AORTIC DISEASES

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Thoracic Aortic Aneurysm

ANATOMY & NATURAL HISTORY :

- Ascending Aorta 51%
- Aortic Arch 11%
- Descending Aorta 38%
- Dissection 53%,

Atherosclerosis 29%, Aortitis 8%, Cystic medial necrosis 6%, 25% Concomitant abdo aneurysm

Thoracic Aortic Aneurysms

- **Etiology**
- **Cystic medial degeneration**

- Smooth muscle cell necrosis & elastic fiber degeneration →cystic spaces in the media
- Most often involves the root and ascending aorta, but can also involve the entire aorta – Seen commonly in Marfan's syndrome
- "Forme fruste" Marfan's syndrome associated with TAA but without typical phenotype

Thoracic Aortic Aneurysms: Etiology

- **Genetic**

– **Bicuspid aortic valve** :

- 25-50% of those with bicuspid valves have a dilated ascending aorta

- Increased risk for aortic dissection or rupture

- BAV may not be clinically evident

- **Familial Thoracic Aortic Aneurysm Syndrome :**

- Aortic root or ascending aortic aneurysm

- Aortic dissection

- Screen all 1st degree relatives of those

Thoracic Aortic Aneurysms: Etiology

Atherosclerosis

- Begins with intimal plaques →secondary degeneration of the underlying media
- –Abdominal aorta >> descending aorta > ascending aorta
- Often associated with thoracoabdominal aneurysms

Uncommon causes

– Clinically silent prior aortic dissection

– Syphilitic aortitis – late consequence

– Vasculitis (Takayasu's arteritis Giant cell arteritis)

Infectious aortitis (mycotic aneurysm)

Aortitis

- **Giant cell aortitis**:

– Occurs in approximately 15% of those with GCA

– Older, women, sx of PMR

– May present with fevers, occlusive symptoms

– Treatment with corticosteroid therapy

- **Takayasu arteritis**

– Fevers in the acute phase and occlusive sxs during chronic phase

– Disease of Asian women, but may be seen in all races and in men

– Aortic and pulmonary artery aneurysms may develop during acute phase; left subclavian usual

– Visceral occlusions not uncommon

Thoracic Aortic Aneurysms: Clinical Manifestations

- Most (50-75%) are asymptomatic at time of diagnosis
- Aortic insufficiency
  - Murmur, +/- secondary CHF
  - Dilatation of sinuses of Valsalva (aortic root) or proximal ascending aorta, incomplete AoV closure
- Large aneurysms can cause symptoms from mass effect:
  - Pain, cough, hoarseness, dysphagia
- Acute aortic syndrome: dissection, Intramural hematoma, rupture

Genetic Disorders: Thoracic Aortic Disease

Genetic Syndrome	Common Clinical Features	Genetic Defect	Diagnostic Test
Marfan Syndrome	Skeletal features Ectopic lentle	*FBN1* mutations*	Ghent diagnostic Criteria, DNA for sequencing
Loeys-Dietz Syndrome	Bifid uvula or cleft palate Arterial tortuosity Hypertelorism	*TGFBR2* or *TGFBR1* mutations	DNA for sequencing
Ehlers-Danios Syndrome	Thin, translucent skin GI rupture Rupture of gravid uterus Rupture of medium to large arteries	COL3A1 mutations	DNA for sequencing Dermal fibroblasts for analysis of type 3 collagen
Turner Syndrome	Short stature Primary amenorhea BAV Aortic coarctation	45 X karyotype	Cells for karyotype analysis

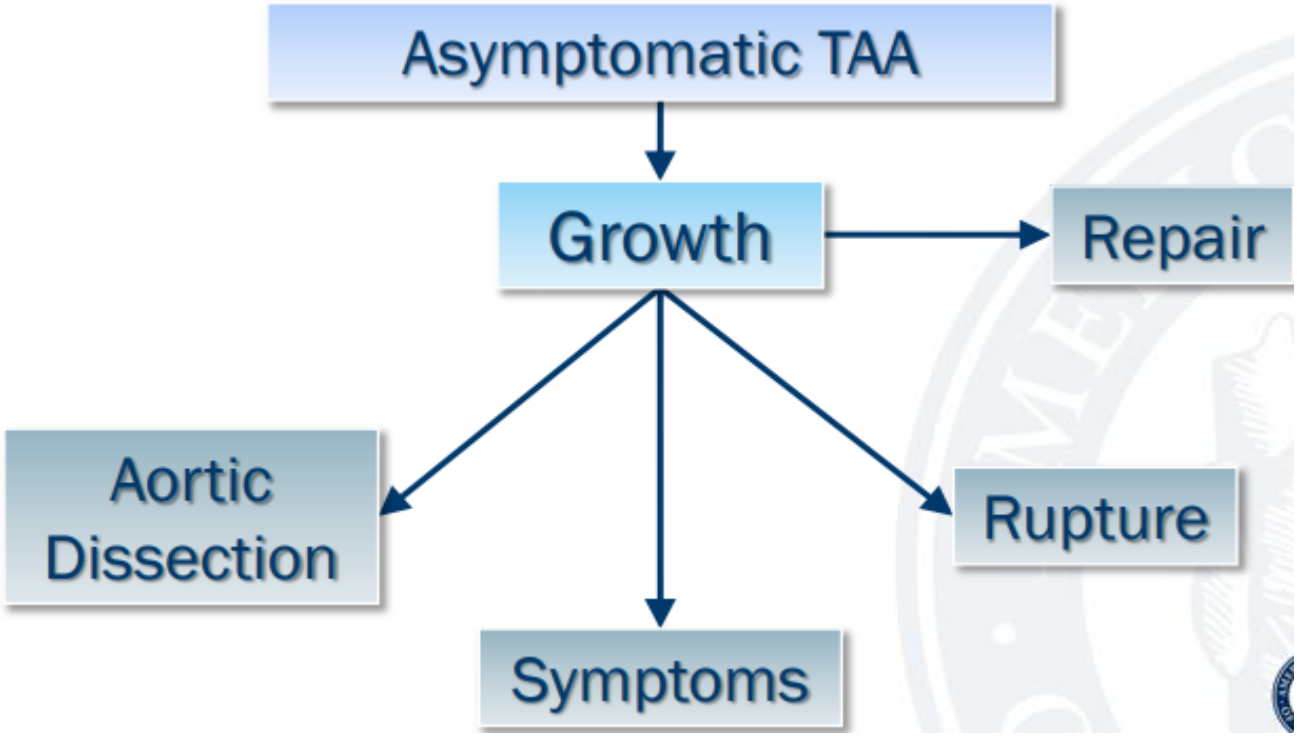
Familial TAAD Genes: Genetic Heterogeneity

ACTA2	α-actin	10-14%
MYH11	myosin heavy chain	1%
MYLK	myosin light chain kinase	1%
PRKG1	cGMP-dependent kinase I	1%
TGFBR1	TGF-β receptor type I	2%
TGFBR2	TGF-β receptor type I	4 %
SMAD3	Smad3	5%
TGFB2	TGF-β2	1%
FBN1	fibrillin-1	4 %
FTAAD families with identified gene		30%

Which Diagnostic Modality to Choose: A General Guideline

- Routine TAA: CT
- Contraindication to IV contrast: MRI
- Tortuous aorta or arch aneurysm: CT with 3-D reconstruction or MRI
- Disease of the aortic root: Echocardiogram

