Update on the individualized risk of rupture assessment of abdominal aortic aneurysm using artificial intelligence

A development and validation study for individual prognosis

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Disclosures

None

Background

- Timing of elective surgery for abdominal aortic aneurysms (AAA) to prevent ruptures is based upon the cost effeffient balance between the risk of repair and the risk and rupture

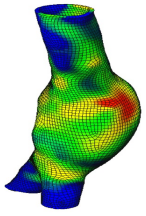
  It stands on two large RCTs from the 90´ties: 5.5 cm

  Supplemented by rapid growth >1 cm/year and symptoms

- BUT
  - About a tenth of ruptures (rAAA) occur in smaller aneurysms
  - Numbers needed to treat: 2
  - Consequently, 1 out of 2 complications or death is due to repair of an AAA that never would have caused problems
    – a genuine ethical dilemma which can´t be solved,- only to be minimized as much as possible

Aim

- Develop a precision-decision tool for rupture risk of abdominal aortic aneurysm (AAA) based upon clinical available data
- Inputs: Features from clinical data and CT imagines
  - Utilize machine learning (AI) for analysis (Shap-fire model, Microsoft)
  - To isolate key risk factors and predict rupture risk as a decision supporting tool
- Compare the diagnostic accuracy of the AI algorithm to using the maximal anterior-posterior (AP) diameter alone
- Last year it improved diagnostic accuracy from AUC=0.75 to 0.86
- Since then: **+ 5 key FEA outcomes calculated by A4Vascops®**



Design and Materials

Case Selection

- All surgeries for rAAA
- Location: Region of Southern Denmark
- Timeframe: 2009 - 2016
- Exclusion:
  - Incorrect classification
  - Previous AAA surgery
  - Not living in the region
  - Missing preoperative scans

Control Selection

- Two matched controls for each case
- Elective surgery for AAA
- Same time frame
- Same exclusion criteria
  - Additional criterion:
    No AAA symptoms leading to a scan

Their medical records and preoperative CT scans were revisited to extract about 130 suspected risk markers
+ 5 key FEA outcomes calculated by A4Vascops®
Rupture was used as the dependent variable

Table 1 - Baseline Characteristics of the case control study population stratified by subgroup

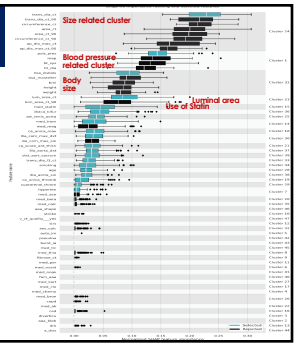
Variables	Total	Training	Validation	P-value
N	637	318	319	NA
Age	73 (69-77)	73 (69-77)	73 (69-78)	.4835
Male sex	540 (84.8%)	266 (83.6%)	274 (85.9%)	.4303
Smoking				.5413
Never	75 (11.8%)	36 (11.3%)	39 (12.2%)	
Former	301 (47.3%)	145 (45.6%)	156 (48.9%)	
Active	239 (37.5%)	126 (39.6%)	113 (35.4%)	
Familiar disposition to abdominal aortic aneurysm	24 (3.8%)	15 (4.7%)	9 (2.8%)	.1743
BMI	27.1 (4.45)	27.1 (4.48)	27 (4.44)	.3621
BSA (DuBois)	1.97 (.212)	1.96 (.212)	1.97 (.212)	.8844
Systolic blood pressure	144.5 (20.92)	143.1 (20.7)	146 (21.07)	.1218
Diastolic blood pressure	82.7 (13.63)	82.4 (13.51)	83 (13.78)	.9404
Medication				
Platelet inhibitors	373 (58.6%)	169 (53.1%)	191 (59.9%)	.0746
Anticoagulatory	64 (10%)	29 (9.1%)	35 (11%)	.4365
Statin	375 (58.9%)	184 (57.9%)	191 (59.9%)	.6005
NSAID	30 (4.7%)	16 (5%)	14 (4.4%)	.7149
Beta-blockers	199 (31.2%)	98 (30.8%)	101 (31.7%)	.8178
Thiazide	150 (23.5%)	66 (20.8%)	70 (21.9%)	.7138
ACE/AT2	283 (44.4%)	150 (47.2%)	133 (41.7%)	.1602
Calcium antagonists	186 (29.2%)	91 (28.6%)	95 (29.8%)	.7409
Bronchodilator	88 (13.8%)	51 (16%)	37 (11.6%)	.1073
Co-morbidities				
Hypertension	414 (65%)	212 (66.7%)	202 (63.3%)	.70
Diabetes	84 (13.2%)	48 (15.1%)	36 (11.3%)	.3716
Ischemic Heart Disease	186 (29.2%)	88 (27.7%)	98 (30.7%)	.3321
Former stroke	14 (2.2%)	9 (2.8%)	5 (1.6%)	.498
Chronic Obstructive Lung Disease	111 (17.4%)	61 (19.2%)	50 (15.7%)	.2821
Former Aortic Dissection	3 (.5%)	2 (.63%)	1 (.3%)	.6051
Autoimmune disease	29 (4.6%)	13 (4.1%)	16 (5%)	.8075
Maximal Anterior-Posterior diameter (cm)	6.14 (5.48-7.59)	6.16 (5.48-7.43)	6.1 (5.48-7.34)	.6491
Transverse diameter (cm)	6.28 (5.51-7.65)	6.32 (5.53-7.63)	6.25 (5.46-7.75)	.6823
Circumference (cm)	19.66 (17.46-23.93)	19.69 (17.48-23.93)	19.61 (17.45-24.12)	.7722
Rupture	211 (33.42%)	104 (33.12%)	107 (33.65%)	.8654

