Optimizing Vascular Imaging Programs
David L. Dawson, MD, FACS

Disclosures
No financial relationships relevant to today’s presentation

Overview
1. Imaging systems
2. Training for surgeons
3. Improving the processes for interpretation

Elements of Modern Vascular Surgery Practice

Themes
- Imaging is integral to the practice of vascular surgery
- Imaging by surgeons or interpretation of imaging by surgeons is necessary
- Ongoing training and certification needed to keep the bar high
- Imaging-related training integral to training of the next generation of surgeons
Imaging Systems for Vascular Surgery

- Angiography
- Duplex ultrasound
- CT angiography
- MR angiography

Regular Capital Investment Need

- Imaging systems become obsolete

Increasing Examination Efficiency

- Integration of workflow
  - Radiology Information Systems (RIS)
  - Imaging system workstation
  - Picture Archiving and Communication System (PACS)
- Rapid imaging acquisition
- Human factors
  - Ergonomics
  - Accessibility and portability
  - Reduced risks to patients and health care

Improved Diagnostic Capabilities

- Digital image generation and image processing
- Automated pre- and post-processing algorithms
- Improved imaging resolution
  - Spatial
  - Temporal
- User-friendly display of information
- Image fusion

Increased Safety

- Greater precision with image-guided therapies
- Reduced radiation exposure to patients and staff
- Decreased diagnostic error, fewer non-diagnostic examinations
- Reduced technologist work-related injuries

Changes in Technology Drive Changes in Practice

- Advanced imaging necessary for today's cutting edge interventions
  - Retrograde tibiopedal access
  - Carotid artery stenting
  - Fenestrated aortic grafts
- Advanced imaging enables more nuanced management strategies
  - Observation for minimal arterial injuries
History of Arteriography

- First successfully performed by Egas Moniz (neurologist) 1927
- Surgeons performed arteriography via trans-lumbar or surgical approaches
- Technique for safe access developed by Sven-Ivar Seldinger (radiologist) 1953
- Radiology was dominant specialty performing arteriography until last decade

Current Status: Vascular Surgery

While variability remains in extent that imaging and endovascular techniques adopted in established practices, vascular surgeons now recognized as legitimate imaging and endovascular specialists.

Arteriography Techniques and Catheter-Based Interventions

- Vascular surgeons recognized the need to master new skills to remain relevant (and competitive)
  - Aortic aneurysm
  - Peripheral artery disease
  - Carotid artery disease

  2013: Endovascular knowledge and skills are fundamental to vascular surgery practice

Planning Considerations

- Location/ Organization
- Room size and preparation
  - OR team of 8 to 20 people
  - 70 square meters including a control room
  - Technical room and preparation areas is recommended.
  - 2-3 mm lead shielding and potentially reinforced floor and/or ceiling
Planning Considerations

- Workflow
- Lights, monitors and booms
  - Multiple surgical (operating) lights
    - Coverage for all areas
    - No interference or collision paths
    - Camera
  - Ambient lighting for interventional procedures
    - Dimming

Operational Issues

- Logistics
  - Equipment and supplies
- Utilization
  - Endovascular specific vs. general OR use
- Staffing
  - Cath Lab, Radiology, Operating Room
  - Call coverage with specialized vs. general staffing

Surgeons’ Key Roles

*Hybrid Operating Room*

- Users
- Define requirements for patient care
- Communicate changing procedural standards
  - EVAR as preferred approach for ruptured AAA
  - Hybrid procedures for acute ischemia
- Coordinate with other users
  - Cardiologists and CT surgeons for TAVR

Non-invasive Vascular Imaging

*Historical Perspective*

- Development of the vascular laboratory
- Changes in vascular surgery practice
- Role of MR and CT in peripheral arterial applications
  
  *With these considerations, what to do next?*

Diagnostic Medical Ultrasound

*History and Development*

- Field began in the 1940s and 1950s based on earlier military and industrial uses of ultrasound
  - SONAR (SOund Navigation And Ranging)
  - Metal flaw detection
  - SONAR for Submarine Navigation
  - Materials testing for flaws