Thoracic Aortic Aneurysms: Natural History

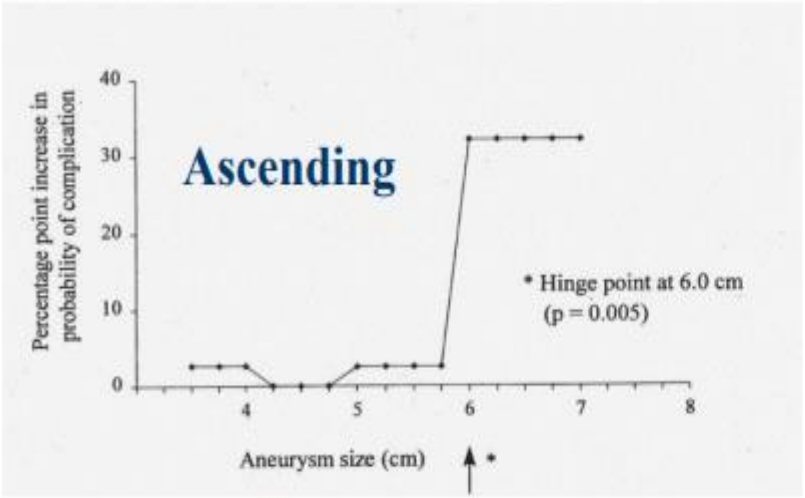


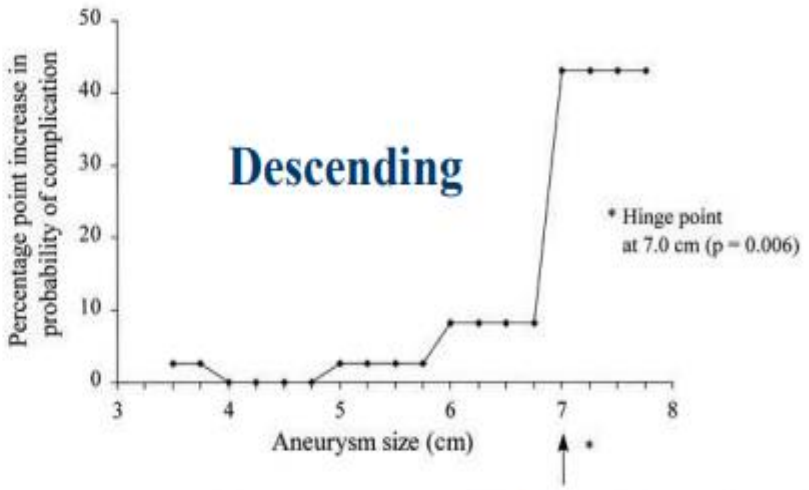
Ascending / Descending Aneurysms WHEN SHOULD WE OPERATE?

- **Effect of size on risk of complications**

– Ascd: Beyond 6 cm →→30% risk of rupture/dissection

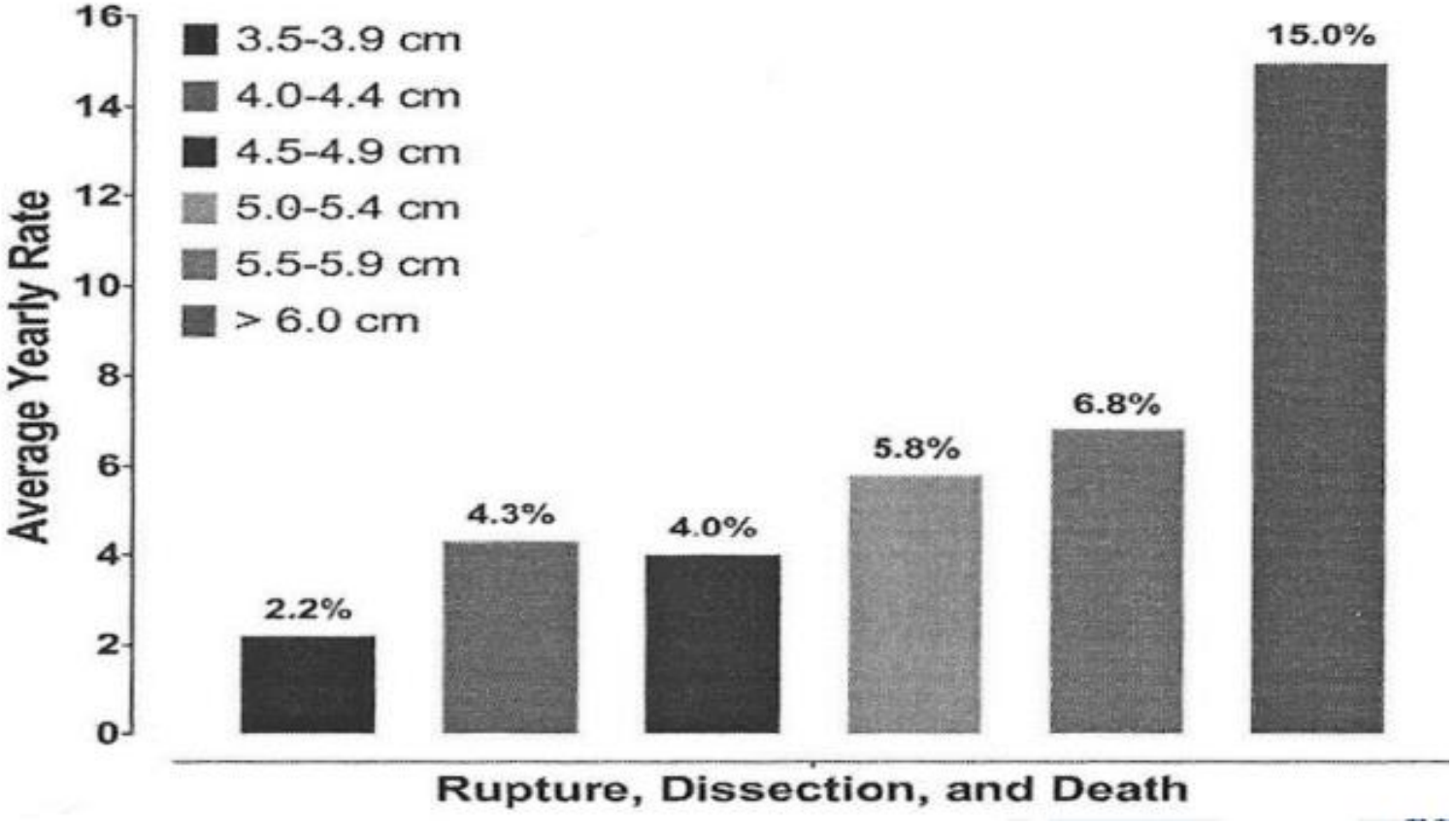
– Dsec: Beyond 7 cm →→ 40% risk of rupture/dissection





Elective surgery at 5.5 cm Ascd, 6.5 Desc - before the "hinge point"

Average Yearly Rates of the Composite Endpoint of Rupture, Dissection and Death at Various Aortic Sizes



The Revised Ghent Nosology for the Marfan Syndrome

In the absence of family history:

- (1) Ao (Z≥2) + EL = MFS
- (2) Ao (Z≥2) + FBN1 = MFS
- (3) Ao (Z≥2) + Syst (≥7pts) = MFS
- (4) EL + FBN1 with known Ao = MFS

In the presence of family history:

- EL + FH of MFS (as defined above) = MFS
- Syst (≥7 pts) + FH of MFS (as defined above) = MFS
- Ao (Z≥3) + FH of MFS (as defined above) = MFS

Systemic Features Scoring (> 7 points)

Feature	Value
Wrist and Thumb sign	3
Wrist or Thumb sign	1
Pectus Carinatum deformity	2
Pectus Excavatum or chest asymmetry	1
Hindfoot deformity	2
Plain flat foot (pes planus)	1
Pneumothorax	2
Dural Ectasia	2
Protrusio acetabulae	2
Reduced US/LS ratio and increased arm span/height	1
Scoliosis or thoracolumbar kyphosis	1
Reduced elbow extension	1
3 or 5 facial features	1
Skin striae	1
Myopia (>3 diopters)	1
Mitral valve prolapse	

