IVYSPRING INTERNATIONAL PUBLISHER

Theranostics

2018; 8(22): 6384-6385. doi: 10.7150/thno.30753

Editorial

Virtual TEVAR: Overcoming the Roadblocks of In-Silico Tools for Aortic Dissection Treatment

Vanessa Diaz-Zuccarini[1,2]✉, Mirko Bonfanti[2,1], Gaia Franzetti[1], Stavroula Balabani[1]

1. University College London, Department of Mechanical Engineering, Multiscale Cardiovascular Engineering Group, UK
2. WEISS Centre for Surgical and Interventional Sciences, University College London, UK.

✉ Corresponding author

Received: 2018.10.17; Accepted: 2018.10.30; Published: 2018.12.07

Abstract

The use of in silico tools for the interventional planning of complex vascular conditions, such as Aortic Dissections has been often limited by high computational cost, involving long timescales for accurate results to be produced and low numbers of patients, precluding the use of statistical analyses to inform individual-level models. In the paper [*Theranostics* 2018; 8(20):5758-5771. doi:10.7150/thno.28944], Chen *et al.* proposed a novel algorithm to compute patient-specific 'virtual TEVAR' that will help clinicians to approach individual treatment and decision-making based on objective and quantifiable metrics and validated on a cohort of 66 patients in real time. This research will significantly impact the field and has the potential to transform the way clinical interventions will be approached in the future.

Related article: *Theranostics* 2018; 8(20):5758-5771. doi:10.7150/thno.28944

Aortic dissection (AD) is a vascular condition with high morbidity and mortality rates [2]. AD is characterized by the separation of the layers of the aortic wall: a tear in the intima layer allows blood to flow within the aortic wall inducing the formation of two flow channels, the true (TL) and false lumen (FL), separated by an intimal flap (IF) [3]. Diagnosis, management and treatment of AD are incredibly patient-dependent and difficult; experts claim that "difficulty in diagnosis, delayed diagnosis or failure to diagnose are so common as to approach the norm for this disease, even in the best hands…" [4]. Initial management of acute AD focuses on pain control, heart rate and blood pressure management, followed by surgical intervention, typically involving stenting of the entry tear. Although type B dissections (*i.e.* AD involving only the descending aorta) have lower initial mortality than type A (*i.e.* AD of the ascending aorta), they carry a poor long-term prognosis, with late-term complications reported in 20–50% of cases within 5 years [5].

Within this context, assessing the risk/benefits ratio of any intervention is of paramount importance for clinicians and patients alike. Current clinical guidelines are limited by the complexity of the pathophysiology, risk factors and co-morbidities, and patient heterogeneity [6,7]. Thoracic Endovascular Aortic Repair (TEVAR) is the interventional approach of choice for most patients with complicated dissections and most likely to supplant open surgical treatment in the near future [8–10]. However, there is a lack of high level evidence in support of TEVAR for this clinical condition. Information on late outcomes is scant [11]. Challenges in trial design and heterogeneity of patient groups often result in patient management plans relying on clinical experience. In the case of ADs, each patient's treatment is highly individualized, and clear and objective quantifiable metrics are often not available.

The whole process is complicated, subjective and cost and time-inefficient. *In silico* models and virtual tools designed to guide the treatment of type B AD have been met with considerable clinical interest [12–21] and hold significant promise. However, the simulation community still has important barriers to overcome, in order to analyze and represent the enormous amount of information needed to timely, reliably and accurately capture the condition's complexity and variability. In particular, there are challenges around the time it takes for simulations to produce results in clinically meaningful timescales (ideally in real time) and around clinical acceptance, founded on the premises of high-quality studies in comprehensive cohorts of a significant number of patients.

Research published in issue 20 of *Theranostics* reports a transformative approach to *in silico* tools for type-B aortic dissection treatment by proposing a "virtual TEVAR" simulation framework, tackling both, the time-constraint and accuracy issues that have been holding the field back. In a real tour-de-force, the authors have developed an efficient and effective methodology to develop a computational framework able to compute patient-specific "virtual interventions" that will help clinicians to approach individual treatment and make decisions based on objective and quantifiable metrics meticulously validated on a cohort of 66 patients. The research team developed a virtual stenting algorithm based on simplex (deformable) meshes and mechanical contact analysis, with parameters derived from mechanical tests on aortic tissue and commonly-used stent-grafts. The testing and validation, involved pre- and post-treatment computed tomography angiography datasets of type-B aortic dissection cases (n = 66), providing fast, real-time and accurate predictions of stent-graft deployment with luminal deformation tracking.

This compelling piece of research opens up multiple application avenues for this condition and it propels the whole field forward, making a clear case for the use of virtual tools for patient-specific clinical support strategies based on quantifiable metrics of individualised outcome and risk assessment in real time for aortic dissections and other complex, vascular conditions.

Competing Interests

The authors have declared that no competing interest exists.

References

[1] Chen D, Wei J, Deng Y, Xu H, Li Z, Meng H, Han X, Wang Y, Wan J, Yan T, Xiong J, Tang X. Virtual stenting with simplex mesh and mechanical contact analysis for real-time planning of thoracic endovascular aortic repair. Theranostics 2018; 8(20):5758-5771. doi:10.7150/thno.28944

[2] Nienaber CA, Clough RE, Sakalihasan N, Suzuki T, Gibbs R, Mussa F, et al. Aortic dissection. Nat Rev Dis Prim 2016;2:16053. doi:10.1038/nrdp.2016.53.

