CJC Open 6 (2024) 836–839

Case Report

A Novel Application of Artificial Intelligence in the Management of Abdominal Aortic Aneurysm

Martina Vergouwen, BN,[a] Ali Fatehi Hassanabad, MD, MSc,[b] Arianna Forneris, PhD,[c,d] Elena S. Di Martino, PhD,[c,d] and Randy D. Moore, MD, FRCSC[d,e,f]

[a] *University of Calgary, Cumming School of Medicine, Calgary, Alberta, Canada*

[b] *Department of Cardiac Surgery, University of Calgary, Calgary, Alberta, Canada*

[c] *Department of Biomedical Engineering, Schulich School of Engineering, University of Calgary, Calgary, Alberta, Canada*

[d] *R&D Department, ViTAA Medical Solutions, Montreal, Quebec, Canada*

[e] *Calgary Aortic Program, Calgary, Alberta, Canada*

[f] *Department of Vascular Surgery, University of Calgary, Calgary, Alberta, Canada*

The use of artificial intelligence (AI) technologies in healthcare has evolved rapidly in recent years, but surgical applications of AI remain limited relative to more-diagnostic disciplines. This case demonstrates novel AI technology that may be applied to the surgical management of abdominal aortic aneurysms (AAAs). We present a patient with an AAA, of a size below the threshold for surgical repair, that was clinically determined to be at high risk of rupture, along with the results of an AI-based assessment of the biomechanical properties of the patient's aortic wall. The patient received open aortic repair.

Novel Teaching Points

- In some cases, patients may have an AAA that has concerning features and unrecognized enhanced tissue failure, despite being relatively small in size; decision-making in these cases is challenging.
- AI-based technology that assesses the biomechanical properties of the aortic wall to determine regional aortic weakness may help clinicians appreciate the precise risk of each AAA they manage.

Case

A 56-year-old man was referred to the vascular surgery clinic after a screening abdominal ultrasound identified an AAA. A computed tomography (CT) angiogram revealed an abdominal aorta with a maximal transverse diameter of 4.6 cm and an anteroposterior diameter of 3.6 cm. Mild aortic margin irregularity also was noted. His past medical history was remarkable for significant smoking. Given his small body habitus (height: 1.58 m; weight: 55 kg; body surface area: 1.55 m^2) and the unusual aortic appearance on CT, an urgent surgical AAA repair was recommended by the treating vascular surgeon. The patient provided informed consent for surgery with complete aneurysm excision and participation in a research study of an AI-based technology that assesses the biomechanical properties of the aorta to estimate focal aortic wall weakness.

Preoperative AI analysis was performed on the AAA using electrocardiography-gated dynamic CT as the source imaging. Simpleware ScanIP (Synopsys, Sunnyvale, CA) was used to delineate the aortic geometry through a proprietary AI-based segmentation protocol.[1] A system of 24 unique patches was created by sectioning both the lumen and the outer wall perpendicular to the lumen centerline, and the 3-dimensional geometry was extracted as a triangulated surface mesh (Fig. 1). Unsteady computational fluid dynamic simulations were performed using a semi-implicit method for a pressure-linked equations algorithm for pressure-velocity coupling and a second-order implicit transient formulation. Blood was assumed to be an isotropic and incompressible Newtonian fluid, and the arterial wall was assumed to be rigid. Three biomarkers were then examined—intraluminal thrombus thickness, time-averaged wall shear stress, and strain. These biomarkers are described in greater detail and have been validated in previous publications demonstrating their individual contributions to aortic wall deterioration.[2,3] Regional aortic weakness was calculated as a composite of these

Received for publication February 16, 2024. Accepted March 27, 2024.

Corresponding author: Dr Ali Fatehi Hassanabad, Section of Cardiac Surgery, Department of Cardiac Sciences, Foothills Medical Center, 1403 29th St NW, Calgary, Alberta T2N 2T9, Canada. Tel.: +1-403-944-5480; fax: +1-403-355-4035.