Diameter Thresholds for Elective Repair

Clinical Condition	Diameter Threshold	ACC/AHA Class/LOE	Comments and Modifiers
Degenerative, not associated with genetic syndromic or non-syndromic condition leading to earlier AoD	5.5-6.0cm	Class: I LOE: C	• Growth rate >0.5/year • 5.5cm by STS guideline • Consider adjustment for smaller body size
Marfan Syndrome	5.0cm	Class: I LOE: C	• <5.0cm if family history of AoD at smaller diameter, rapidly expanding or significant AI • 4.0cm for women contemplating pregnancy
Familial TAAD	4.0-5.0cm	Class: I LOE: C	• Lower diameter if family history of AoD at smaller diameter
Bicuspid Ao Valve	5.0-5.5cm	Class: I LOE: C	• 5.0 cm if family history or AoD or ≥0.5 cm growth
Incidental to other cardiac surgical procedure	>4.5cm	Class: I LOE: C	
Growth rate when diameter below threshold for condition	0.5cm/year	Class: I LOE: C	

Diameter Thresholds for Elective Repair

Clinical Condition	Diameter Threshold	ACC/AHA Class/LOE	Comments and Modifiers
Loeys-Dietz Syndrome or confirmed TGFBR1 or TGFBR2 mutation (includes some patients with FTAAD)	≥ 4.2 cm TEE ≥ 4.4-4.6 (CT)	Class: IIA LOE: C	
Ehlers-Danlos Syndrome, vascular type	4.0-5.0cm	Class: I LOE: C	• Tissue fragility problematic
Turner Syndrome	4.0-5.0 cm	Class: I LOE: C	• ASI >2.5cm/m^2

Surgical Approach: Descending Aorta

- Newer techniques have reduced frequency to 3%
  – Regional hypothermic protection of spinal cord with epidural cooling during repair
  – Reimplantation of patent intercostal arteries
  – Cerebrospinal fluid drainage
- Risk of post-op complications: MI, CHF, stroke, renal failure, hemorrhage, pneumonia, respiratory failure, and sepsis

Thoracic Aortic Aneurysms: Endovascular Stent-Graft Repair

- Alternative to surgery for some descending TAAs
- Far less invasive than surgery with fewer postoperative complications
- “Newer devices and more precise stent-graft deployment show higher success rates and lower complication rates

Survival in Open Surgical Repair (OSR) vs. Thoracic Endovascular Aortic Repair (TEVAR)

No. of patients at risk:	0 yr	1 yr	2 yr	3 yr
TEVAR	1,689	1,234	925	681
OPEN	9,466	6,339	5,404	4,621

TAA Management Medical Therapy

- Decrease dP/dT with beta blockers – Mainstay of therapy – Use maximal dose maximal tolerated
- Goal is HR in 50's-60's, SBP 110-125
- Additional antihypertensives as needed – ARB's, ACE inhibitors, CCB, diuretics
- Monitor BP regularly

TAA Management Serial Imaging

- **Serial imaging studies to follow aneurysm growth**
  - First scan in 6 months after TAA detected
  - Then, annually for life
    - Contrast-enhanced CT or MRA
      - Use same modality each time
      - 3-D imaging for aortic root, arch, or tortuous aorta
    - Image abdominal aorta also if involved
    - Interpretation must include measurements
      - “No significant change” may be up to 3mm larger
      - Both size and rate of growth are important

Medical Therapies

- **Class: I**
  - Beta blocker <130/80; lower is better especially in acute presentation; Monitor BP closely
  - Smoking cessation
  - Other CV risk reduction measures
- **Class: IIA**
  - Losartan (ARB) for MFS

If new diagnosis not at threshold for repair

– 3.5 - 4.4cm - annually

– 4.5 - 5.5cm - 6 months depending

Follow Them: Suggested After Repair

Pathology	Interval	Study
Acute dissection	Before discharge, 1 mo, 3 mo, 6 mo, yearly	CT or MR, chest plus abdomen
Chronic dissection	Before discharge, 1y, 2 to 3y	CT or MR, chest plus abdomen
Aortic root repair	Before discharge, yearly	TTE
AVR plus ascending	Before discharge, yearly	TTE
Aortic arch	Before discharge, 1y, 2 to 3y	CT or MR, chest plus abdomen
Thoracic aortic stent	Before discharge, 1mo, 2mo, 6mo, yearly or 30 days	CXR, CT, chest plus abdomen
Acute IMH/PAU	Before discharge, 1mo, 3mo, 6mo, yearly	CT or MR, chest plus abdomen

Acute Aortic Syndromes

- Aortic dissection (classic)
- Intramural hematoma (IMH)
- Penetrating atherosclerotic ulcer
- Rapidly expanding aortic aneurysm

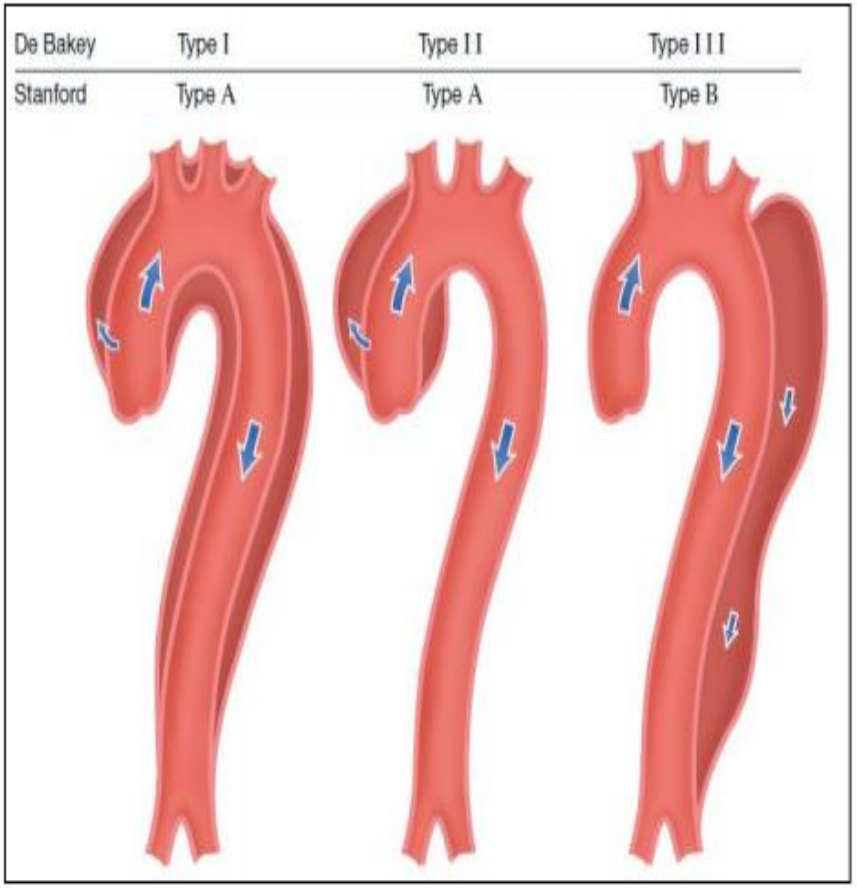
AAS: Classification

DeBakey

- Category I: Dissection tear in the ascending aorta propagating distally to include at least the aortic arch and typically the descending aorta
- Category II: Dissection tear only in the ascending aorta
- Category III: Dissection tear in the descending aorta propagating most often distally
- Category IIIa: Dissection tear only in the descending thoracic aorta
- Category IIIb: Tear extending below the diaphragm

Stanford

- Type A: All dissections involving the ascending aorta irrespective of the site of tear
- Type B: All dissections that do not involve the ascending aorta; note that involvement of the aortic arch without involvement of the ascending aorta in the Stanford classification is labeled as Type B



ESC : Acute (≤14 days), Sub-acute (2-6 weeks), Chronic (>6 weeks)

IRAD : Hyperacute (30 days), Acute (2-7 days), Sub-acute (8-30days), Chronic (>30 days)