History of the Vascular Lab

- Indirect “noninvasive” tests
- Physiologic testing methods were initially developed in the research setting
  - Plethysmography
  - Doppler flow detection
- Early ultrasound systems lacked resolution for vascular details
- Doppler added to imaging → duplex scan

D. Eugene Strandness, Jr.
Indirect Physiologic Testing

- Strain-gauge plethysmography
  - Arterial pressures and waveforms
- Continuous-wave Doppler
  - Indirect limb blood pressures
  - Analog arterial waveform

Introduction of Continuous Wave Doppler

- Vascular lab tool
  - Pressure measurement
  - Qualitative assessment
- Point of care testing

Prototype Duplex Scanner:
Strandness Laboratory, University of Washington

Prototype Duplex System and Scanhead

Duplex Scanning

- Evolution in technology and applications
- Diagnosis, screening, surveillance
- Fundamental part of vascular surgeon’s knowledge and skill set

Intra-Procedure Duplex
_Ultrasound Imaging an Integral Part of Modern Vascular Surgery Practice_

- Evaluation of vein grafts and endarterectomies
- Vascular access for endovascular procedures
- Ultrasound guided therapies

Current Status: Vascular Lab

- Vascular laboratory (duplex ultrasound scanning and physiologic testing) support is essential to modern vascular surgery practice
- Integral part of clinical practice and procedures
- Required in vascular surgeon’s training
- Important revenue source
- Vascular surgeons have leadership roles in individual vascular laboratories, technical training, and accreditation programs
CT Scan: Initial Development

- 1st commercially viable CT system invented by Godfrey Hounsfield in 1967
  - THORN EMI Central Research Laboratories
  - Publicly announced 1972
  - Profits from Beatle’s record sales enabled EMI to fund Hounsfield’s research
- Hounsfield and Cormack (Tufts University) 1979 Nobel Prize in medicine

Prototype CT Scanners

- First EMI-Scanner in Wimbledon, England
  - EMI-Scanner only took brain tomographic sections
  - First patient brain-scan 1972
- Acquired image data in about 4 minutes (scanning two adjacent slices)
- Computation time about 7 minutes/picture
- Image resolution 80 x 80 pixels

CT Evolution

- Spiral (helical) acquisition
  - Volumetric data
  - Amenable to reconstruction in multiple formats
- Multiple detectors
  - Further decrease in scan time
- Arterial phase contrast

CT Angiography

- Volumetric image acquisition
  - Data set acquired contains 3-D set of information about scanned object
- Axial and three-dimensional images
- Multiplanar reformation (MPR)
- Volume rendering (VR)
- Curved planar reformations (CPR)

Imaging Processing

- Multi-planar reformatting (MPR)
  - Sagittal
  - Coronal
  - Arbitrary planes
- Modeling to arteriographic appearance
  - Maximum intensity projection (MIP)
- Variable display of tissue thickness
  - Slices
  - Slabs
Volume Rendering

• 3D reformatting of axial imaging data
• Visualization of tissues and vessels
• Manipulate to view from multiple angles
• Demonstrate relationships

Advances in CT Technology

• Faster multi-detector arrays (256+)
• Increased computational ability of workstations for post-processing
• Network-enabled imaging processing applications
• Dual energy CT to overcome imaging shortcomings
• CT capabilities in endovascular suite

Comparison of CTA and DSA

• Nearly identical diagnostic information

ACC/AHA Guidelines

<table>
<thead>
<tr>
<th>Class I</th>
<th>Class IIa</th>
<th>Class IIb</th>
<th>Class III</th>
</tr>
</thead>
</table>

• Classification of recommendation considers size of treatment effect
• Class I
  – Benefit >>> Risk
  – Procedure or treatment SHOULD be performed or administered
• Class II
  – (a) REASONABLE to perform procedure/administer treatment
  – (b) Procedure or treatment MAY BE CONSIDERED