E-mail: ali.fatehihassanabad@ahs.ca

See page 839 for disclosure information.

https://doi.org/10.1016/j.cjco.2024.03.012

2589-790X/© 2024 The Authors. Published by Elsevier Inc. on behalf of the Canadian Cardiovascular Society. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

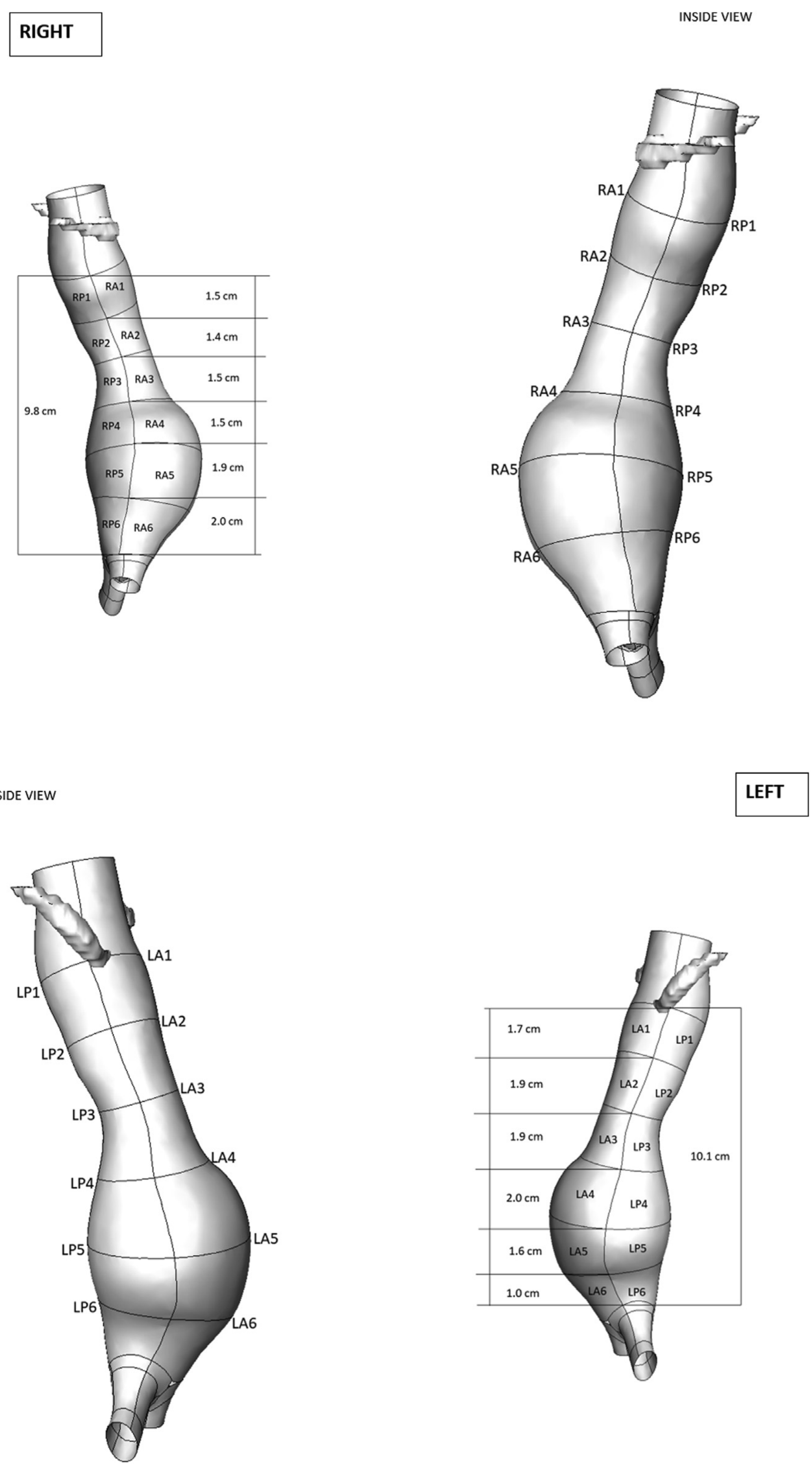

Figure 1. Geometry of the aortic wall demonstrating the location-based patching system used. Inside view denotes the luminal surface; the other view is the outer aortic wall. LA, left anterior; LP, left posterior; RA, right anterior; RP, right posterior.

biomarkers over each of the patches; this is a novel approach to aortic wall-strength assessment.