Etiology of Aortic Dissection: Risk Factors

- Advanced age (63y)
- Male gender (65%)
- History of hypertension (72%)
- Known aortic aneurysm (16%)
- Marfan's syndrome (5%)
- Bicuspid aortic valve (5%)
- Peripartum period of pregnancy
- Cardiac catheterization (2%)
- Prior cardiac surgery (18%)

Aortic Dissection: Introduction

- Incidence ? 6/100,000 per year
- 50% die at home
- Life-threatening condition
  - Early mortality 1-2% per hour
    - Survival is improved with prompt therapy
- Presentation may be classic, or may be non-specific with risk factors that are not evident

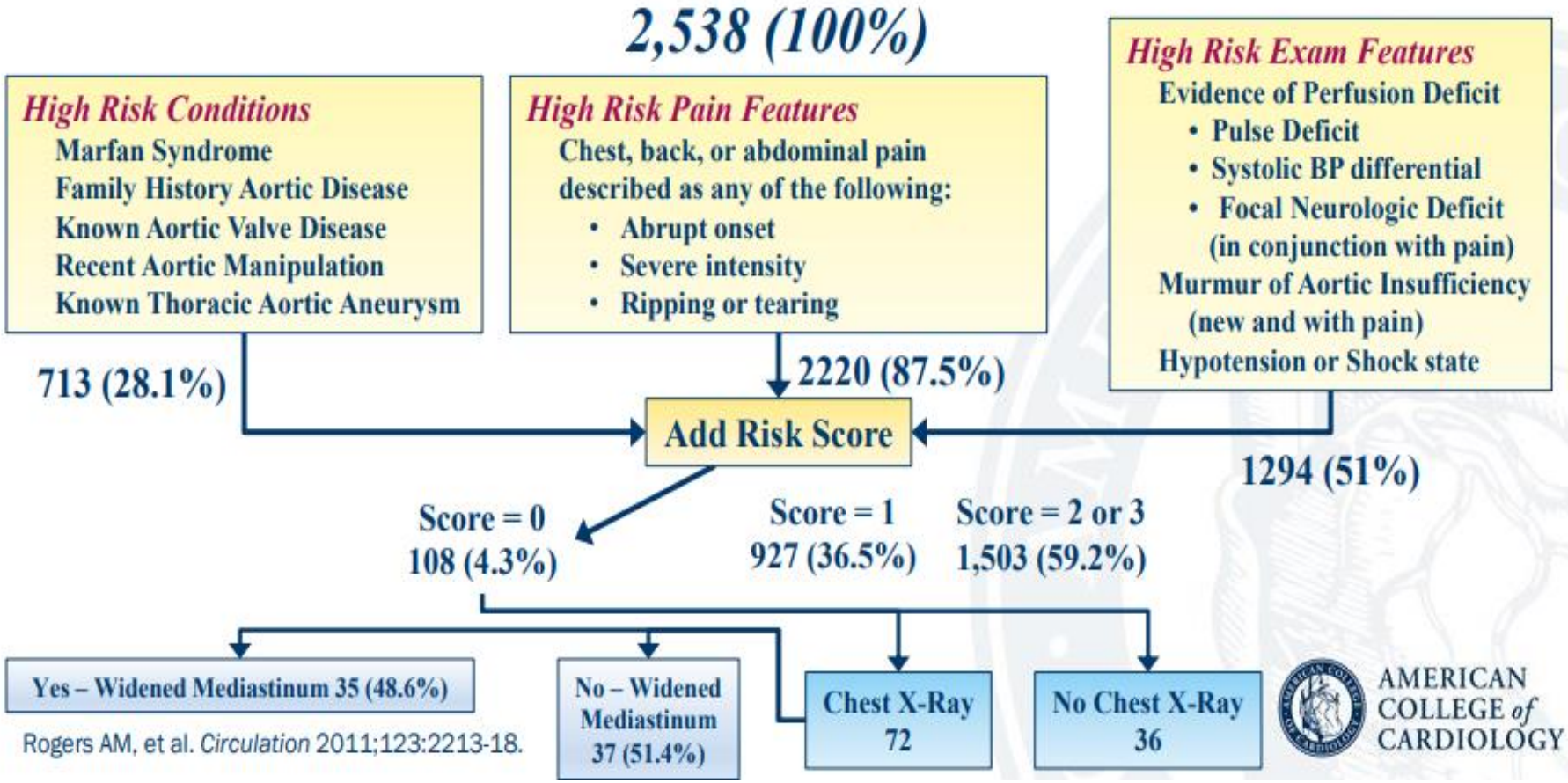
Features of the Classic Presentation

- Acute chest pain and/or interscapular pain
- Pain is abrupt in onset
- Pain is severe, may be worst ever
- Pain is worst at the outset
- Pain is often described as tearing or stabbing
- Pain may migrate
- Patients are restless, can’t get comfortable

International Registry of Aortic Dissection (IRAD): Presenting Symptoms

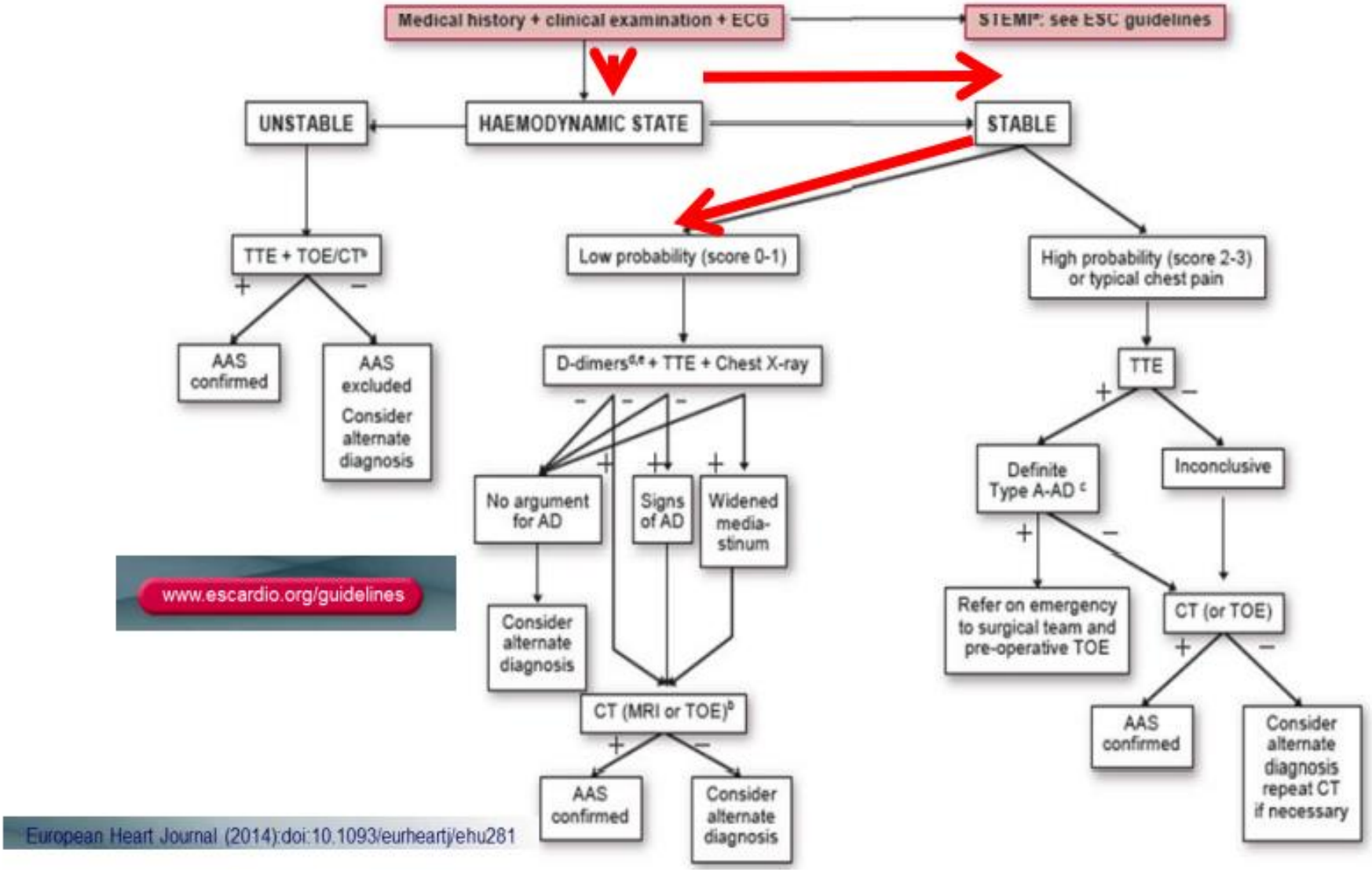
Variable	All	Type A	Type B	P-value
Pain	95.5%	93.8%	98.3%	0.2
Abrupt	84.8%	85.4%	83.8%	NS
Anterior	60.9%	71.0%	44.1%	<0.001
Back	53.2%	46.6%	63.8%	<0.001
Sharp	64.4%	62.0%	68.3%	NS
Tearing	50.6%	49.4%	52.3%	NS
Syncope	9.4%	12.7%	4.1%	NS

