ANEURYSMS OF THE AORTA
AND ILIAC ARTERIES

2ND ANNUAL SVS-UCLA SYMPOSIUM
35th ANNUAL UCLA VASCULAR REVIEW COURSE
DISCLOSURES

• NELLIX: DSMB CHAIR
ABDOMINAL AORTIC ANEURYSM

DEFINITIONS

A LOCALIZED DILATATION

- ABSOLUTE DIAMETER EXCEEDING 3.0 CM*
- DIAMETER 1.5X ADJACENT NORMAL DIAMETER

*SVS GUIDELINES
ABDOMINAL AORTIC ANEURYSM
ABDOMINAL AORTIC ANEURYSM

NOTABLE VICTIMS

- KING GEORGE II*
- AUGUSTE RODIN
- ROY ROGERS
- SENATOR R. DOLE
- JOE DIMAGGIO
- RODNEY DANGERFIELD
- CANDIDO JACUZZI

- DUKE OF WINDSOR
- CHARLES DEGAULLE*
- GEORGE C SCOTT*
- LUCILLE BALL*
- ALBERT EINSTEIN*
- EMILE ZOLA

* CAUSE OF DEATH
ABDOMINAL AORTIC ANEURYSMS

PREVALENCE*

- MEN OVER 55 YEARS
  - > 3CM 4.6%
  - > 4CM 1.4%
- WITH FAMILY HISTORY 5%

*DATA FROM ADAM TRIAL, 1977
## Abdominal Aortic Aneurysm Incidence

<table>
<thead>
<tr>
<th>POPULATION</th>
<th>INCIDENCE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unselected, autopsy</td>
<td>1.5</td>
</tr>
<tr>
<td>Unselected, U-S screened</td>
<td>3.2-4.9</td>
</tr>
<tr>
<td>Male smokers &gt; 65</td>
<td>6.0-7.0</td>
</tr>
<tr>
<td>CAD, U-S screened</td>
<td>10.0</td>
</tr>
<tr>
<td>PVD, U-S screened</td>
<td>10.0</td>
</tr>
<tr>
<td>POP or fem aneurysm</td>
<td>40-53</td>
</tr>
</tbody>
</table>
ABDOMINAL AORTIC ANEURYSM

MAGNITUDE OF PROBLEM: USA

- 1.7 MILLION PEOPLE HAVE AAA
- 190,000 NEW AAA DIAGNOSED ANNUALLY
- 50,000 AAA REPAIRS ANNUALLY
- 10,000-15,000 DEATHS / YEAR FROM RUPTURE
- 2ND MOST FREQUENT CAUSE OF DEATH FROM ALL EMERGENCY SURGICAL CONDITIONS
- AAA RUPTURE IS 13TH LEADING CAUSE OF DEATH IN MEN; 10TH IN MEN OVER 65
## RUPTURED AAA

### TRENDS IN INCIDENCE

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>PERIOD</th>
<th>START</th>
<th>END</th>
<th>MORT (%)</th>
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<tbody>
<tr>
<td>W. AUSTRALIA</td>
<td>71-81</td>
<td>3</td>
<td>10</td>
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<td>SWANSEA (UK)</td>
<td>74-83</td>
<td>7</td>
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<td>80</td>
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<td>WORTHING (UK)</td>
<td>79-86</td>
<td>9</td>
<td>18</td>
<td>89</td>
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<tr>
<td>EAST LONDON</td>
<td>81-86</td>
<td>13</td>
<td>21</td>
<td>81</td>
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<tr>
<td>SWINDON (UK)</td>
<td>82-87</td>
<td>9</td>
<td>17</td>
<td>86</td>
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<tr>
<td>GOTEBOURG</td>
<td>52-88</td>
<td>1</td>
<td>7</td>
<td>85</td>
</tr>
</tbody>
</table>

*PER 100,000/YEAR
AAA-RELATED DEATHS

DECREASE IN ENDOVASCULAR ERA

GILES ET AL, JVS 2009
REDUCED MORTALITY FROM AAA RUPTURE

- ENGLAND, WALES & SCOTLAND
- 1997-2009
- DECREASED ADMISSIONS FOR AAA
- DECREASED RUPTURED AAA
- FACTORS
  - DECREASED SMOKING
  - DECREASED HYPERTENSION
  - INCREASED STATIN USE
  - INCREASE ELECTIVE REPAIRS IN PATIENTS > 75

AORTIC ANEURYSM MORTALITY

WORLD-WIDE TRENDS

- DECREASED MORTALITY
  - NOT UNIFORM
- LINEAR RELATIONSHIP WITH TRENDS IN
  - SBP
  - CHOLESTEROL
  - SMOKING
  - BMI (NEGATIVE)
- DIABETES: NO IMPACT

SIDLOFF ET AL. CIRCULATION 2014
CIGARETTE SMOKING AND AAA

- LINEAR RELATIONSHIP WITH:
  - DEVELOPMENT
  - EXPANSION
  - RUPTURE

- THE ONLY KNOWN MODIFIABLE RISK FACTOR
AAA MORTALITY AND SMOKING

US annual adult per capita cigarette consumption and US age-adjusted AAA mortality per 100,000 white men by year.

Frank A. Lederle Circulation. 2011;124:1097-1099
SMOKING AND AAA

- AAA MORE RELATED TO CIGARETTE SMOKING ONLY 2ND TO LUNG CANCER
- SMOKING INCREASES AAA GROWTH 35%
- EACH YEAR OF SMOKING INCREASES INCIDENCE OF AAA 4%
- SMOKERS 7X MORE LIKELY TO HAVE AAA THAN NON-SMOKERS
DEMOGRAPHIC FACTORS

- MALE : FEMALE : 3:1 - 6:1
- AGE : 7TH - 8TH DECADES
- RACE : 90% CAUCASIAN ; 5% BLACK
- LOCATION : 95% INFRARENAL
  - 5-15% SUPRA-RENNAL
  - 2.5% THORACO-ABDOMINAL
- CORONARY ART DISEASE : 25% SYMPTOMATIC
- HYPERTENSION : 40%
- PERIPH OCCLUSIVE DISEASE : 20-30%
- SMOKING: 90%
ABDOMINAL AORTIC ANEURYSM