Description of some selected features for the AI model stratified by elective or rupture

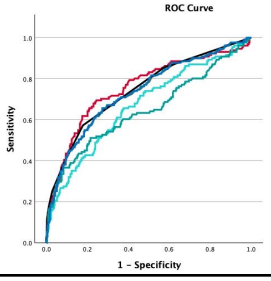
Variables	Total	Elective	Ruptures	P-value
N	637	424	213	NA
Age	73 (68-77)	73 (68-77)	73 (68-78)	.3537
Smoking				.0282
BSA (DuBois)	1.97 (.212)	1.96 (.201)	1.98 (.238)	.2188
Pulse Pressure	61.82 (16.812)	62.75 (15.756)	59.06 (19.444)	.0203
Medication				
Platelet inhibitors	373 (58.6%)	281 (66.3%)	79 (37.1%)	<0.001
Statin	375 (58.9%)	292 (68.9%)	83 (39%)	<0.001
Co-morbidities				
Hypertension	414 (65%)	288 (67.9%)	126 (59.2%)	.0011
CT scan post-processing measurements				
Maximal transversal diameter (cm)	6.73 (1.7)	6.13 (1.2)	7.9 (1.9)	<0.001
Luminal area (cm2)	15.77 (13.2)	12.36 (8.4)	23.27 (18)	<0.001
Distance between iliac bifurcations (cm)	7.31 (1.3)	7.43 (1.3)	7.07 (1.3)	.0004
Distance between lowest renal artery to the aortic bifurcation (cm)	12.72 (2.6)	12.64 (2.8)	12.89 (1.9)	.0037
Calcification-score (agatston) of max. slice over 15mm	175.03 (286.4)	190.7 (309.4)	144.02 (232.8)	.0083
Right iliac artery maximal diameter (cm)	18.59 (9.1)	18.37 (8.4)	19.12 (10.6)	.7715
Anterior Wall thickness (mm)	1.17 (.2)	1.14 (.2)	1.23 (.2)	<0.001
Distance between right iliac bifurcation to the aortic bifurcation (cm)	6.15 (1.4)	6.14 (1.4)	6.17 (1.4)	.4039
Distance between the aortic bifurcation to os sacrum (cm)	6.1 (1.6)	5.89 (1.6)	6.53 (1.7)	<0.001
Transvers outer-to-outer diameter of L3 (cm)	4.5 (.4)	4.48 (.4)	4.54 (.5)	.235
Distance between left iliac bifurcation to the aortic bifurcation (cm)	6.41 (1.6)	6.4 (1.6)	6.43 (1.5)	.4905
Max rupture risk	0.66 (0.43)	0.56 (0.27)	0.93 (0.63)	<0.001
Mean rupture risk	0.33 (0.18)	0.29 (0.11)	0.46 (0.26)	<0.001
Max wall stress	250.7 (73.8)	237.5 (59.2)	286.5 (94.7)	<0.001
Mean wall stress	128.2 (36.5)	212.8 (28.6)	145.8 (48.2)	<0.001
Rupture equivalent diameter	70.2 (39.2)	62.3 (30.7)	91.1 (50.6)	<0.001

Results

- 213 cases of rAAA
- 424 controls of elective repairs
- Variables were clustered when r > 0.7
- Clusters ranked according to imformation value
- 19 features were selected for the model
- Five most correlated (important) features:
  1. Transversal diameter of AAA
  2. Pulse pressure
  3. Body-surface-area (DuBois)
  4. Luminal area (cm^2)
  5. Statins…..
- DM, sex and family disposition was not included
- **Neither were any of the core outcomes of FEA**

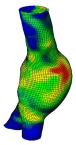


The reason for FEA outcomes not to be included - it didn´t prove add value and wasn´t better that size itself



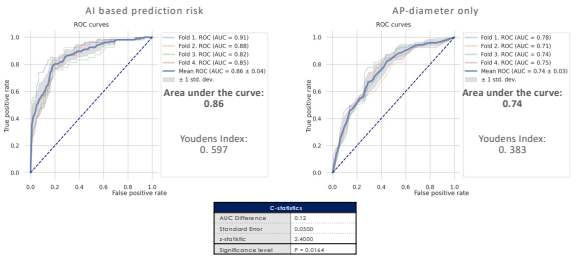
Source of the Curve

- Maximal AP diameter
- Max. wall rupture risk
- Max. wall stress
- Mean wall rupture risk Index
- Mean wall stress
- Rupture Risk Equivalent Diameter



Area Under the ROC Curve				
		Std.		95% CI
Test Result Variable(s)	Area	Error	p	
Max. Wall stress	.869	.029	.000	.813 .926
Mean wall stress	.646	.031	.000	.585 .707
Max.wallrupture risk	.734	.027	.000	.681 .786
Rupture risk equivalent diameter	.735	.027	.000	.683 .788
Mean rupture risk index	**.745**	**.026**	**.000**	**.694 .797**
Maksimal APDiameter	**.756**	**.027**	**.000**	**.703 .808**

Results – Diagnostic accuracy



C-statistics	
AUC Difference	0.12
Standard Error	0.0500
z-statistic	2.4000
Significance level	P = 0.0164

Conclusions

- An AI based algorithm consisting of 19 rupture risk markers are significantly better at identifying ruptures compared to AP diameter alone by improving AUC by 12%
- It holds the potential to decrease the numbers needed to treat to prevent one rupture
- Adding key rupture risk outcomes of finite element analysis didn´t improve this further