merriam Webster. Poiseuille's law. Available at: https://www.merriam-webster.com/medical/Poiseuille%27s%20law#:~:text=Medical%20Definition%20of%20Poiseuille's%20law,and%20the%20coefficient%20of%20viscosity. Accessed October 20, 2021.