Sensitivity of ACC/AHA Guidelines for Acute Aortic Dissection



Rogers AM, et al. *Circulation* 2011;123:2213-18.

Emergency Room: Acute Chest Pain



European Heart Journal (2014) doi:10.1093/eurheartj/ehu281

Intramural Hematoma: Variant of Aortic Dissection

- 15% of those presenting with AAS
- It has a distinctly different and less obvious appearance on aortic imaging studies
- Natural history of acute IMH appears to be similar to classic aortic dissection
- Risk factors and the presenting signs & symptoms are the same as for aortic dissection

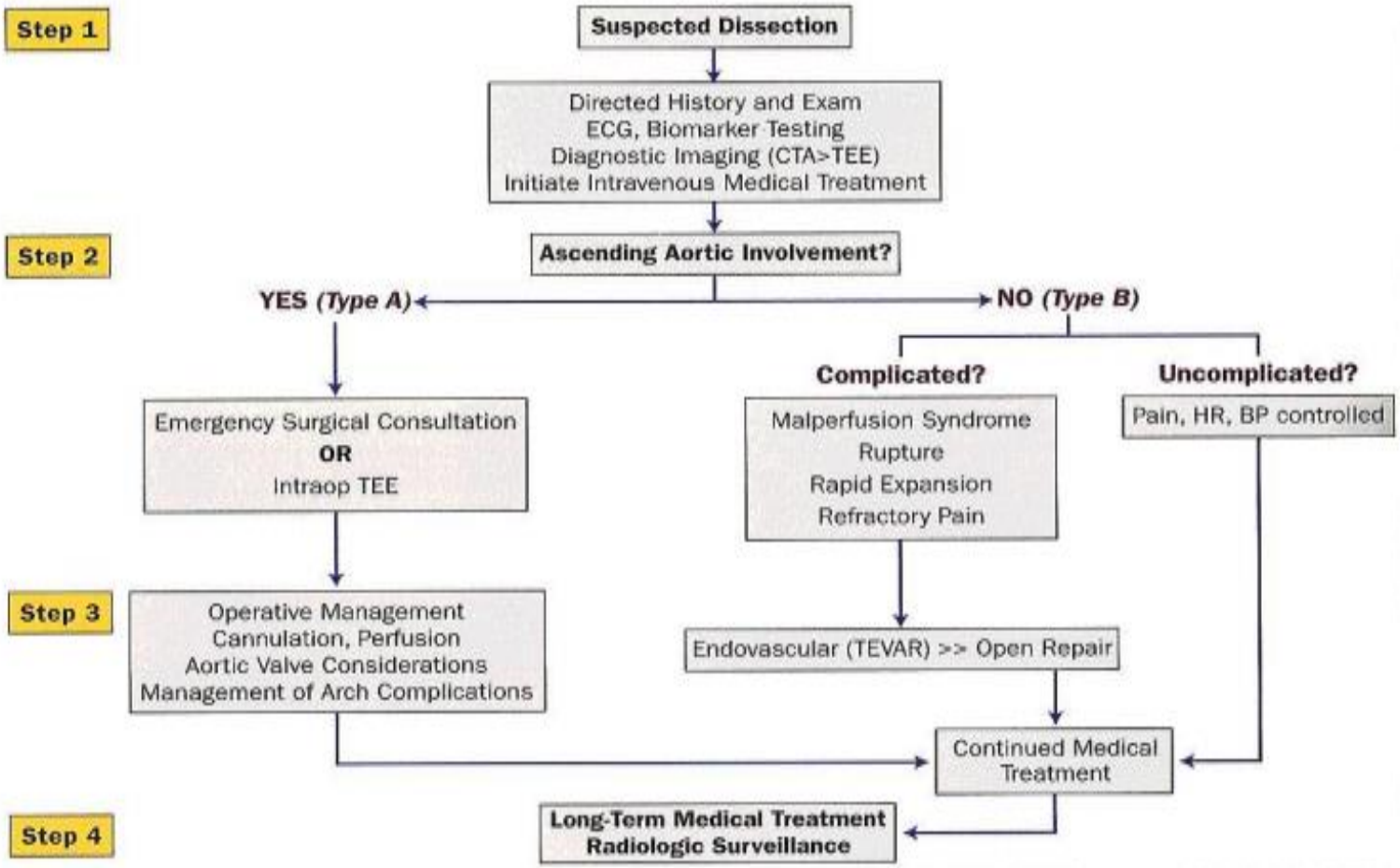
Traumatic Aortic Transection

- Catastrophic aortic injury typically related to rapid deceleration
- Typically occurs at distal aortic arch, due to ‘fixture’ of the aorta at the site of ligamentum arteriosum
- Most often results in death at scene of injury; if survival, time is of the essence to make the diagnosis and surgically intervene
- Role of endovascular therapies unclear

Therapy for Acute Aortic Syndromes A General Guideline

- **Proximal aortic syndromes:**
  - Up-front medical therapy should include beta blockade and intravenous vasodilator therapy
  - Barring contra-indication, urgent surgery is almost always indicated
  - Pre-operative evaluation generally should not include cardiac catheterization
  - Pericardiocentesis for cardiac tamponade discouraged unless patient in extremis
- **Distal aortic syndromes:**
  - Up-front medical therapy should include beta blockade and intravenous vasodilator therapy
  - Barring urgent indication for the operating room, medical therapy appears to be comparable (if not superior) to routine surgical therapy
  - Indications for surgery: rupture, impending rupture, mesenteric (or other branches) ischemia, uncontrollable pain, expansion of aortic size
  - Role of endovascular therapy relative to medical therapy unclear

Management Pathway: Acute Aortic Dissection



Surgical Indications for Acute and Chronic Aortic Dissection

Acute Dissection	Chronic Dissection
Type A: **All patients**	**Type A:** Maximal dimension ≥5.5 cm Marfan syndrome with maximum dimension ≥4.5-5 cm Increase in dimension ≥1 cm/yr Severe aortic regurgitation Symptoms suggestive of expansion or compression
Type B: **With complications** Rupture Extension Rapid aneurysm expansion Malperfusion syndrome Marfan syndrome?	**Type B:** Maximal dimension ≥6 cm Increase in dimension ≥1 cm/yr Symptoms suggestive of expansion or compression

Subsequent "Therapy" for Aortic Dissection

- Lifelong treatment of hypertension and atherosclerotic risk factors
- Maintain BP ≤ 120/80mmHg
- Image aorta serially
  - 1, 3, 6 months after discharge
  - 1 or 2x / year thereafter
- Educate the patient – what to do if recurrent symptoms

