

- Neff L.P., Tillman B.W., Yazdani S.K., Machingal M.A., Yoo J.J., Soker S., Christ G.J. 2011. Vascular smooth muscle enhances functionality of tissue-engineered blood vessels in vivo. *J. Vasc. Surg.* V. 53. P. 426.
- Negishi J., Hashimoto Y., Yamashita A., Zhang Y., Kimura T., Kishida A., Funamoto S. 2017. Evaluation of small-diameter vascular grafts reconstructed from decellularized aorta sheets. *J. Biomed. Mater. Res. A.* V. 105. P. 1293.
- Pashneh-Tala S., MacNeil S., Claeysens F. 2015. The tissue-engineered vascular graft—past, present, and future. *Tissue Eng. Part B. Rev.* V. 22. P. 68.
- Porter T.R., Taylor D.O., Fields J., Cysan A., Akosah K., Mohanty P.K., Pandian N.G. 1993. Direct in vivo evaluation of pulmonary arterial pathology in chronic congestive heart failure with catheter-based intravascular ultrasound imaging. *Am. J. Cardiol.* V. 71. P. 754.
- Radke D., Jia W., Sharma D., Fena K., Wang G., Goldman J., Zhao F. 2018. Tissue engineering at the blood-contacting surface: a review of challenges and strategies in vascular graft development. *Adv. Healthcare Mater.* <https://doi.org/10.1002/adhm.201701461>
- Ren X., Feng Y., Guo J., Wang H., Li Q., Yang J., Li W. 2015. Correction: Surface modification and endothelialization of biomaterials as potential scaffolds for vascular tissue engineering applications. *Chem. Soc. Rev.* V. 44. P. 5745.
- Rosellini E., Vozzi G., Barbani N., Giusti P., Cristallini C. 2010. Three-dimensional microfabricated scaffolds with cardiac extracellular matrix-like architecture. *Int. J. Artif. Organs.* V. 33. P. 885.
- Shevtsov M.A., Nikolaev B.P., Ryzhov V.A., Yakovleva L.Y., Dobrodumov A.V., Marchenko Y.Y., Guzhova I.V. 2015. Brain tumor magnetic targeting and biodistribution of superparamagnetic iron oxide nanoparticles linked with 70-kDa heat shock protein study by nonlinear longitudinal response. *J. Magn. Mater.* V. 388. P. 123.
- Song H.J., Xue W.J., Li Y., Tian X.H., Song Y., Ding X.M., Li Z.L. 2009. Improved islet survival and function with rat endothelial cells in vitro co-culture. *Transpl. P.* V. 41. P. 4302.
- Stegemann J.P., Kaszuba S.N., Rowe S.L. 2007. Review: Advances in vascular tissue engineering using protein-based biomaterials. *Tissue Eng.* V. 13. P. 2601.
- Stekelenburg M., Rutten MC, Snoeckx H.E.H., Baaijens F.P. 2008. Dynamic straining combined with fibrin gel cell seeding improves strength of tissue-engineered small-diameter vascular grafts. *Tissue Eng. Part A.* V. 15. P. 1081.
- Stowell C.E.T., Wang Y. 2018. Quickening: Translational design of resorbable synthetic vascular grafts. *Biomaterials.* V. 173. P. 71.
- Van Hinsbergh V.W. 2012. Endothelium-role in regulation of coagulation and inflammation. *Semin. Immunopathol.* V. 34. P. 93.
- Wang W., Xu X., Li Z., Kratz K., Ma N., Lendlein A. 2019. Modulating human mesenchymal stem cells using poly(n-butyl acrylate) networks in vitro with elasticity matching human arteries. *Clin. Hemorheol. Microcirc.* V. 71. P. 277.
- Wilson H.K., Canfield S.G., Shusta E.V., Palecek S.P. 2014. Concise review: Tissue-specific microvascular endothelial cells derived from human pluripotent stem cells. *Stem Cells.* V. 32. P. 3037.
- Xu S., Lu F., Cheng L., Li C., Zhou X., Wu Y., Qi Z. 2017. Preparation and characterization of small-diameter decellularized scaffolds for vascular tissue engineering in an animal model. *Biomed. Eng. Online.* V. 16. <https://doi.org/10.1186/s12938-017-0344-9>
- Yau J.W., Teoh H., Verma S. 2015. Endothelial cell control of thrombosis. *BMC Cardiovasc. Disord.* V. 15. P. 130.
- Yudintceva N.M., Bogolubova I.O., Muraviov A.N., Sheykhov M.G., Vinogradova T.I., Sokolovich E.G., Shevtsov M.A. 2018. Application of the allogenic mesenchymal stem cells in the therapy of the bladder tuberculosis. *J. Tiss. Eng. Regen. Med.* V. 12. P. e1580. <https://doi.org/10.1002/term.2583>
- Zhao Q., Cui H., Wang J., Chen H., Wang Y., Zhanget L., Wang M. 2018. Regulation effects of biomimetic hybrid scaffolds on vascular endothelium remodeling of biomimetic hybrid scaffolds on vascular endothelium Remodeling. *ACS Appl. Mater. Interfaces.* V. 10. P. 23583.

Small-Diameter Vessels Reconstruction Using Cell Tissue-Engineering Graft Based on the Poly(ϵ -Caprolactone)

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Poly(ϵ -caprolactone) (PCL) is widely applied for the construction of small-diameter tissue-engineered vascular grafts (TEVGs) due to its biomechanical properties, slow degradation, and good biocompatibility. In the present study the TEVG based on a tubular scaffold seeded with smooth muscle aortic cells (SMCs) in a rat abdominal aorta replacement model was tested. Polyester tubular scaffolds were generated by thermally induced phase separation and seeded with rat SMCs. To track the implanted SMCs *in vivo*, cells were labeled with superparamagnetic iron oxide nanoparticles (SPIONs). Histological evaluation of the migration of autologous endothelial cells (ECs) and forma-

tion of the endothelial lining was performed 4, 8, and 12 weeks after graft interposition. TEVG demonstrated a high patency rate without any complications at the end of the 12-week period. The migration of ECs into the lumen of the implanted TEVG and formation of the cell monolayer were already present at 4 weeks, as confirmed by histological analysis. The architecture of both neointima and neoadventitia were similar to those of the native vessel. SPI-ON-labeled SMCs were detected throughout the TEVG, indicating the role of these cells in the endothelization of scaffolds. The SMC-seeded scaffolds demonstrated improved patency and biointegrative properties when compared to the acellular grafts.

Keywords: smooth muscle and endothelial cells, polycaprolactone, tubular scaffold, small diameter vessel, superparamagnetic iron oxide nanoparticles, tissue engineering graft