[3] Strayer RJ, Shearer PL, Hermann LK. Screening, evaluation, and early management of acute aortic dissection in the ED. Curr Cardiol Rev 2012;8:152–7.

[4] Elefteriades JA, Barrett PW, Kopf GS. Litigation in Nontraumatic Aortic Diseases – A Tempest in the Malpractice Maelstrom. Cardiology 2007;109:263–72. doi:10.1159/000107790.

[5] Doyle BJ, Norman PE. Computational Biomechanics in Thoracic Aortic Dissection: Today's Approaches and Tomorrow's Opportunities. Ann Biomed Eng 2016;44:71–83. doi:10.1007/s10439-015-1366-8.

[6] Fattori R, Cao P, De Rango P, Czerny M, Evangelista A, Nienaber C, et al. Interdisciplinary Expert Consensus Document on Management of Type B Aortic Dissection. J Am Coll Cardiol 2013;61:1661–78. doi:10.1016/j.jacc.2012.11.072.

[7] Nienaber CA, Clough RE. Management of acute aortic dissection. Lancet 2015;385:800–11. doi:10.1016/S0140-6736(14)61005-9.

[8] Kinoshita H, Fujimoto E, Arase H, Kurobe H, Chikugo F, Sogabe H, et al. Efficacy and Optimal Timing of Endovascular Treatment for Type B Aortic Dissection. Ann Vasc Dis 2015;8:307–13. doi:10.3400/avd.oa.15-00069.

[9] Yuan X, Mitsis A, Ghonem M, Iakovakis I, Nienaber CA. Conservative management versus endovascular or open surgery in the spectrum of type B aortic dissection. J Vis Surg 2018;4:59. doi:10.21037/jovs.2018.02.15.

[10] Kamman A V, Brunkwall J, Verhoeven EL, Heijmen RH, Trimarchi S. Predictors of aortic growth in uncomplicated type B aortic dissection from the Acute Dissection Stent Grafting or Best Medical Treatment (ADSORB) database 2017. doi:10.1016/j.jvs.2016.09.033.

[11] Criado FJ. Aortic dissection: a 250-year perspective. Texas Hear Inst J 2011;38:694–700.

[12] Dillon-Murphy D. Computational haemodynamics and strain analysis of aortic dissection in idealised and patient specific aortic geometries: Understanding the impact of dissection on cardiovascular function. 2016.

[13] Cheng Z, Wood NB, Gibbs RGJ, Xu XY. Geometric and Flow Features of Type B Aortic Dissection: Initial Findings and Comparison of Medically Treated and Stented Cases. Ann Biomed Eng 2014;43:177–89. doi:10.1007/s10439-014-1075-8.

[14] Cheng Z, Riga C, Chan J, Hamady M, Wood NB, Cheshire NJW, et al. Initial findings and potential applicability of computational simulation of the aorta in acute type B dissection. J Vasc Surg 2013;57:35S–43S. doi:10.1016/j.jvs.2012.07.061.

[15] Bonfanti M, Balabani S, Greenwood JP, Puppala S, Homer-Vanniasinkam S, Díaz-Zuccarini V. Computational tools for clinical support: a multi-scale compliant model for haemodynamic simulations in an aortic dissection based on multi-modal imaging data. J R Soc Interface 2017;14:20170632. doi:10.1098/rsif.2017.0632.

[16] Bonfanti M, Balabani S, Alimohammadi M, Agu O, Homer-Vanniasinkam S, Díaz-Zuccarini V. A simplified method to account for wall motion in patient-specific blood flow simulations of aortic dissection: Comparison with fluid-structure interaction. Med Eng Phys 2018. doi:10.1016/j.medengphy.2018.04.014.

[17] Alimohammadi M, Bhattacharya-Ghosh B, Seshadhri S, Penrose J, Agu O, Balabani S, et al. Evaluation of the hemodynamic effectiveness of aortic dissection treatments via virtual stenting. Int J Artif Organs 2014;37:753–62. doi:10.5301/ijao.5000310.

[18] Alimohammadi M, Sherwood JM, Karimpour M, Agu O, Balabani S, Díaz-Zuccarini V. Aortic dissection simulation models for clinical support: fluid-structure interaction vs. rigid wall models. Biomed Eng Online 2015;14:34. doi:10.1186/s12938-015-0032-6.

[19] Shang EK, Nathan DP, Fairman RM, Bavaria JE, Gorman RC, Gorman JH, et al. Use of computational fluid dynamics studies in predicting aneurysmal degeneration of acute type B aortic dissections. J Vasc Surg 2015;62:279–84. doi:10.1016/j.jvs.2015.02.048.

[20] Yu SCH, Liu W, Wong RHL, Underwood M, Wang D. The Potential of Computational Fluid Dynamics Simulation on Serial Monitoring of Hemodynamic Change in Type B Aortic Dissection. Cardiovasc Intervent Radiol 2016;39:1090–8. doi:10.1007/s00270-016-1352-z.

[21] Xu H, Li Z, Dong H, Zhang Y, Wei J, Watton PN, et al. Hemodynamic parameters that may predict false-lumen growth in type-B aortic dissection after endovascular repair: A preliminary study on long-term multiple follow-ups. Med Eng Phys 2017;7:35–0. doi:10.1016/j.medengphy.2017.08.011.