Penetrating Aortic Ulcer

- Pain syndrome similar to dissection or enlarging aneurism
- More common in descending portion of the aorta
- Management depends on lateral extent and vertical extent of lesion

Intramural Hematoma

- Questionable relationship to dissection
- Etiologies include:
  - Rupture from vasa vasorum
  - Unseen or very small tear of aortic intima
- Management currently similar to aortic dissection; however, recent literature from Asia suggesting altered prognosis

Assessment of the Aorta

CT

- Advantages
  - Rapid and available to the ED
  - Visualize surrounding structures
  - Assess coronary arteries
- Disadvantages:
  - Ionizing radiation
  - Nephrotoxic contrast
  - Little physiologic information

TEE

- Advantages:
  - No ionizing radiation
  - Physiology and flow information
  - Portable and ease of performance in ED or ICU setting
- Disadvantages:
  - Esophageal intubation
  - Difficulty viewing aortic arch
  - Limited views chest anatomy

MRI

- Advantages:
  - No ionizing radiation
  - Physiology and flow information
  - Relationship to surrounding structures
- Disadvantages:
  - Implanted devices
  - Availability
  - Procedure duration

Abdominal Aortic Aneurysm

- **Male: Female 4 - 5:1**
- **Deaths/Year From AAA ~ 15,000**
- **Mortality from elective surgical repair 3 - 4%**
- **Mortality from rupture 80-90%**

Risk Factor	Comments
Smoking	Risk increases with duration of smoking: Smoking also increases risk of aneurysm expansion and rupture
Male Gender	Men are 5-10 times more likely than women to have an abdominal aneurysm
Age	Typically appearing after age 45 in men, age 65 in women
Family History of Abdominal Anuerysm (First degree relative)	Confers a twofold (and for siblings a fourfold) increased risk of abdominal aortic aneurysm
Hypertension	Treat hypertension effectively in patients with abdominal aortic aneurysm
Hyperlipidemia	Statin therapy to treat hyperlipidemia is reasonable
Atherosclerosis	There is a clear association of atherosclerosis and abdominal aneurysms, but it remains unclear if the relationship is casual

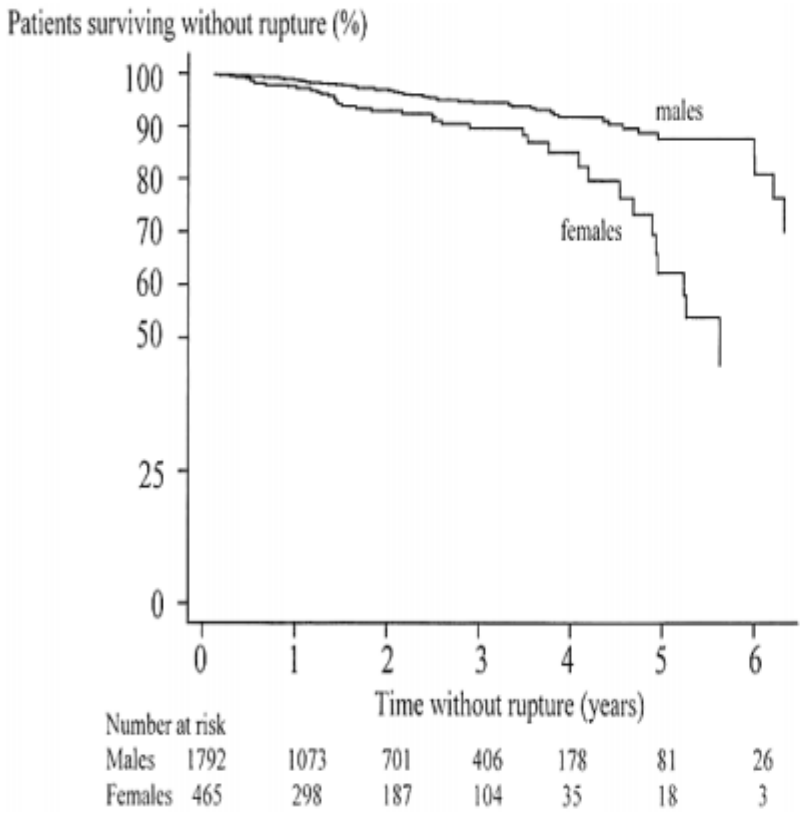
AAA Risk: ADAM Study

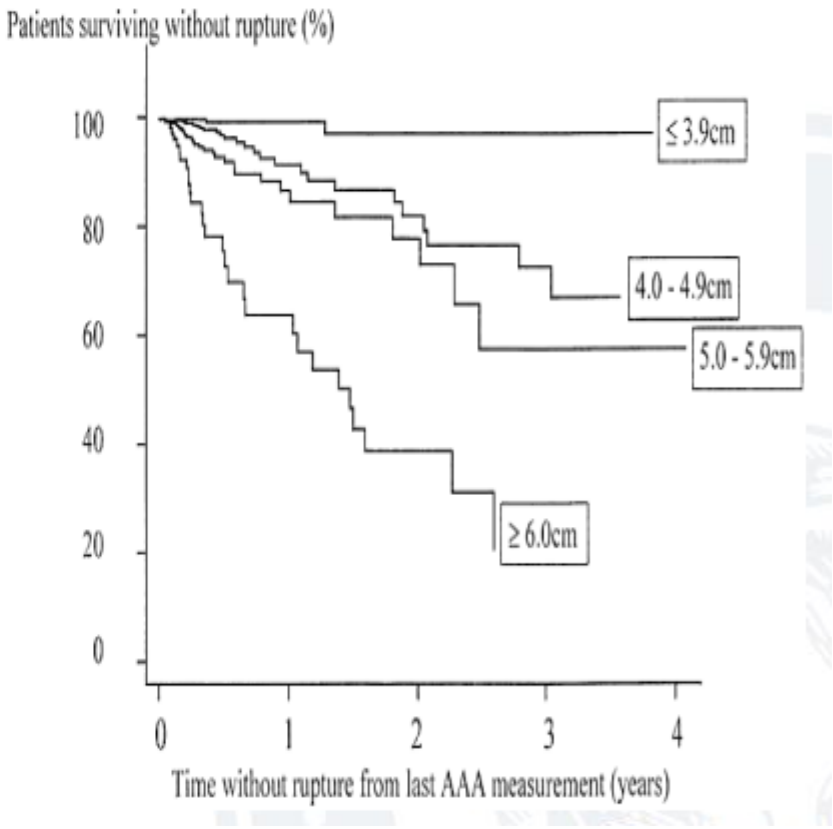
	OR	CI
Age	1.81	(1.65-1.99)
Gender (female)	0.12	(0.02-0.88)
Black Race	0.59	(0.39-0.91)
Family Hx	1.94	(1.45-2.59)
Ever smoked	4.45	(3.27-6.05)
Diabetes	0.50	(0.39-0.65)