ACC/AHA Practice Guidelines
Hirsch et al.
Magnetic Resonance Angiography

Class I Recommendations

• MRA of the extremities is useful to diagnose anatomic location and degree of stenosis of PAD (Level of Evidence: A)
• MRA of the extremities is useful in selecting patients with PAD as candidates for endovascular intervention (Level of Evidence: A)

ACC/AHA Practice Guidelines

Class IIb Recommendations

• MRA of the extremities may be considered to select patients...for surgical bypass and to select the sites of surgical anastomosis (Level of Evidence: B)
• MRA may be considered for post-revascularization (endo and surgical) surveillance in patients with PAD (Level of Evidence: B)

ACC/AHA Practice Guidelines

Computed Tomographic Angiography

Class IIb

• CTA of the extremities may be considered to diagnose anatomic location and presence of significant stenosis in patients with lower extremity PAD (Level of Evidence: B)
• CTA of the extremities may be considered as a substitute for MRA for those patients with contraindications to MRA (Level of Evidence: B)

ACC/AHA Practice Guidelines

Post-processing Tools

• Bone editing
• Vascular segmentation
• Vascular procedure planning
• Volume rendering (3-D modeling)
• Workstation and network access
  – Thin client software allows manipulation of imaging source data on server
  – Access from anywhere

Workstation offers surgeon hands-on access to manipulate CT data
Endovascular Procedures Fundamentally Changed Vascular Surgery

3-D CT Angiography

- Enables anatomic visualization
- More accurate measurements of diameters, lengths, angulation and tortuosity
- Need for marker catheter aortogram eliminated
- Model endografts as aid to preoperative planning

Improved “situational awareness”

CT Angiography (CTA) Adopted for Many Uses

- Guiding access for endovascular procedures
- Selection of patients for intervention
- Planning for complex interventional cases
- Same day imaging with consultation
- Evaluation of concomitant vascular problems

Learning CT Post-processing

Company training and customer service

YouTube videos  User manuals
### Questions

- **Should we?**
  - Yes. Imaging expertise has (will) become integral to our practices
- **Can we?**
  - Yes. Surgeons have anatomic knowledge and clinical expertise.
- **How do we?**
  - Adopt available tools in practice.
  - Include technical training in GME and CME programs.
  - Collaborate.

### Future Directions?

- Surgical fellowships in advanced imaging and endovascular techniques
- Advanced fellowships for graduates of integrated vascular surgery residencies

### How do you get to Carnegie Hall?

**“Practice, practice, practice”**

Choose an approach that considers users needs and resources

- **$200** Easy to learn and use
- **$3000** More versatile, robust capabilities

### Emphasis on Imaging in Training and Certification

- Vascular laboratory curriculum required by ACGME for fellowships and residencies
- Registered Physician in Vascular Interpretation (RPVI) certificate becomes a prerequisite to VSB-ABS qualifying examination in 2014
- RPVI credential mandated by some vascular laboratories as element of IAC accreditation
UC Davis Vascular Laboratory Curriculum

- Practicum sessions with technologists
  - Ten 4-hour modules with defined objectives
  - Readings from Strandness text
- Physics and instrumentation
  - Online lectures, comprehensive, self-directed
  - 10 vascular physics and 14 vascular modules
  - 23.5 hours of core concepts, optional 17.5 hours of customized review
- Direct and indirect supervision by faculty
- > 500 cases as primary interpreting physician
- Physician Vascular Interpretation examination
  - RPVI an American Board of Surgery prerequisite

ACS offers programs to assist surgeons with training and credentialing

PVI Examination

- Registered Physician in Vascular Interpretation (RPVI) examination
- Introduced by American Registry for Diagnostic Medical Sonography in 2006
  - 1,800 now hold the credential
- Focused on physician interpretation of vascular laboratory examinations
  - Distinct from focus of Registered Vascular Technologist (RVT) credential
PVI Prerequisite B1: Formal Training

- Licensure
  - MD or DO degree earned in U.S. or Canada
- Training
  - ACGME or RCPSC accredited residency or fellowship
  - Must include didactic and clinical vascular laboratory/ultrasound interpretation experience as integral part of program