ASSOCIATED ANEURYSMS

- THORACIC 12%
- ILIAC 25%
- FEM / POP 14%
AAA IN WOMEN

- LOWER PREVALENCE UNTIL MENOPAUSE
- PATIENTS OLDER WHEN DIAGNOSED
- FASTER GROWTH RATE
- INCREASED RUPTURE RATE
  - RUPTURE RISK 4X THAT OF MALES
  - RUPTURE AT SMALLER SIZE (5-10 MM)
  - LOWER REPAIR RATES
- OVER 1/3 OF ALL AAA DEATHS OCCUR IN WOMEN
- INCREASED OPERATIVE MORTALITY
  - OLDER AGE
  - MORE RISK FACTORS
  - LESS WELL-CONTROLLED RISK FACTORS
  - SMALLER VESSELS; LESS EVAR
ABDOMINAL AORTIC ANEURYSM

INCIDENCE AND AGE

---

ALL AAA

RUPTURED

AFTER CRONNENWETT
AAA MORTALITY: MEN VS WOMEN

ANNUAL IN-HOSPITAL MORTALITY

*P=0.003; P<.0001; ΔP<.0001

McPHEE ET AL. JVS 2007
AAA IN WOMEN

- INCREASED SUPRA-RENAL INVOLVEMENT
- STRONGER RELATIONSHIP WITH SMOKING
  - HIGHER INCIDENCE THAN NON-SMOKING MEN
  - INCREASED SMOKING WORLD-WIDE
  - DECREASE SMOKING < DECREASE IN MEN
- STRONGER FAMILY HISTORY
- ALMOST NO FEM / POP ANEURYSMS
- ESTROGEN PROTECTIVE EFFECT
  - DECREASED MACROPHAGE PRODUCTION MMP-9
  - DISAPPEARS AFTER MENOPAUSE
SCREENING FOR AAA

USPSTF

ONE-TIME SCREENING

- MEN 65-75 YEARS
  - SMOKING HISTORY (>100 CIGS)
- MEN OR WOMEN
  - FAMILY HISTORY OF AAA
- PART OF WELCOME TO MEDICARE PHYSICAL
SCREENING FOR AAA

METHODS

- ULTRASOUND
  - IDENTIFIES ANEURYSMS
  - DETERMINES SIZE

- SERUM BIOMARKERS
  - FIBRINOGEN, D-DIMER, IL-6, CRP
  - MMP-9, TIMP-1
  - APOLIPOPROEIN-A, APO(a)
  - MICRO RNAs
ULTRASOUND SCREENING

- DECREASE AAA RUPTURE
- DECREASE EMERGENCY SURGERY
- DECREASE AAA-RELATED MORTALITY 50%
- DECREASE ALL-CAUSE MORTALITY
- COST EFFECTIVE

CONCERNS
- ONLY 40% ELIGIBLE ARE SCREENED
- ONLY 65% FOLLOWUP OF POSITIVE SCANS
SURVEILLANCE FREQUENCY

- META-ANALYSIS OF 18 STUDIES
- 15,471 PATIENTS
  - 13,728 MEN
  - 1,743 WOMEN
- AAA < 5.5 CM
- TIME TO REACH THRESHOLD OF 5.5 CM
  - 3.0 CM: 7.4 YEARS
  - 4.0 CM: 3.2 YEARS
  - 5.0 CM: 8 MONTHS
- 4X RISK OF RUPTURE FOR WOMEN

BOWN MJ ET AL. JAMA 309:806, 2013
SURVEILLANCE INTERVALS

AAA SIZE

3.0-3.9 CM  24 MONTHS*
4.0-4.9 CM  12 MONTHS
5.0-5.4 CM  6 MONTHS

*SVS GUIDELINES: 36 MONTHS

THOMPSON ET AL, JAMA 2013:309;806
ABDOMINAL AORTIC ANEURYSMS

EXPANSION RATE

INITIAL DIAMETER (CM)

<table>
<thead>
<tr>
<th>INITIAL DIAMETER (CM)</th>
<th>ENLARGEMENT RATE (CM/yr)</th>
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</thead>
<tbody>
<tr>
<td>3.5-4.0</td>
<td>0.2</td>
</tr>
<tr>
<td>4.0-5.0</td>
<td>0.4</td>
</tr>
<tr>
<td>5.0-5.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>
ABDOMINAL AORTIC ANEURYSM

CLINICAL MANIFESTATIONS

- PAIN
- COMPRESSION OF ADJACENT STRUCTURES
- DISTAL EMBOLIZATION
- THROMBOSIS
- PULSATION
- 2/3 DISCOVERED ON TEST PERFORMED FOR ANOTHER REASON
ABDOMINAL AORTIC ANEURYSM

METHODS OF DETECTION

- PHYSICAL EXAMINATION
- PLAIN ABDOMINAL / SPINE X-RAYS
- IMAGING STUDIES
- CARDIAC CATHETERIZATION
AORTO-CAVAL FISTULA

PEVEC WC, ET AL. JVS 2010;51:475
CT SCAN FOR AAA

- DETECTS ANATOMIC VARIATIONS
- DETECTS MURAL THROMBUS/PLAQUE
- DETERMINE WALL STRESS

RETROAORTIC LEFT RENAL VEIN
DIAGNOSIS OF AAA: CT SCAN

RUPTURE
**ABDOMINAL AORTIC ANEURYSM**

**ASSOCIATED ARTERIAL LESIONS**

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Patients</th>
<th>Number</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Suprarenal Extension</td>
<td>680</td>
<td>46</td>
<td>6.7</td>
</tr>
<tr>
<td>Renal Stenosis / Occlusion</td>
<td>763</td>
<td>138</td>
<td>18.0</td>
</tr>
<tr>
<td>ACC / Multiple Renal STENOSIS</td>
<td>680</td>
<td>92</td>
<td>13.5</td>
</tr>
<tr>
<td>Celiac / SMA Stenosis</td>
<td>628</td>
<td>87</td>
<td>13.8</td>
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<tr>
<td>Ilio-Fem-Pop Stenosis</td>
<td>680</td>
<td>296</td>
<td>43.8</td>
</tr>
<tr>
<td>Ilio-Fem-Pop Aneurysm</td>
<td>680</td>
<td>243</td>
<td>34.2</td>
</tr>
</tbody>
</table>

*Angiographically determined collected series*
ETIOLOGIC CLASSIFICATION

- Atherosclerotic
- Degenerative
- Inflammatory / Immunologic
- Infectious (Mycotic)
- Traumatic
- Post-dissection
- Congenital
ETIOLOGY OF AAA

