Abdominal Aortic Aneurysm Sac Wall Compliance: How to Measure It, and Whether It Predicts Rupture Potential; Correlation with Finite Element Analysis

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Purpose

Aneurysmal wall stress can predict impending rupture as shown by Finite Element Analysis. Intrasac pressures can be measured, but are difficult to interpret in terms of operational forces at the sac wall. We have attempted to employ ultrasonography and complex software treatment of data to measure compliance in the untreated aneurysm wall, and strain following treatment by open repair (OR) and endovascular aneurysm repair (EVAR) methods. Prior to treatment, intrasac pressure was assumed to approximate systemic pressure. It is not possible to estimate compliance following treatment as it is not possible to measure sac pressure in this setting. In the latter instance we have measured sac wall strain, which is the systolic-diastolic diameter change/diastolic diameter.

Methods

A total of 63 patients were studied using ultrasonographic scanning (HDI5000, Philips Medical). Images acquired as cineloops were analyzed off-site using a wall tracking software HDILab (ATL Corp, Bothell, WA) which measures aortic diameter during cardiac cycles. Brachial blood pressure was measured and Elastic Modulus (Ep) and Stiffness (b) were calculated in the preoperative group. Both parameters are the inverse of compliance. Ep and b were determined at Neck (N), Inflection Points (IP), and Mid Sac (MS) levels. In the postoperative group, measurements of strain were calculated in MS only for technical reasons.

Results

There was no significant difference in compliance between the IP and MS areas preoperatively (Ep 23.2 versus 27.3, b 15.5 versus18.7; $p > .05$ Wilcoxon). However, the neck region (N) was significantly more compliant than the former (Ep 12.7, b 8.5; $p < .001$).

After surgery there was a significant difference in strain parameters between OR and EVAR (0.071 versus 0.010; $p < .001$). There was also a significant difference in strain estimates between EVAR without endoleak and EVAR with endoleak (0.027 versus 0.0163;
$p < .001$) In addition, strain measurements were carried out on 10 patients before and after EVAR. Of eight patients without endoleakage, four exhibited a fall and four showed an increase in strain. In two patients with endoleakage, one showed a fall, and one showed increased strain.

Conclusions

There is significantly higher compliance at the neck of an aneurysm as compared with the inflection point and the mid sac regions. There was no difference in compliance between the latter two regions.

Mid sac strain measurements are highest after open repair, and least after EVAR with endoleak. Strain is significantly higher after EVAR without endoleak as compared with EVAR with endoleak. No consistent pattern of strain parameters was observed in a small cohort of patients before and after EVAR. From this study, strain measurements at mid sac level using ultrasound are unlikely to be helpful in predicting rupture of abdominal aortic aneurysms following EVAR.

Prior to repair, compliance studies, especially over time, may give some information regarding rupture risk, but this will only become evident by creation of a large database, as in the case of the published data from finite element analysis. Magnetic resonance imaging offers the prospect of measuring compliance over the whole sac rather than just the mid sac region, and this unit is currently investigating this modality.