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REVIEW

Biomechanical Imaging Markers as Predictors of Abdominal Aortic Aneurysm Growth or Rupture: A Systematic Review

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WHAT THIS PAPER ADDS

None of the proposed biomechanical imaging markers are conclusively associated with AAA rupture or growth. Although peak wall stress (PWS), as calculated with finite element analysis (FEA), was significantly higher in ruptured AAAs than in intact AAAs across multiple studies, there was confounding bias between groups because of baseline differences in AAA diameter. In addition, there is conflicting evidence on whether increased wall stress is associated with growth. Furthermore, although FEA is frequently applied in research, the methodology has not been standardised and its technical limitations have only marginally improved.

Objectives: Biomechanical characteristics, such as wall stress, are important in the pathogenesis of abdominal aortic aneurysms (AAA) and can be visualised and quantified using imaging techniques. This systematic review aims to present an overview of all biomechanical imaging markers that have been studied in relation to AAA growth and rupture.

Methods: This systematic review followed the PRISMA guidelines. A search in Medline, Embase, and the Cochrane Library identified 1503 potentially relevant articles. Studies were included if they assessed biomechanical imaging markers and their potential association with growth or rupture.

Results: Twenty-seven articles comprising 1730 patients met the inclusion criteria. Eighteen studies performed wall stress analysis using finite element analysis (FEA), 13 of which used peak wall stress (PWS) to quantify wall stress. Ten of 13 case control FEA studies reported a significantly higher PWS for symptomatic or ruptured AAAs than for intact AAAs. However, in some studies there was confounding bias because of baseline differences in aneurysm diameter between groups. Clinical heterogeneity in methodology obstructed a meaningful meta-analysis of PWS. Three of five FEA studies reported a significant positive association between several wall stress markers, such as PWS and 99th percentile stress, and growth. One study reported a significant negative association and one other study reported no significant association. Studies assessing wall compliance, the augmentation index and wall stress analysis using Laplace's law, computational fluid dynamics and fluid structure interaction were also included in this systematic review.

Conclusions: Although PWS is significantly higher in symptomatic or ruptured AAAs in most FEA studies, confounding bias, clinical heterogeneity, and lack of standardisation limit the interpretation and generalisability of the results. Also, there is conflicting evidence on whether increased wall stress is associated with growth.

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INTRODUCTION

Abdominal aortic aneurysms (AAAs) are mostly asymptomatic, but are life-threatening in the event of rupture. A large AAA is more likely to rupture, and for this reason prophylactic surgery is performed for AAAs with a minimum diameter of 55 mm. However, some AAAs rupture at smaller diameters, whereas others grow to larger sizes without

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rupturing. Therefore, AAA diameter is not an accurate predictor of rupture and, by extension, not an accurate indicator of the need for prophylactic surgery. Hence, better predictors are needed to guide clinical decision making.

Biomechanics is the study of mechanical laws applied to living structures. Previous research has focused on AAA biomechanics because of its involvement in AAA pathogenesis.[1] The biomechanical perspective in AAAs is based on the principles of material failure, that is where an AAA ruptures when the mural stresses exceed the strength of the AAA wall.[1] Therefore, Laplace's law has been offered as the theoretical basis for AAA diameter, as this law states that stress is related to diameter. However, Laplace's law is only applicable to simple shapes with a constant diameter, whereas AAAs often have complex shapes.[1] In addition, there are also different types of stresses, such as peak wall stress (PWS) and wall shear stress (WSS). PWS is circumferential stress on the AAA wall that arises perpendicular to blood flow, whereas WSS is stress on the AAA wall that is parallel to blood flow. Because of the complex shape of AAAs, calculation of these stresses requires more advanced methodology than Laplace's law, such as finite element analysis (FEA) or computational fluid dynamics (CFD). To employ these methodologies, imaging data are necessary to reconstruct AAA geometry. As such, PWS and WSS are regarded as biomechanical imaging markers.

Whether biomechanical imaging markers may serve to predict rupture or growth is currently unclear. Therefore, this systematic review aims to give an overview of all biomechanical imaging markers that have been studied in relation to AAA growth and rupture.

METHODS

This review was conducted according to the PRISMA and PRISMA-P statement.[2] The review protocol was registered in the PROSPERO database (CRD42015024892).

Medline, Embase, and the Cochrane Library were searched. References of included studies were searched for additional relevant studies. A clinical librarian assisted with the search strategy (Electronic supplementary material, Appendix 1). Systematic reviews and meta-analyses were used to complete the search. No language or date restrictions were applied. The final search was performed on February 1, 2016.

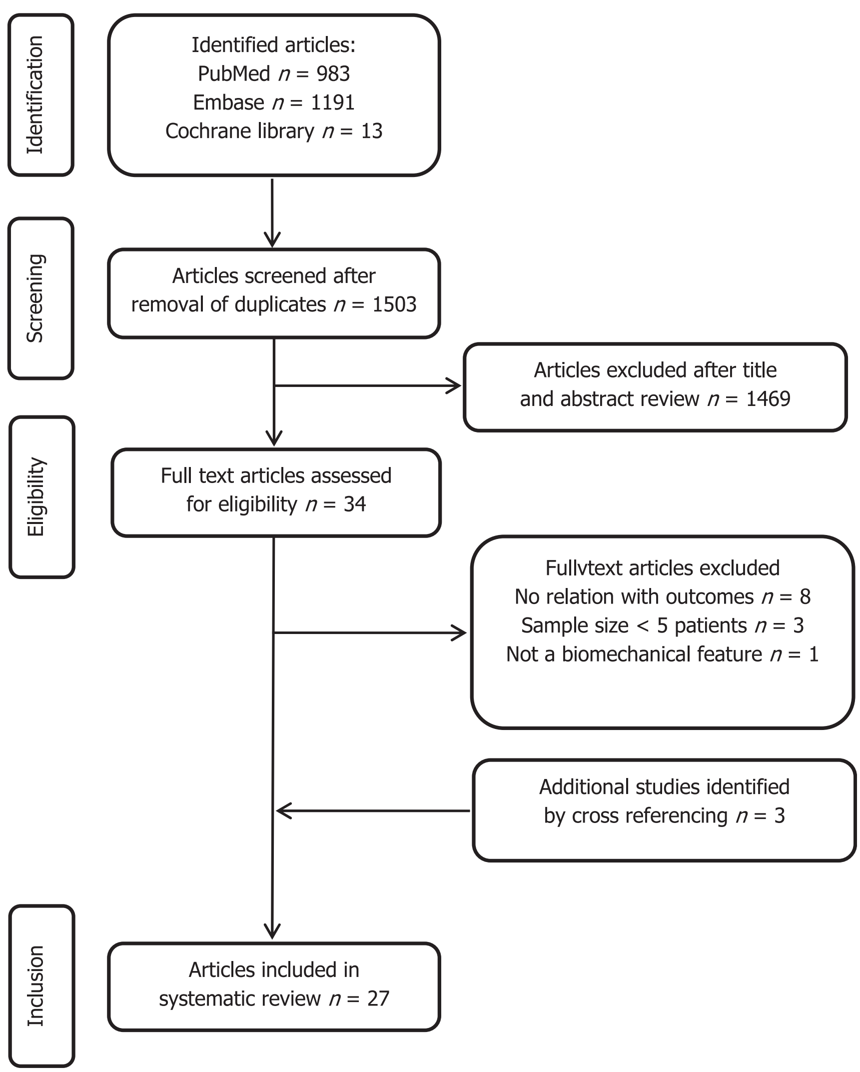

Figure 1. Study selection process.

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