PVI Prerequisite B1: Interpretation Experience

- Documented interpretation experience with minimum of 500 vascular laboratory studies
- Distributed over testing areas:
  - Carotid duplex ultrasound
  - Transcranial Doppler
  - Peripheral arterial physiologic testing
  - Peripheral arterial duplex ultrasound
  - Venous duplex ultrasound
  - Visceral vascular duplex ultrasound

Documentation

- Copy of medical school diploma
- Letter from program director verifying dates of training and ≥ 500 interpretations of vascular laboratory examinations
  - ARDMS.org/sampleletters
- Applicants should maintain a patient log or other record of interpretation

Verification

- Log not submitted with application but may be requested as part of a random audit
- This documentation should be maintained for at least three years

PVI Application Audit Program

Expected to be implemented by December 31, 2014
- Random audit of PVI applicants
- Applicants selected for audit will be required to submit the patient log which will checked for accuracy
- Improve credibility of RPVI certification

Changing to “Testing Windows”

- PVI examination will be offered during two testing windows each year
- Scores will follow 60 days after the end of the window
- Applicants must be aware of this timeline, as RPVI certificate is VSB-ABS prerequisite
Windowed PVI Registration

• Apply
• Send in documents
• Receive eligibility
• Schedule during next “testing window”
  – 30 days each
  – Spring and Fall


Score Reports

• Currently provided at the testing site, immediately following the test
• With windowed testing, scores will be available online, approximately 60 days after the window ends

When is the Change?

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>May 31, 2013</td>
<td>Last date for applications through current process</td>
</tr>
<tr>
<td>August 1, 2013</td>
<td>First date to apply for the first PVI testing window</td>
</tr>
<tr>
<td>November 14 – December 16, 2013</td>
<td>First PVI testing window</td>
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<tr>
<td>February 15, 2014</td>
<td>Score reports available</td>
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Changes Improve Testing Quality

• Facilitates introduction of new item types
• Increases content currency
  – Delayed score reports allows the exam to be built with new, up-to-date questions and simulations
• Maintains psychometric rigor

Advance Item Type (AIT) Questions

• Hotspot questions introduced December 2012
  – Display image and question
  – Examinee indicates correct answer using cursor to mark image
• Higher level of thinking and processing than conventional multiple choice question

Anticipated Future Changes

• Assessment tools that more realistically evaluate physician competencies
  – Interpretation of cases with multiple images delivered in simulated PACS system
  – New item types will not affect pass rates
• Re-evaluation of the passing standard after the first window closes
Semi-Interactive Console Used for Sonography and Principles and Instrumentation Examination (RVT prerequisite)

- Presents display of information in manner similar to systems used in practice
- Asks test-taker to make appropriate manipulations of controls
- Assesses ability to recognize and respond to specific conditions

What Won’t Change?

- Application requirements
- The PVI Content Outline
- Basic multiple-choice question (MCQ) structure
- Test length
- Testing locations

PVI Content Outline

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<thead>
<tr>
<th>Category</th>
<th>Subcategory</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Anatomy &amp; Physiology [8%]</td>
<td>Abdominal/Visceral</td>
<td>[8%]</td>
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<tr>
<td></td>
<td>Cerebrovascular</td>
<td>[8%]</td>
</tr>
<tr>
<td></td>
<td>Peripheral arterial</td>
<td>[8%]</td>
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<tr>
<td></td>
<td>Venous</td>
<td>[8%]</td>
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<tr>
<td>Pathology [10%]</td>
<td>Abdominal/Visceral</td>
<td>[10%]</td>
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<tr>
<td></td>
<td>Cerebrovascular</td>
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<tr>
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<tr>
<td></td>
<td>Venous</td>
<td>[10%]</td>
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<td>Protocols [16%]</td>
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<td>[16%]</td>
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<td></td>
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<td>Physics &amp; Instrumentation [10%]</td>
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<td>Bioeffects</td>
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<td>Imaging instruments</td>
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<td></td>
<td>GA/Statistics (sens/spec, pos/neg pred value, accuracy)</td>
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<tr>
<td>Other [4%]</td>
<td>New Technologies</td>
<td>[4%]</td>
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<td></td>
<td>Traumatic injury</td>
<td>[4%]</td>
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<tr>
<td></td>
<td>Physician’s role in procedure</td>
<td>[4%]</td>
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2012 Testing Results