ASSOCIATIONS

- Atherosclerosis
- Cigarette smoking
- Aging
- Male gender
- Pulmonary emphysema / ing hernia
- Hypertension
- Family history
ANEURYSMAL VS OCCLUSIVE DISEASE

DISTINGUISHING CHARACTERISTICS

- Transmural vs Intimal Process
- Localized vs Diffuse
- Entire Circumference vs Eccentric
- Not Associated with
  - Diabetes Mellitus (Diabetic Paradox)
  - Hyperlipidemia
  - Hyperhomocystinemia
ETIOLOGY OF AAA

ESTABLISHED PATHOLOGIC FACTS

- THINNING OF AORTIC WALL
- CHRONIC INFLAMMATION OF AORTIC WALL
- DECREASED MEDIAL SMC
- DEGRADATION OF STRUCTURAL PROTEINS
- INCREASED EXPRESSION OF MATRIX METALLOPROTEASE (MMP 2, 9)
AORTIC LAMELLAR STRUCTURE

COLLAGEN FIBERS

ELASTIN MICROFIBRILS

X 21,000
PATHOGENESIS OF AAA

CURRENT CONCEPTS

● ANEURYSM FORMATION
  - ELASTIN FRAGMENTATION
    » NOT SYNTHESIZED IN ADULT AORTA
    » HALF-LIFE 40-70 YEARS

● ANEURYSM GROWTH AND RUPTURE
  - COLLAGEN DEGRADATION
    » DEPOSITION
    » REMODELING
PATHOGENESIS OF AAA

INFLAMMATION

- INFLAMMATION IS PROMINENT FEATURE IN ADVENTITIA OF AAA (MACROPHAGES, T AND B LYMPHOCYTES).

- INFLAMMATORY CELLS ELABORATE PROTEOLYTIC ENZYMES AND CYTOKINES THAT MODULATE EXPRESSION OF MATRIX PROTEINS AND PROTEOLYTIC ENZYMES BY MESENCHYMAL AND SM CELLS.

- LEUKOCYTES IN AAA HAVE INCREASED ELASTASE ACTIVITY.

- INFLAMMATORY MEDIATORS MAY BE ELABORATED SECONDARILY IN RESPONSE TO CHEMICAL, MECHANICAL OR OTHER INJURY.
PATHOGENESIS OF AAA

MMP-9

- Also known as Gelatinase B and Type IV Collagenase
- Increased in serum of 50% of pts with AAA
- Levels return to normal after AAA repair
- Found in abundance in AAA wall and inflammatory cells and macrophages
- Aortic infusion with RMMP-9 in MMP-9 knockout mice produces AAA
ESTROGEN-MEDIATED REDUCTION IN MACROPHAGE MMP-9 PRODUCTION

EXPRESSION UP 10 HIGHER IN MALE RATS
PATHOGENESIS OF AAA

- INFLAMMATION
- TRAUMA
- SMOKING
- HEMODYNAMIC STRESS
- OXIDANT INJURY
- AUTOIMMUNITY
- CYTOKINES
- ATHEROSCLEROSIS

MATRIX DEGRADATION

DYSFUNCTIONAL REMODELING

DECREASE TENSILE STRENGTH
GENETICS AND AAA

- **FAMILIAL CLUSTERING OF AAA**
- **15-25% OF PATIENTS UNDERGOING AAA REPAIR HAVE 1ST DEGREE RELATIVE WITH AAA (ONLY 2-3% IN AGE-MATCHED CONTROLS)**
- **OVER TRIAL: 13.7% HAD FAMILY HISTORY OF AAA**
- **INCREASED INCIDENCE OF AFFECTED RELATIVES IN WOMEN WITH AAA (12% VS 7% IN MEN)**
- **BROTHERS OF PATIENTS WITH AAA HAVE UP TO 18 TIMES INCREASED RISK OF AAA**
FAMILIAL AAA

- PATIENTS 5-7 YEARS YOUNGER
- MORE OFTEN WOMEN
- RUPTURE MORE FREQUENTLY
- RUPTURE AT SMALLER SIZE
UNUSUAL ABDOMINAL ANEURYSMS

- INFLAMMATORY
- MARFAN’S
- SACCULAR
- INFECTED
TREATMENT OF AORTIC ANEURYSM

GOALS

- RELIEVE SYMPTOMS, IF PRESENT
- PREVENT RUPTURE
- PROLONG LIFE
TREATMENT OF AAA

MEDICAL MANAGEMENT

- SMOKING CESSATION
- BETA BLOCKADE
  - PROPANOLOL
- MMP INHIBITION
  - DOXYCYCLINE
  - ROXITHROMYCIN
- STATINS
- NON-STEROIDAL ANTI-INFLAMMATORY DRUGS
- ACE INHIBITORS
- EXERCISE
- EARLY DETECTION
REPAIR OF AORTIC ANEURYSMS

DECISION TO OPERATE

- AAA RUPTURE RISK
- ELECTIVE OPERATIVE RISK
  - PATIENT RISK FACTORS
  - SURGEON / HOSPITAL VOLUME
- LIFE EXPECTANCY
- PATIENT PREFERENCE
RUPTURE OF AAA

RISK FACTORS

- FEMALE GENDER
- SIZE
- PEAK WALL STRESS
- COPD
- CURRENT SMOKING
- FAMILY HISTORY
- HYPERTENSION
- SACCULAR SHAPE
- RAPID EXPANSION
<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>RR / YR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0-5.4</td>
<td>1.0</td>
</tr>
<tr>
<td>5.5-5.9</td>
<td>9.4</td>
</tr>
<tr>
<td>6.0-6.9</td>
<td>10.2</td>
</tr>
<tr>
<td>6.5-6.9</td>
<td>19.1</td>
</tr>
<tr>
<td>&gt;7.0</td>
<td>32.5</td>
</tr>
<tr>
<td>&gt;8.0</td>
<td>26.7 (6 MOS)</td>
</tr>
</tbody>
</table>

Lederle ET AL, JAMA, 2002
PATIENTS UNFIT FOR AAA REPAIR

DECLINING RUPTURE RISK

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>5.0-5.9 CM</td>
<td>3.3</td>
<td>3.5</td>
</tr>
<tr>
<td>6.0-6.9 CM</td>
<td>9.4</td>
<td>4.1</td>
</tr>
<tr>
<td>&gt;7.0 CM</td>
<td>24.0</td>
<td>6.3</td>
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</tbody>
</table>