AAA *Rupture* Risk Factors

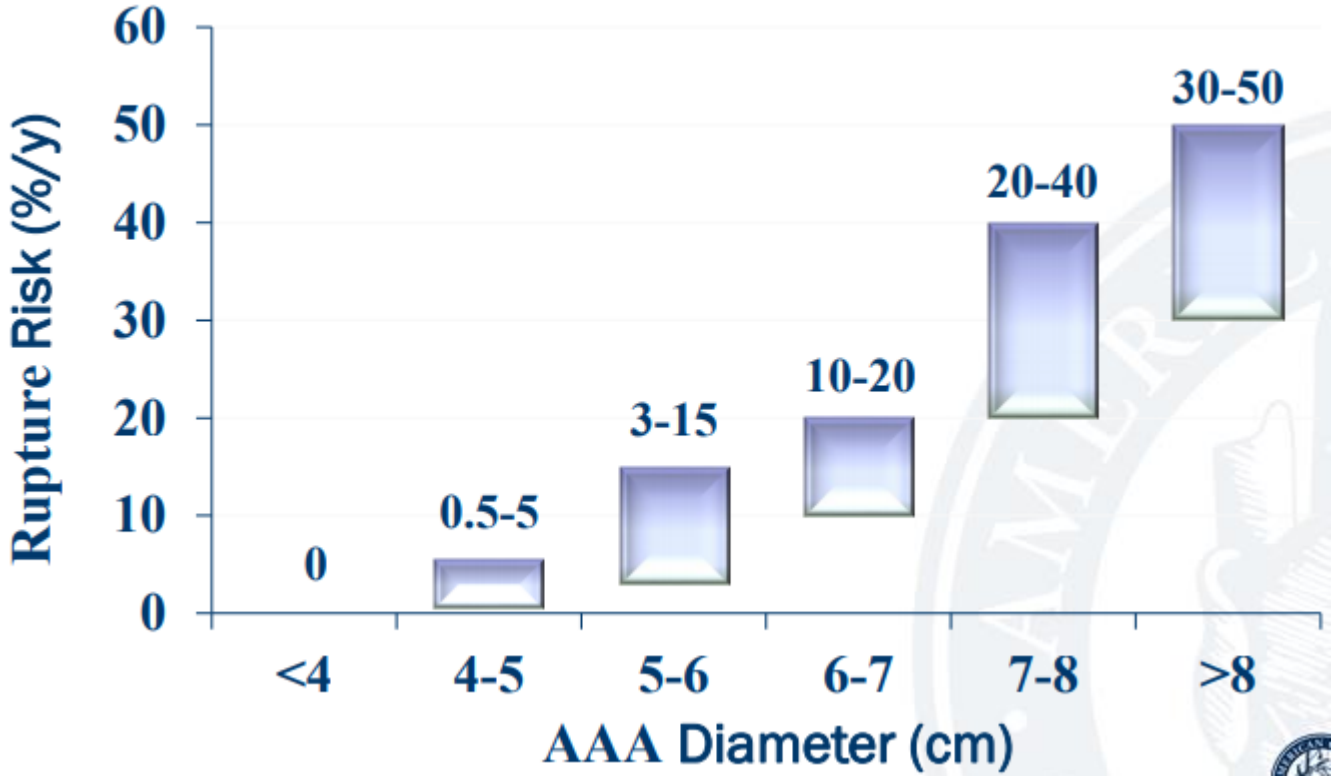
	Hazard	p
Age	1.03	0.038
Gender (female)	3.00	<0.001
AAA Size	2.94/cm	<0.001
Current smoker	1.40	0.06
COPD (FEV1)	0.62/1	<0.001
Mean BP	1.02/mm	0.037

AAA Rupture Risk Factors





Estimated Annual Rupture Risk



Rupture Risk

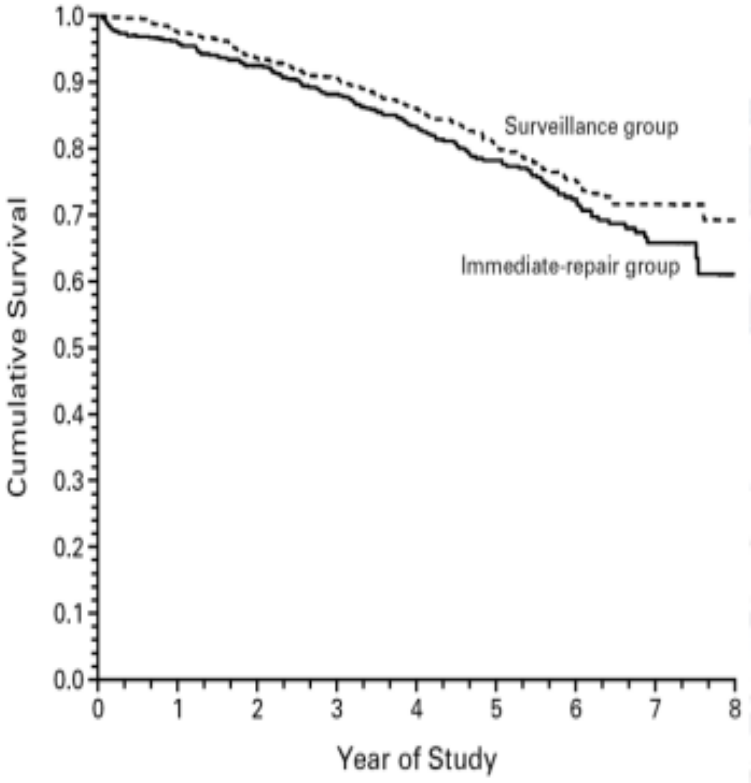
	Low Risk	Average Risk	High Risk
Diameter	<5cm	5-6cm	>6cm
Expansion	<0.3cm/y	0.3-0.6cm/y	>0.6cm/y
Smoking/COPD	None, mild	Moderate	Severe/steroids
Family History	No relatives	One relative	Numerous Relatives
Hypertension	Normal BP	Controlled	Poorly Controlled
Shape	Fusiform	Saccular	Very eccentric
Wall stress	Low (35 N/cm^2)	Mdm. (40 N/cm^2)	High (45 N/cm^2)
		Male	Female

US Preventive Services Task Force Recommendations for Screening for AAA

- One time ultrasound screening of men aged 65-75 years who have ever smoked (B Recommendation): Prevalence 6-7%
- Selectively offer screening for men aged 65-75 years who have never smoked (C Recommendation): Prevalence ~2%
- Insufficient evidence-balance of benefit and harms to screening women 65-75 years who have ever smoked (I Statement): Prevalence 0.8%; overall; 2% active smokers
- Recommends against routine screening for women who have never smoked (D Recommendation): Prevalence 0.03-0.6%

AAA Risk: ADAM Study

- • Patients age 50-79
- Aneurysm size 4.0-5.4 cm
- 1136 patients randomized to immediate repair or surveillance
- CT or US every 6 months
- Surgery recommended for surveillance group if size ≥ 5.5 cm
- Mean follow-up 4.9 years



No. at Risk								
Surveillance	567	552	530	513	393	274	183	76
Immediate repair	569	545	526	502	383	264	172	67

Independent Risk Factors for Operative Mortality After Elective Abdominal Aortic Aneurysm Repair

Risk Factor	Odds ratio	95% CI
Creatinine >1.8mg/dL	3.3	1.5-7.5
Congestive Heart Failure	2.3	1.1-5.2
ECG Ischemia	2.2	1.0-5.1
Pulmonary Dysfunction	1.9	1.0-3.8
Older Age (per decade)	1.5	1.2-1.8
Female Gender	1.5	0.7-3.0

Aortic Aneurysm Stent-Grafting

- Anatomic limitations
- ? Surgical candidates
- ? Importance of complete exclusion
- ? Size limitations

Endoleaks After EVAR

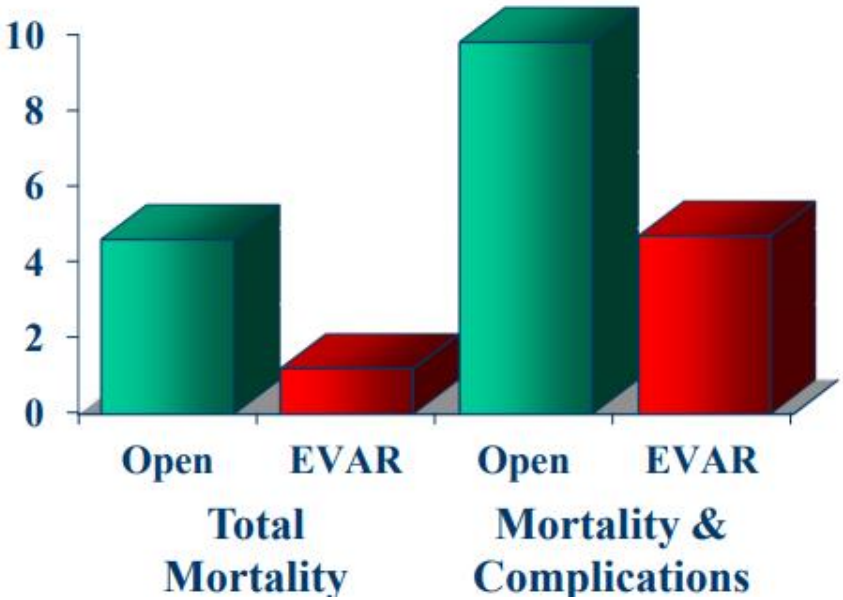
Type I: Leak at margin of a stented cuff