Results from intraluminal thrombus thickness, time-averaged wall shear stress, and strain analysis are demonstrated, along with the composite regional aortic weakness index, in Figure 2. Increased intraluminal thrombus and low time-averaged wall shear stress were found within the AAA, which is consistent with hemodynamic instability, local

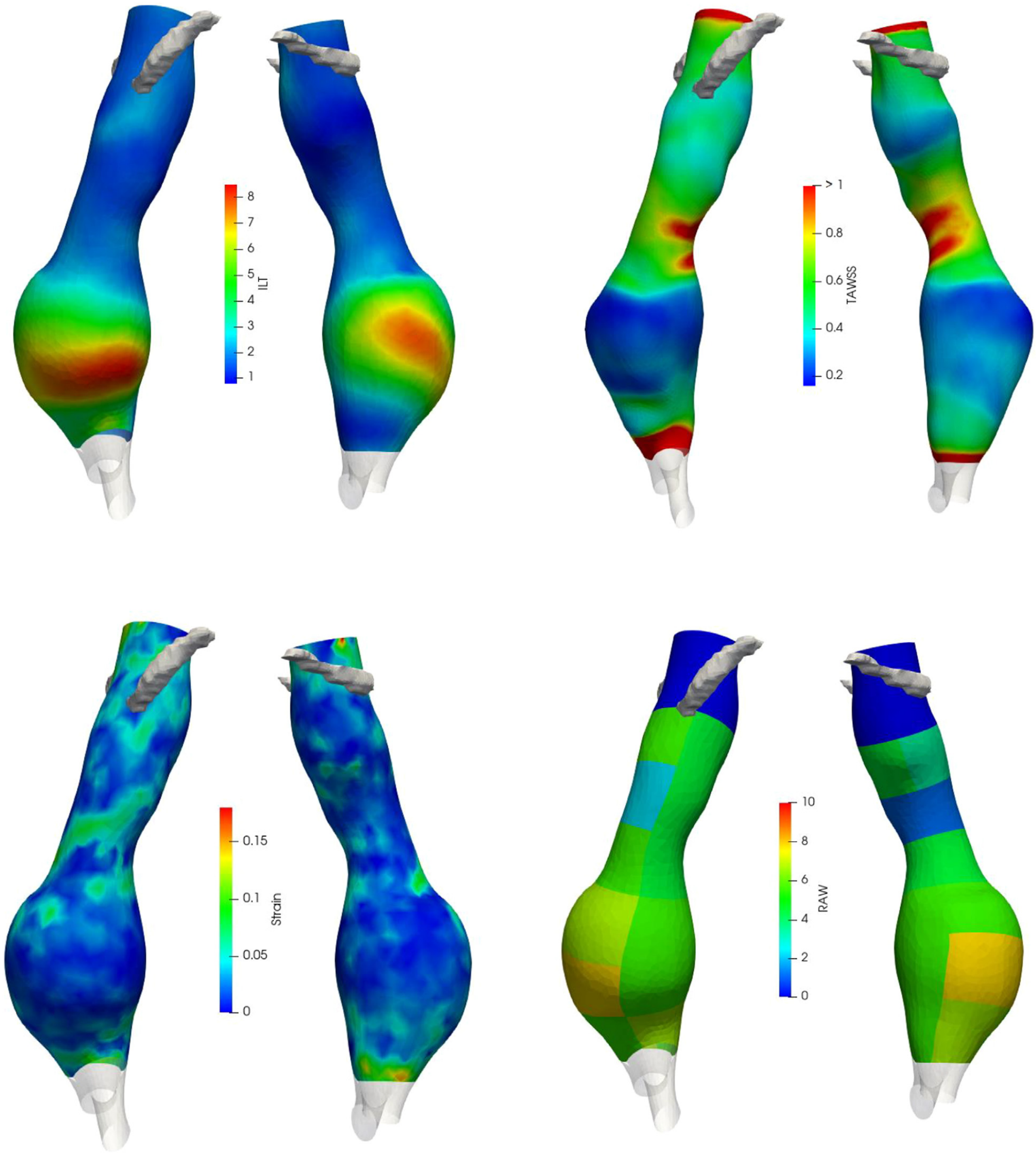

Figure 2. Preoperative artificial intelligence (AI) analysis of the abdominal aortic aneurysm. **Warm colours** (**red, orange, yellow**) are assigned to elevated values; **cool colours** (**indigo, cyan**) correspond to lower values. Intraluminal thrombus (ILT), time-averaged wall shear stress (TAWSS), and peak wall strain (Strain) are shown as continuous variables. Regional area weakness (RAW) is shown as an average over corresponding patch sections; values > 6 indicate a high level of predicted tissue weakness.

tissue weakening, and increased aneurysm growth—a surrogate marker for increased risk of rupture.[2,3] The impact of strain on this patient's AAA rupture risk prediction was minimal—no areas of very elevated strain were identified. High regional aortic weakness (>6.5) was found within the AAA, related to the increased intraluminal thrombus and the low time-averaged wall shear stress. Previously published data indicate that regional aortic weakness of $\geq$ 6.5 is predictive of rapid relative aortic wall growth at 1-year follow-up.[3]

The treating surgeon remained blinded to these results until open aortic repair was completed, to reduce the risk of bias. Knowledge of the biomechanical properties of the aorta has the potential to influence surgical decision-making. For example, awareness of focal weakness proximal or distal to an AAA could encourage more-extensive repair.