META-ANALYSIS; 1514 PATIENTS

• OVERALL RUPTURE RATE FOR >5.5CM: 5.3% / YEAR
• 42% OF THOSE OFFERED SURGERY SURVIVED
• RISK OF DEATH FROM RUPTURE > RISK OF DEATH FROM OTHER CAUSES

PARKINSON, JVS 2015;61:1602
LAW OF LAPLACE

\[ T = PR \]

**T**: TANGENTIAL STRESS

**P**: TRANSMURAL PRESSURE

**R**: RADIUS

Transmural pressure = \( P_1 - P_3 \)
ABDOMINAL AORTIC ANEURYSM

RUPTURE AND SIZE

- SMALL AAA (<5CM) CAN RUPTURE
- LARGE AAA MAY NOT RUPTURE
- AAA OF SAME DIAMETER MAY HAVE DIFFERENT RUPTURE POTENTIAL
SIZE AND AAA RUPTURE

5.3 CM

25 CM

KRIEVES, JVS 61;2015
ABDOMINAL AORTIC ANEURYSM

PEAK WALL STRESS

- CAN BE CALCULATED FROM ROUTINE CT SCANS
  - FINITE ELEMENT ANALYSIS
- DISTRIBUTION NONHOMOGENEOUS
- INCREASED BY ASYMMETRY
- DOES NOT CORRELATE WITH MAX DIAMETER
- SIGNIFICANTLY AFFECTED BY WALL THICKNESS
- EFFECT OF MURAL THROMBUS CONTROVERSIAL
RUPTURE OF AORTIC ANEURYSM

SIZE vs WALL STRESS

- WALL STRESS IS HIGHER IN SYMPTOMATIC AND RUPTURED ANEURYSMS
  FILLINGER MF, ET AL. JVS 2002;36:589-97
  FILLINGER MF, ET AL. JVS 2003;37:724-32

- PWS HIGHEST IN AREAS OF RUPTURE

- CT SCAN-DERIVED WALL STRESS IS PROBABLY BETTER THAN SIZE AND MAY BECOME CLINICALLY PRACTICAL IN THE NEAR FUTURE

- INCLUDING WALL THICKNESS MAY BE BETTER

MALKAWI AH JVS 2010
## AAA RUPTURE RISK

<table>
<thead>
<tr>
<th></th>
<th>LOW</th>
<th>AVERAGE</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIAMETER</strong></td>
<td>&lt;5 CM</td>
<td>5-6 CM</td>
<td>&gt;6 CM</td>
</tr>
<tr>
<td><strong>EXPANSION</strong></td>
<td>&lt;0.3 CM/YR</td>
<td>&lt;0.3-0.6 CM/YR</td>
<td>&gt;0.6 CM/YR</td>
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<tr>
<td><strong>SMOKING/COPD</strong></td>
<td>NONE, MILD</td>
<td>MODERATE</td>
<td>SEVERE/STEROID</td>
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<tr>
<td><strong>FAMILY HIST</strong></td>
<td>NO RELATIVES</td>
<td>1 RELATIVE</td>
<td>NUM RELATIVES</td>
</tr>
<tr>
<td><strong>HYPERTENSION</strong></td>
<td>NORMAL BP</td>
<td>CONTROLLED</td>
<td>POOR CONTROL</td>
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<tr>
<td><strong>SHAPE</strong></td>
<td>FUSIFORM</td>
<td>SACCULAR</td>
<td>ECCENTRIC</td>
</tr>
</tbody>
</table>

*SVS/AAVS, 2003*
ELECTIVE AAA REPAIR

THRESHOLD DIAMETER

- MEN: 5.5 CM (SVS 5.0)
- WOMEN: 4.5CM
# SMALL AAA TRIALS

<table>
<thead>
<tr>
<th></th>
<th>UNITED KINGDOM</th>
<th>ADAM</th>
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<tbody>
<tr>
<td>INSTITUTIONS</td>
<td>93</td>
<td>16</td>
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<tr>
<td>RANDOMIZED</td>
<td>1090</td>
<td>1136</td>
</tr>
<tr>
<td>AGE</td>
<td>60-76</td>
<td>50-79</td>
</tr>
<tr>
<td>MALE</td>
<td>82%</td>
<td>94%</td>
</tr>
<tr>
<td>OP MORT</td>
<td>5.8%</td>
<td>1.8%</td>
</tr>
<tr>
<td>MEAN F/U</td>
<td>4.6 YRS</td>
<td>4.8 YRS</td>
</tr>
<tr>
<td>SURVIVAL</td>
<td>61%</td>
<td>61%</td>
</tr>
<tr>
<td>RUPT RISK</td>
<td>1.0%/YR</td>
<td>0.5%/YR</td>
</tr>
</tbody>
</table>
SMALL AAA

ADAM TRIAL

UK TRIAL

NEJM 2002

BRIT J SURG 2007
EVAR FOR SMALL AAA

EVAR vs OBSERVATION

- NO SURVIVAL BENEFIT FOR EVAR
  - CESAR TRIAL
    » CAO ET AL.
      - EUR J VASC ENDOVASC SURG 2011;41:13
  - PIVOTAL TRIAL
    » OURIEL ET AL.
      - J VASC SURG 2010;51:1081
OPEN SURGERY FOR AAA

TECHNICAL ASPECTS

- OPEN vs EVAR
- MIDLINE vs RETROPERITONEAL
- BIFURCATION vs TUBE GRAFT
- ePTFE vs POLYESTER

RUTHERFORD, 7TH ED
## TREATMENT OF AORTIC ANEURYSMS

### OPERATIVE MORTALITY

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Mortality</th>
</tr>
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<tbody>
<tr>
<td>Elective</td>
<td>2-10%</td>
</tr>
<tr>
<td>Rupture</td>
<td>37-50%</td>
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<tr>
<td>Urgent</td>
<td>8-18%</td>
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Combined data sources
# TREATMENT OF AORTIC ANEURYSMS

## OPERATIVE MORTALITY

**NSQIP DATASET 2011-2013**

<table>
<thead>
<tr>
<th></th>
<th>EVAR (%)</th>
<th>OPEN (%)</th>
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<tbody>
<tr>
<td>Asymptomatic</td>
<td>1.4 (82%)</td>
<td>4.3</td>
</tr>
<tr>
<td>Symptomatic</td>
<td>3.8 (69%)</td>
<td>7.7</td>
</tr>
<tr>
<td>Ruptured</td>
<td>22 (52%)</td>
<td>34</td>
</tr>
</tbody>
</table>