Type II: Retrograde blood flow through branch vessels that were excluded from lumen

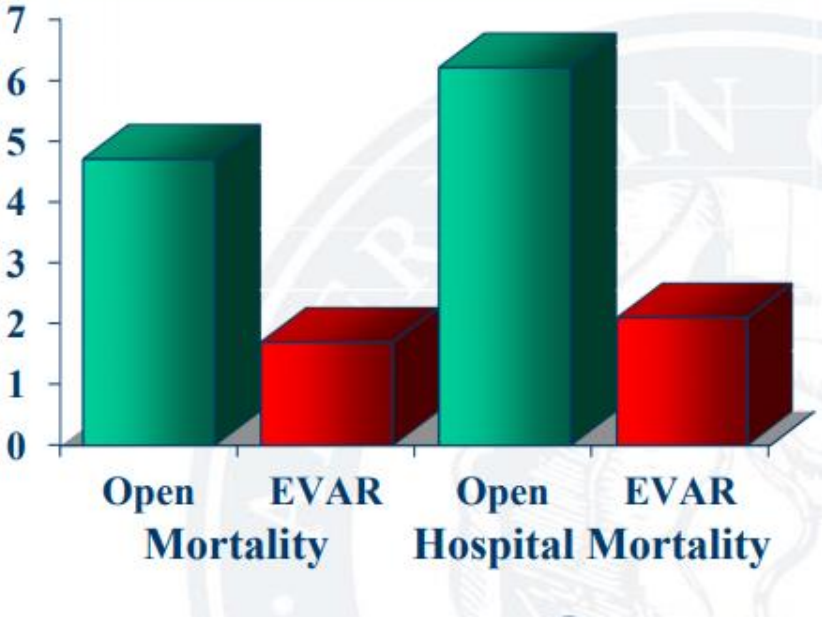
Type III: Blood leaks directly through graft material (indication for further repair)

Type IV: Diffuse leakage through porous graft material (usually resolves spontaneously)

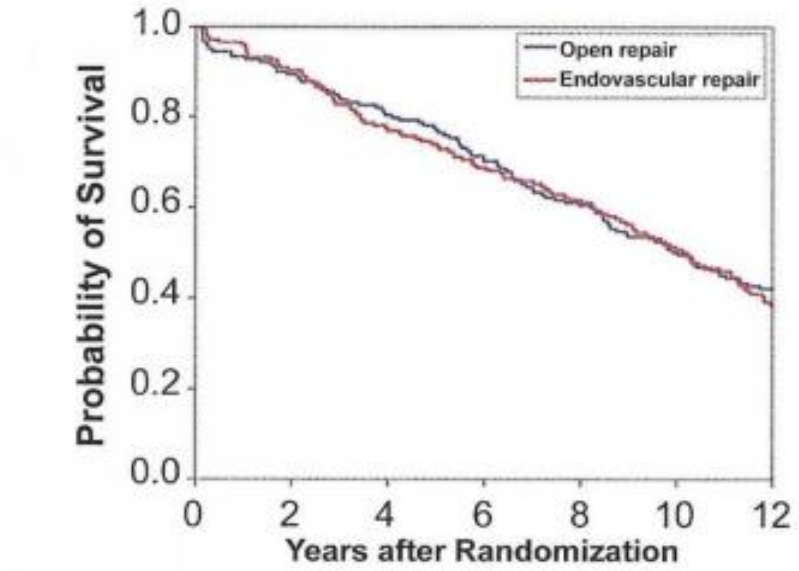
Endovascular AAA vs. Open Repair: DREAM Study



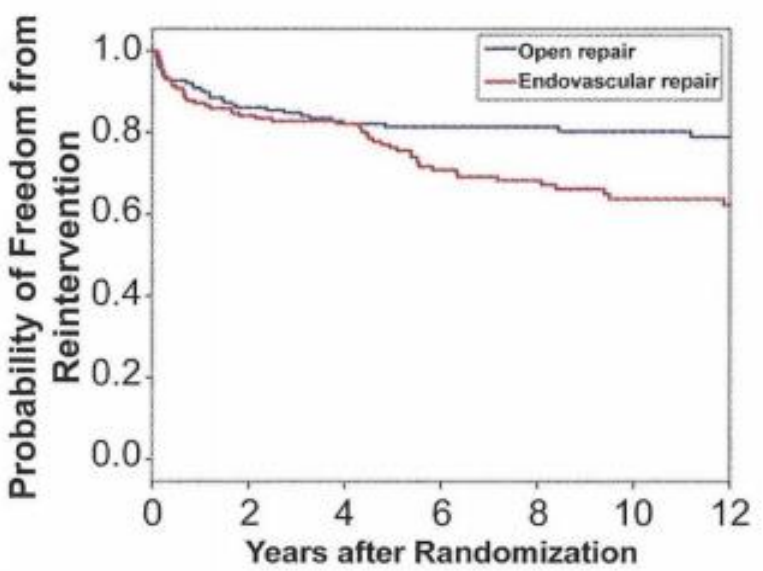
Endovascular AAA vs. Open Repair: EVAR-1 Study



Survival after Open Surgery vs. EVAR



NAR	OSR	178	159	143	123	106	88	72
	EVAR	173	156	133	117	103	83	63
Events	OSR	0	19	35	53	70	88	102
	EVAR	0	17	40	54	66	84	104
LFU	OSR	0	0	0	2	2	2	3
	EVAR	0	0	0	1	3	5	5



NAR	OSR	178	140	119	95	73	67	58
	EVAR	173	135	115	88	68	52	42
Events	OSR	0	24	30	31	31	32	33
	EVAR	0	26	30	44	48	52	53
LFU	OSR	0	0	0	2	2	2	3
	EVAR	0	0	0	1	3	5	5

Key Clinical Points
Abdominal Aortic Aneurysms

- Abdominal aortic aneurysms are usually asymptomatic until they rupture, with an ensuing mortality of 85 to 90%
- Symptomatic patients require urgent repair
- U.S. Preventive Services Task Force recommendations support screening in men 65 to 75 years of age with a history of smoking and selective screening in men 65 to 75 years of age without a smoking history, although the optimal cohort to be screened remains controversial
- The usual threshold for elective repair is an aortic diameter of 5.5 cm in men and 5.0 cm in women
- Endovascular repair results in lower perioperative morbidity and mortality than open repair, but the two methods are associated with similar mortality in the long term (8 to 10 years)
- Patients treated with endovascular repair require long-term surveillance owing to a small risk of aneurysm sac reperfusion and late rupture
- Decisions regarding prophylactic repair — whether to pursue it and, if so, what type of repair to perform – Must take into account anatomy (not all patients have anatomy amenable to endovascular repair), operative risk, and patient preference

AAA Guideline Recommendations

- BP and lipids should be monitored and treated Class I
- Advised to stop smoking and be offered interventions Class I
- Infra/Juxta renal AAA's ≥5.5cm diameter should be repaired Class I
- AAA's 4.0-5.4 should be monitored at 6-12 months with CT or ultrasound Class I
- Intervention not recommended for stable AAA

Class III