Following AI-based analysis and standard preoperative investigations, open aortic repair was completed, taking into account the patient's young age and to allow complete aneurysm excision. A transperitoneal approach via a midline incision extending from the xiphoid to the pubis was used. A Conjoint Health Research Ethics Board–approved protocol allowed for modification of the standard endoaneurysmorrhaphy technique for open aneurysm repair, as follows: complete aortic excision was performed for tissue analysis following appropriate exposure and dissection. Aortic reconstruction was performed with end-to-end placement of a bifurcated Dacron graft, complete coverage of the graft with omental flap, and confirmation of distal perfusion. The patient had an uneventful postoperative recovery.

Discussion

The use of AI in healthcare research has expanded rapidly in the past 5 years, predominantly in diagnostic specialties. Less emphasis has been placed on how AI may improve surgical decision-making, particularly in vascular surgery.[4] In this case, we present a tool that may improve the ability of clinicians to recognize AAAs that have biomechanical properties that increase the risk of rupture.

Strict adherence to the 2018 Society for Vascular Surgery (SVS) guidelines would have resulted in this patient being managed conservatively, with serial imaging and surveillance, rather than with urgent aortic repair: his fusiform AAA was below the size-threshold, and no other clear indication for surgery was present.[5] The decision to operate was informed by the clinical recommendation of an aortic care specialist with over 30 years of experience. Whether this patient would have had a poor outcome, such as AAA rupture, without surgical intervention, is unknown. However, open surgery was chosen based on a combination of patient-specific factors and suspected irregularities on CT. This decision was made blind to the results of the completed AI analysis. An important point to acknowledge is that not all vascular surgeons, particularly those with less experience managing AAAs, would have made the decision to take this approach, outside of current guidelines, and operate on this patient.

Conclusion

Clinician identification of AAAs with increased wall weakness, which are at high risk of rapid growth that can increase the risk of rupture, is essential, and the use of AI technologies may improve surgical decision-making by facilitating precise aortic care. Instead of relying on population-based size guidelines, clinicians can appreciate the unique biomechanical characteristics of each AAA they manage, and plan their intervention accordingly. This case demonstrates that incorporating AI-based assessment of regional aortic weakness into clinical decision-making for operative repair may be feasible. Prior to using these tools as an adjunct to surgical planning, further study is needed—ideally, randomized controlled trials.

Ethics Statement

This case report adheres to all patient-related and institutional ethics guidelines.

Patient Consent

The authors confirm that patient consent forms have been obtained for this article.

Funding Sources

There are no funding sources to declare for this case report.

Disclosures

A.F., E.S.D.M, and R.D.M are shareholders of the company ViTAA Medical Solutions. The other authors have no conflicts of interest to disclose.

References

1. Abdolmanafi A, Forneris A, Moore RD, Di Martino ES. Deep-learning method for fully automatic segmentation of the abdominal aortic aneurysm from computed tomography imaging. Front Cardiovasc Med 2022;9:1040053.

2. Forneris A, Kennard J, Ismaguilova A, et al. Linking aortic mechanical properties, gene expression and microstructure: a new perspective on regional weakening in abdominal aortic aneurysms. Front Cardiovasc Med 2021;8:1-14.

3. Forneris A, Beddoes R, Benovoy M, et al. AI powered assessment of biomarkers for growth prediction of abdominal aortic aneurysms. JVS Vasc Sci 2023;4:1-8.

4. Javidan AP, Li A, Lee MH, Forbes TL, Naji F. A systematic review and bibliometric analysis of applications of artificial intelligence and machine learning in vascular surgery. Ann Vasc Surg 2022;85:395-405.

5. Chaikof EL, Dalman RL, Eskandari MK, et al. The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. J Vasc Surg 2018;67:2-77.e2.