**JUXTARENAL: 15%**

AAA MORTALITY RISK PREDICTION

- GLASGOW ANEURYSM SCORE
- LEIDEN RISK MODEL
- SVS COMORBIDITY SCORING SYSTEM
- HARDMAN INDEX
- EAGLE SCORE
- GILES MEDICARE SCORE
- VGNW MODEL
- VSGNNE
OPEN AAA REPAIR

PREDICTORS OF OPERATIVE MORTALITY

- CONGESTIVE HEART FAILURE
- CORONARY ARTERY DISEASE
- CHRONIC KIDNEY FAILURE
- CHRONIC OBSTRUCTIVE LUNG DISEASE
- ADVANCED AGE
- AAA DIAMETER
- HOSPITAL / SURGEON VOLUME
UN-OPERATED AAA

NATURAL HISTORY

- 154 PATIENTS, HELSINKI UNIV HOSP, 2000-2010
- AAA > 5.5CM DIAMETER
- REASONS FOR NO SURGERY
  - CARDIORESPIRATORY 33%
  - OVERALL CONDITION 33%
  - CANCER 8%
  - PATIENT CHOICE 21%
- CAUSE OF DEATH
  - RUPTURE 43%
  - 5 / 12 (42%) SURVIVED OP FOR RUPTURE

NORENEN ET AL. EUR J VASC ENDOVASC SURG 2013; 45:326
EVAR vs OPEN REPAIR

MAYO CLINIC 2000-2011 1534 PATIENTS
PROPENSITY SCORE MATCHED

SURVIVAL

FREEDOM INTERVENTION

HUANG ET AL. JVS 2015;62:304
JUXTA- vs PARA-RENAL ANEURYSMS

- JUXTARENAL
  - NO NORMAL AORTA BELOW RENAL ARTERIES
  - REQUIRES SUPRARENAL CLAMPING FOR INFRA RENAL AORTIC REPAIR

- PARARENAL
  - ANEURYSM INVOLVES AORTA AT LEVEL OF RENAL ARTERIES OR ABOVE
  - REQUIRES SUPRA-SMA OR SUPRACELIAC CLAMPING FOR RENAL ARTERY AND AORTIC REPAIR

- BOTH MAY REQUIRE LEFT RENAL VEIN DIVISION
- MORBIDITY AND MORTALITY INCREASE WITH HIGHER PLACEMENT OF AORTIC CROSS CLAMP
JUXTARENTAL ANEURYSMS

- META-ANALYSIS
  - 21 REPORTS
  - 1986-2008
  - 1256 CASES
  - AVE DIAMETER: 6.1 CM
  - MORTALITY: 2.9%
  - PRE-OP RENAL INSUFF: 16.7% (0-52)
  - POST-OP RENAL DYSFUNCTION: 0-39%
  - POST-OP DIALYSIS: 3.3%

- RENAL ISCHEMIA TIME: 27 MIN (19-44)

JONGKIND V, ET AL. JVS 2010;52:760-7
OPEN COMPLEX AAA REPAIR

Table III. Univariate analysis of perioperative outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Infrarenal AAA, % (n = 1091)</th>
<th>Complex AAA, % (n = 443)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thirty-day mortality</td>
<td>1.2</td>
<td>3.6</td>
<td>.002</td>
</tr>
<tr>
<td>Myocardial infarction (any)</td>
<td>6.2</td>
<td>7</td>
<td>.5</td>
</tr>
<tr>
<td>Dysrhythmia</td>
<td>13</td>
<td>15</td>
<td>.3</td>
</tr>
<tr>
<td>CHF</td>
<td>3.8</td>
<td>7.2</td>
<td>.005</td>
</tr>
<tr>
<td>Respiratory complication</td>
<td>10</td>
<td>19</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Renal complication (creatinine increase &gt;0.5 mg/dL)</td>
<td>8.2</td>
<td>20</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>0.5</td>
<td>1.1</td>
<td>.004</td>
</tr>
<tr>
<td>Return to OR</td>
<td>5.9</td>
<td>8.4</td>
<td>.08</td>
</tr>
</tbody>
</table>

AAA, Abdominal aortic aneurysm; cAAA, complex abdominal aortic aneurysm; CHF, congestive heart failure; OR, operating room. Bolded rows show where differences presented are statistically significant at P ≤ .05.

Long term survival by type of open AAA repair

Log Rank P = 0.08

VSGNE DATABASE 2003-2011

Deery et al JVS 2016;63:1195
FEVAR vs OPEN REPAIR

COLLECTIVE REVIEW, 33 CASE SERIES

- SIMILAR SHORT-TERM OUTCOMES
- LONG-TERM FEVAR ASSOCIATED WITH:
  - INCREASED PROGRESSION TO RENAL IMPAIR
  - INCREASED SECONDARY INTERVENTIONS
  - LOWER SURVIVAL

RAO ET AL. JVS 2015;61:242
### Perioperative Mortality Rates for Open Repair and FEVAR studies

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Mortality Rate</th>
<th>Mortality Rate and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dubois 2013</td>
<td>0.041</td>
<td></td>
</tr>
<tr>
<td>Gross 2012 (CR)</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Thal 2012</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Feindel 2010</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>Shulman 2010</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Chao 2006 (CR)</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>Mitrano-Trischitta 2001</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Mikhaylova 2001</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>Krom 2006</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>Yeong 2006</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Pearce 2007</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Boezel 2005</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Ryall 2004</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>Kudo 2004</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>Bicknell 2003</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Stropoli 2003</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Sarac 2002</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Ayar 2001</td>
<td>0.113</td>
<td></td>
</tr>
<tr>
<td>Glidden 2000</td>
<td>0.056</td>
<td></td>
</tr>
<tr>
<td>Allon 1993</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Patals 1982</td>
<td>0.053</td>
<td></td>
</tr>
</tbody>
</table>