<table>
<thead>
<tr>
<th>Examination</th>
<th>Number</th>
<th>Pass Rate</th>
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<tbody>
<tr>
<td>Abdominal Sonography</td>
<td>4,743</td>
<td>60%</td>
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<tr>
<td>Adult Echocardiography</td>
<td>2,305</td>
<td>59%</td>
</tr>
<tr>
<td>Breast</td>
<td>1,047</td>
<td>73%</td>
</tr>
<tr>
<td>Fetal Echocardiography (RDMS)</td>
<td>83</td>
<td>79%</td>
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<tr>
<td>Fetal Echocardiography (RCMS)</td>
<td>123</td>
<td>72%</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>172</td>
<td>97%</td>
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<tr>
<td>Neurosonology</td>
<td>100</td>
<td>70%</td>
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<tr>
<td>Obstetrics and Gynecology</td>
<td>3,500</td>
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</tr>
<tr>
<td>Pediatric Echocardiography</td>
<td>246</td>
<td>64%</td>
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<tr>
<td>PVI</td>
<td>401</td>
<td>95%</td>
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<tr>
<td>Sonography Principles and Instrumentation</td>
<td>10,622</td>
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<tr>
<td>Vascular Technology</td>
<td>3,910</td>
<td>58%</td>
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<td>Totals:</td>
<td>27,236</td>
<td>66%</td>
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</table>

Examination Changes

- Expanded multi-disciplinary Examination Development Task Force (EDTF) improving and updating content
- Windowed exam will allow for large cluster of data to be analyzed simultaneously
  - “Old” test: 75% “old questions”
  - “New” test: 75% “new questions”
- Volunteer item developers sought
Pass Rates for PVI Could Change

- Changing cohort taking the test
  - New ABS requirement does this
- Re-evaluation of the passing standard
  - This will happen after the first windowed administration

Structured Reporting and Data Management:

Pathway to the Paperless Vascular Lab

Electronic Medical Record

- Electronic Charting
- Paperless System
- Computerized Physician Order Entry

Scheduling Software

- Automated
- Link to EMR order
- No entering data for scheduling

Digital Archiving

- PACS
- Obtaining images
- Reviewing images
- Interpretation / workstation

Reporting Software

- Macros & Templates
- Minimize typing time
- Maximize scanning time
- Ease for MD interpretation and report changes
What is Missing?

- **Workflow**
  - Worksheets
  - Transmission of calculations/data from US to report
  - Conveying information to reading physician
  - Developing reports

- **Management Tools**
  - Statistical Reports
  - Productivity Reports
  - Short and Long Term planning measures
  - Accreditation

- **Research**
  - Longitudinal analysis
  - Retrospective reviews
  - Comparison tools
  - Drivers for future clinical practice

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Workflow

Exam Performance  Final Report

Option 1: WonkaVision

Option 2: Incremental Improvements

- Add Text to Image
- Removes Paper
- Physician Satisfaction?
- Data not retrievable
Shortfalls

- Data Entry is not easily retrievable
- Data entered not consistent (not reliable)
- Lacking field based values
- No automated import of history, procedures or prior values
- Transmission of calculations from US machine to worksheet, preliminary report and final report

Option 3: Structured Reporting Programs

Structured Reporting
Disadvantages or Considerations

- Licensing Fees
  - Per Equipment
  - Per User

- Long Term Viability
  - Service
  - Changes to reports

- New Equipment
  - IS systems
  - US equipment

SR Data Retrieval

- Standard DICOM
- Customization

- Manual Entry
- Garbage in...

- Reporting
- Errors
- Cumbersome

Paperless?
Structured Reporting?
Summary

• Updated imaging systems
• Surgeon involvement in planning and implementation
• Acquisition of post-processing and interpretation skills
• Certification in relevant areas
• Standardized processes and use of IT tools