### Perioperative Mortality

**Open Repair versus FEVAR**

- Odds Ratio: 1.059
- Lower Limit: 0.642
- Upper Limit: 1.747
- p-Value: 0.622

### Kaplan Meier Survival Curves


**OAR**

**FEVAR**
OPERATIONS FOR RUPTURED AAA

REDUCED MORTALITY

- INCREASED USE OF EVAR
- HIGH VOLUME HOSPITAL
- INCREASED HOSPITAL SIZE
- TEACHING HOSPITAL
- NOT WEEKEND

LANCET 2014;383:963
## TREATMENT OF AORTIC ANEURYSMS

### LATE SURVIVAL

<table>
<thead>
<tr>
<th></th>
<th>1 YEAR</th>
<th>5 YEARS</th>
<th>10 YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE-MATCHED CONTROLS</td>
<td>95</td>
<td>75</td>
<td>52</td>
</tr>
<tr>
<td>RUPTURED REPAIR</td>
<td>86</td>
<td>64</td>
<td>33</td>
</tr>
<tr>
<td>ELECTIVE REPAIR</td>
<td>97</td>
<td>74</td>
<td>43</td>
</tr>
</tbody>
</table>

ALL FIGURES %
RUPTURED AORTIC ANEURYSM

QUALITY OF LIFE

- 82 SURVIVORS
- RAND 36 INSTRUMENT
- FINDINGS
  - SIGNIFICANT REDUCTION IN ISOLATED DOMAIN OF PHYSICAL FUNCTIONING
- MAJORITY OF PATIENTS REGAIN PRE-OP QOL

KORHONEN 2003
OPEN REPAIR OF AAA

- PROGRESSIVELY IMPROVED RESULTS
- OPERATIVE MORTALITY EQUIVALENT TO EVAR IN MOST TRIALS
- HIGH RISK POORLY DEFINED
- EVAR BETTER THAN OPEN FOR RUPTURE
- LONG TERM SURVIVAL SUPERIOR TO EVAR
- QOL SUPERIOR TO EVAR
OPEN REPAIR IN THE EVAR ERA

- ANATOMICALLY UNSUITED FOR EVAR
  - SHORT ANGULATED NECK
  - MULTIPLE RENAL ARTERIES
  - INADEQUATE ACCESS VESSELS
- COMPLEX ANEURYSMS
- INFECTED ANEURYSM / GRAFT
- FAILED EVAR
  - TYPE I ENDOLEAK WITH ENLARGING SAC
OPEN SURGERY FOR AAA
SVS practice guidelines for the care of patients with an abdominal aortic aneuysm: Executive summary

Ellior L. Chakof, MD, PhD,1 David C. Bonthier, MD,1 Ronald L. Dalman, MD,1 Michel S. Makaroun, MD,1 Karl A. Tencer, MD,2,3 Gregorio A. Sicard, MD,1 Carlos H. Timaran, MD,4 Gilbert J. Lussy, MD,1 and Frank J. Veth, MD,1

Austral, Ga; Boston, Mass; Palo Alto, Calif; Pittsburgh, Pa; Rochester, NY; St. Louis, Mo; Dallas, Tex; Ann Arbor, Mich; and Cleveland, Ohio

DEFINITION OF THE PROBLEM

Purpose of these guidelines

The Clinical Practice Council of the Society for Vascular Surgery charged a writing committee with the task of updating practice guidelines, initially published in 2003, for surgeons and physicians who are involved in the preoperative, operative, and postoperative care of patients with abdominal aortic aneurysm (AAA). This article is an executive summary of the main practice guidelines document and provides recommendations for evaluating the patient, including risk of aneurysm rupture and associated medical co-morbidities, guidelines for selecting surgical or endovascular intervention, intraoperative strategies, perioperative care, long-term follow-up, and treatment of late complications.

From the Department of Surgery, Emory University,1 the Department of Surgery, Massachusetts General Hospital,2 the Department of Surgery, Stanford University,3 the Department of Surgery, University of Pittsburgh,4 the Department of Surgery, University of Rochester,5 the Department of Surgery, Washington University-St. Louis,6 the Department of Surgery, University of Texas-Southwestern,7 the Department of Surgery, University of Michigan,8 and the Department of Vascular Surgery, Cleveland Clinic Foundation.9

Dr Chakof received research (principal investigator) and educational support (program director) from WL Gore, and research and educational support (program director) from WL Gore, Cook Inc, Medtronic and Cook, Inc. Dr Makaroon received research and educational support (program director) from WL Gore, Cook Inc, Medtronic, Cordis, BMT, Abbott, Boston, and Lombard. In the last two years, Dr. Makaroon had consulting agreements with WL Gore, Medtronic, Cook, Inc and Cardiomedics. Dr Veth received procuring, travel expenses, and honoraria from Cook, Inc, speaking and travel expense from Cook, Inc and WL. Gore, and the University of Rochester. Department of Vascular Surgery has received unrestricted educational grant support from Cook, Inc, WL Gore, Medtronic, and Boston Scientific. Dr Timaran received fees for consulting and speaking from WL Gore and Associates, Inc. Dr Veth is a stockholder in Vascular Innovation, a company that may in the future make aortic endografts Nothing in this article was influenced by their ownership

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880

Decision making related to the care of patients with AAA is complex. Aneurysms present with varying risks of rupture, and patient-specific factors influence anticipated life expectancy, operative risk, and the need to intervene. Careful attention to the choice of operative strategy, as influenced by anatomic features of the AAA, along with optimal treatment of medical co-morbidities is critical to achieving excellent outcomes. Moreover, appropriate postoperative patient surveillance and timely intervention in the case of a late complication is necessary to minimize subsequent aneurysm-related death or morbidity. All of these clinical decisions are determined in an environment where cost effectiveness will ultimately dictate the ability to provide optimal care to the largest possible segment of the population. Currently available clinical data sets have been reviewed in formulating these recommendations. However, an important goal of this document is to clearly identify those areas where further clinical research is necessary.

Methodology and evidence

A comprehensive review of the available clinical evidence in the literature was conducted in order to generate a concise set of recommendations. The strength of any given recommendation and the quality of evidence was scored based on the GRADE system (Table). When the benefits of an intervention outweigh its risks, or, alternatively, risks outweighed benefits, a strong recommendation was noted. However, if benefits and risks were less certain, either because of low quality evidence or because high quality evidence suggests benefits and risks are closely balanced, a weak recommendation was recorded. The quality of evidence that formed the basis of these recommendations was scored as high, moderate, or low. Not all randomized controlled trials are alike and limitations may compromise the quality of their evidence. In addition, if there is a large magnitude of effect, the quality of evidence derived from observational studies may be high. Thus, quality of evidence was scored as high when additional research is considered very unlikely to change confidence in the estimate of effect; moderate when further research is likely to have an important impact on the
ISOLATED ILIAC ANEURYSMS

- AAA + COMMON ILIAC ANEURYSM: 20-30%
- ISOLATED
  - 1% OF ALL AAA
  - 0.03% OF ALL ANEURYSMS
  - MALE:FEMALE 7:1
- LOCATION
  - COMMON ILIAC: 70%
  - INTERNAL ILIAC: 20%
  - MULTIPLE: 67%
  - BILATERAL: 33%
- SYMPTOMATIC: 50%
ILIAC ANEURYSMS
ISOLATED Iliac Aneurysms

RISK OF RUPTURE AND SIZE

- 47 cases, all men
- Average diameter: 2.3 cm
- Only 1 rupture (>5 cm)
- Symptoms only if >4 cm
- Elective repair: >3.5 cm

Santilli et al., JVS 2001
<table>
<thead>
<tr>
<th>YEAR</th>
<th>N</th>
<th>AGE</th>
<th>RUPT %</th>
<th>SYMP %</th>
<th>EMERG MORT %</th>
<th>ELEC MORT %</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICHARDSON</td>
<td>1988</td>
<td>72</td>
<td>75</td>
<td>32</td>
<td>55</td>
<td>33</td>
</tr>
<tr>
<td>WEBER</td>
<td>1989</td>
<td>23</td>
<td>72</td>
<td>82</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td>WEIMAN</td>
<td>1990</td>
<td>30</td>
<td>64</td>
<td>23</td>
<td>68</td>
<td>40</td>
</tr>
<tr>
<td>SCHROEDER</td>
<td>1991</td>
<td>53</td>
<td>68</td>
<td>28</td>
<td>96</td>
<td>20</td>
</tr>
<tr>
<td>NACHBUR</td>
<td>1991</td>
<td>53</td>
<td>68</td>
<td>28</td>
<td>96</td>
<td>20</td>
</tr>
<tr>
<td>KRUPSKI</td>
<td>1997</td>
<td>31</td>
<td>69</td>
<td>5</td>
<td>57</td>
<td>0</td>
</tr>
<tr>
<td>KASIRAJAN</td>
<td>1998</td>
<td>33</td>
<td>71</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>SOURY</td>
<td>2001</td>
<td>44</td>
<td>73</td>
<td>13</td>
<td>13</td>
<td>40</td>
</tr>
<tr>
<td>TOTALS</td>
<td>473</td>
<td>69</td>
<td>31</td>
<td>51</td>
<td>28</td>
<td>5</td>
</tr>
</tbody>
</table>
# ISOLATED ILIAC ANEURYSMS

## TREATMENT

| Outcomes                              | EVIR  
\(n = 9016\) | Open repair  
\(n = 4933\) | \(P\) value |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital mortality, %</td>
<td>0.5</td>
<td>1.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cardiac complications, %</td>
<td>1.2</td>
<td>3.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Respiratory complications, %</td>
<td>1.4</td>
<td>9.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peripheral vascular complications, %</td>
<td>1.0</td>
<td>1.4</td>
<td>.022</td>
</tr>
<tr>
<td>Wound dehiscence, %</td>
<td>0.2</td>
<td>0.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Bleeding complications, %</td>
<td>3.2</td>
<td>5.7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Infection, %</td>
<td>0.3</td>
<td>1.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Postoperative complications, %</td>
<td>6.7</td>
<td>17.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Length of stay, days</td>
<td>2.3</td>
<td>6.7</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

NIS 2000-2011

BUCK ET AL, JVS 2015;62:331
ISOLATED ILIAC ANEURYSMS

IMPACT OF ENDOVASCULAR TREATMENT

- NUMBER TREATED INCREASED
- URGENT CASES NOT DECREASED
- MORBIDITY AND MORTALITY DECREASED
- ENDOVASCULAR IS TREATMENT OF CHOICE
INTERNAL ILIAC ANEURYSM
INTERNAL ILIAC ANEURYSM
HYPOGASTRIC ANEURYSMS

EMBOLIZATION

- 14 MEN WITH 17 HYPOGASTRIC ANEURYSMS
- AVERAGE DIAMETER 4.3 CM (3-9 CM)
- 11 OCCURRED AFTER TREATMENT FOR AAA
- GIANTURCO COILS IN ALL CASES (N=3-48)
- SUCCESS IN 16/17
- MODERATE BUTTOCK CLAUDICATION IN 3

MELKI ET AL, ANN VASC SURG 15:312-320, 2001
INTERNAL ILIAC ANEURYSMS

OPEN REPAIR

RANA ET AL. JVS 2014;59:634
TREATMENT OF ILIAC ANEURYSMS

FREEDOM FROM SECONDARY PROCEDURES

CHAER, ET AL. JVS;47:708-13
RUPTURED ABDOMINAL AORTIC ANEURYSM

TRUE MORTALITY

<table>
<thead>
<tr>
<th></th>
<th>Peterborough</th>
<th>Stockholm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>300,000</td>
<td>1,5000,000</td>
</tr>
<tr>
<td>Patients</td>
<td>120</td>
<td>88</td>
</tr>
<tr>
<td>Died outside hospital</td>
<td>56 (46.6%)</td>
<td>24 (27.3%)</td>
</tr>
<tr>
<td>Admitted with diagnosis</td>
<td>52 (43.3%)</td>
<td>23 (26.1%)</td>
</tr>
<tr>
<td>Operations</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>Survival</td>
<td>26 (54%)</td>
<td>5 (38%)</td>
</tr>
<tr>
<td>Mortality</td>
<td>22 (46%)</td>
<td>8 (62%)</td>
</tr>
<tr>
<td>Overall mortality</td>
<td>94 (78%)</td>
<td>83 (94%)</td>
</tr>
</tbody>
</table>
MEDICAL MANAGEMENT OF AAA

RATIONALE FOR BETA BLOCKERS

- REDUCE BLOOD PRESSURE, SHEAR STRESS, AND HEART RATE
- ENHANCE COLLAGEN CROSS-LINKING
- DECREASE ANEURYSM GROWTH AND RISK OF RUPTURE IN EXPERIMENTAL MODELS
- DECREASE PROPORTION OF AAA THAT GROW RAPIDLY (RESROSPECTIVE)
- INHIBIT ANEURYSM EXPANSION IN MARFAN’S
PROPRANOLOL FOR SMALL AAA

CONCLUSIONS OF RCT

- PROPRANOLOL POORLY TOLERATED BY MANY
- POORER QOL (SF-36)
- NO CLINICALLY OR STATISTICALLY SIGNIFICANT EFFECT ON GROWTH RATE
- TREND FOR FEWER PATIENTS WITH RAPID GROWTH AND FEWER PATIENTS TO UNDERGO ELECTIVE AAA REPAIR
MEDICAL MANAGEMENT OF AAA

MMP-9

• DOXYCYCLINE INHIBITS MMP LEVELS INDEPENDENT OF ANTIBIOTIC ACTIVITY

• PRE-OP DOXYCYCLINE REDUCES AORTIC WALL MMP LEVELS IN PATIENTS UNDERGOING AAA REPAIR

• STANDARD DOXYCYCLINE DOSES IN HUMANS PRODUCE COMPARABLE SERUM LEVELS TO THOSE IN ANIMAL MODELS
MEDICAL MANAGEMENT OF SMALL AAA

DOXYCYCLINE TRIAL RESULTS

- MMP-9 LEVELS REDUCED 63%
- NO DIFFERENCE IN AAA GROWTH RATE AT 18 MONTHS
- LESS GROWTH IN DOXYCYCLINE GROUP AT 0-6, 6-12 AND 12-18 MONTH INTERVALS
- AAA EXPANSION > 5MM: 7% vs 41%

MOSORIN ET AL, J VASC SURG 34:606, 2001
STATINS AND AAA

- **STATINS IMPROVE LONG-TERM SURVIVAL OF PATIENTS WITH AAA**
  - KERTAI ET AL, AM J MED 2004;116:96-103
  - SUKHIJA R, AM J CARD 2006;29:279-280

- **STATINS REDUCE GROWTH RATE OF AAA**
  - SCHOUTEN O. EUR J VASC ENDOVASC SURG 2006;32:21-26

- **STATINS ASSOCIATED WITH REDUCED RUPTURE RATE OF AAA**
  - POWELL ET AL, ANN SURG 2008;247:173-179
AAA MORTALITY & OBESITY

GILES ET AL, J VASC SURG 2010;52:1471
TRENDS IN AAA REPAIR

NON-RUPTURED AAA

*P<.0001 for trend

McPHEE ET AL, JVS 2009
AAA: MORPHOLOGIC TYPES

INFRARENAL  JUXTARENAL  PARARENAL  SUPRARENAL

ALL FUSIFORM

THORACOABDOMINAL
<table>
<thead>
<tr>
<th>Conversion (n = 300)</th>
<th>Open repair (n = 7188)</th>
<th>EVAR (n = 24,676)</th>
<th>P value Conversion vs open repair</th>
<th>P value Conversion vs EVAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thirty-day mortality</td>
<td>30 (10.0)</td>
<td>299 (4.2)</td>
<td>415 (1.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Creatine rise &gt;2 mg/dL</td>
<td>22 (7.3)</td>
<td>400 (5.6)</td>
<td>334 (1.4)</td>
<td>.194</td>
</tr>
<tr>
<td>Requiring dialysis</td>
<td>18 (6.0)</td>
<td>253 (3.5)</td>
<td>215 (0.9)</td>
<td>.024</td>
</tr>
<tr>
<td>Respiratory complication</td>
<td>49 (16.3)</td>
<td>1018 (14.2)</td>
<td>549 (2.2)</td>
<td>.292</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>29 (9.7)</td>
<td>559 (7.8)</td>
<td>342 (1.4)</td>
<td>.233</td>
</tr>
<tr>
<td>&gt;48 hours on ventilator</td>
<td>41 (13.7)</td>
<td>772 (10.7)</td>
<td>338 (1.4)</td>
<td>.110</td>
</tr>
<tr>
<td>Reintubation</td>
<td>22 (7.3)</td>
<td>500 (7.0)</td>
<td>384 (1.6)</td>
<td>.801</td>
</tr>
<tr>
<td>Cardiac complication</td>
<td>26 (8.7)</td>
<td>271 (3.8)</td>
<td>340 (1.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>15 (5.0)</td>
<td>156 (2.2)</td>
<td>232 (0.9)</td>
<td>.851</td>
</tr>
<tr>
<td>CPR</td>
<td>16 (5.3)</td>
<td>133 (1.9)</td>
<td>128 (0.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Wound complication</td>
<td>14 (4.7)</td>
<td>319 (4.4)</td>
<td>577 (2.3)</td>
<td>.851</td>
</tr>
<tr>
<td>Wound infection</td>
<td>11 (3.7)</td>
<td>239 (3.3)</td>
<td>530 (2.1)</td>
<td>.747</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>3 (1.0)</td>
<td>103 (1.4)</td>
<td>64 (0.3)</td>
<td>.801</td>
</tr>
<tr>
<td>Return to operating room</td>
<td>28 (9.3)</td>
<td>639 (8.9)</td>
<td>1114 (4.5)</td>
<td>.792</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>2 (0.7)</td>
<td>39 (0.5)</td>
<td>53 (0.2)</td>
<td>.680</td>
</tr>
<tr>
<td>Stroke</td>
<td>3 (1.0)</td>
<td>55 (0.8)</td>
<td>106 (0.4)</td>
<td>.505</td>
</tr>
<tr>
<td>Sepsis</td>
<td>13 (4.3)</td>
<td>263 (3.7)</td>
<td>195 (0.8)</td>
<td>.544</td>
</tr>
<tr>
<td>Septic shock</td>
<td>11 (3.7)</td>
<td>258 (3.6)</td>
<td>152 (0.6)</td>
<td>.944</td>
</tr>
<tr>
<td>Graft failure</td>
<td>3 (1.0)</td>
<td>39 (0.5)</td>
<td>132 (0.5)</td>
<td>.236</td>
</tr>
<tr>
<td>≥1 postoperative transfusion</td>
<td>127 (42.3)</td>
<td>2270 (31.6)</td>
<td>1795 (7.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Any complication</td>
<td>174 (58.0)</td>
<td>3375 (47.0)</td>
<td>3756 (15.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Any complication d</td>
<td>95 (31.7)</td>
<td>1912 (26.6)</td>
<td>2485 (10.1)</td>
<td>.052</td>
</tr>
<tr>
<td>Mean length of stay, days ± SD</td>
<td>10.7 ± 11.2</td>
<td>9.8 ± 9.3</td>
<td>3.3 ± 5.4</td>
<td>.165</td>
</tr>
</tbody>
</table>