Management of postoperative extremity ischemia
Scope

• Etiology
• Ischemia
• Reperfusion
• Compartment syndrome
• A 65 Yr Thai male pt. present with shock at outside hospital had cut down on Left arm 24 hours prior to KCMH.
• Physical examination on left arm
  – Severe Pain
  – Paresthesia
  – Paralysis
  – Pulselessness
Introduction

• Vascular surgery has two main consequences - hemorrhage and ischemia. Or, in the words of an anonymous Czech surgeon, "Bloody vascular surgery - it's either bleeding too much or it's not bleeding enough".
Scope

- Etiology
- Ischemia
- Reperfusion
- Compartment syndrome
Etiology

• Penetrating
  – Gun shot wounds
  – Shot gun wounds
  – IV drug abuse
  – Catheterization

• Blunt
  – Joint displacement
  – Bone fractures
  – Contusion

• Emboli
  – Cardiac

• Thrombosis
• The time interval between ischemia and evaluation must be considered.
• More than 6 hours of “warm” ischemia at body temperature with out cooling the extremity results in irreversible nerve and muscle damage in 10% of patients
Scope

• Etiology
• Ischemia
• Reperfusion
• Compartment syndrome
Injury during ischemia

- Hypoxia – Anoxia
- Diminish energy production [ATP]
- Intracellular energy
- Xanthine dehydrogenase turn to Xanthine oxidase
Injury during ischemia

- Disturbance in cellular ion homeostasis
- Na+, K+, Ca+
Injury during ischemia

• Different organs have different tolerance
  – Skeletal muscle 2 hr
  – Jejunum 30 min
  – Brain 4 min
Pro Inflammatory mediators

• Vascular Endothelial Growth Factor (VEGF)
• Hypoxia Inducible Factor (HIF)
• Etc that is unknown
Result of mediators

- Microvascular endothelial barrier
- Key events during ischemia set the stage for worsening injury during REPERFUSION
Scope

- Etiology
- Ischemia
- Reperfusion
- Compartment syndrome
Reperfusion

- Back to normal
- Exacerbate ischemic injury
Ischaemia  Reperfusion  Reperfusion  Reperfusion

0

Little or no injury
<1 h

Ischaemia-reperfusion injury of skeletal muscle

4–6 h

Skeletal muscle infarction

Reversible injury

Irreversible injury
Percutaneous mechanical thrombectomy device
History

1953
Saldinger technique

1963
Balloon tip catheter

1964
Teflon dilator

Acta radiol. 1953 May;39(5):368-76.
History

- 1974: PTA
- 1985: Metallic stent
- 1991: EVAR

History

2007
Percutaneous Mechanical Thrombectomy (PMT) devices

- Changed the nature of current thrombolysis treatment
- Rapid removal of thrombus burden with restoration of blood flow
- Still need continued thrombolysis to clear remnant clot
Percutaneous Thrombectomy

1. Percutaneous Aspiration Thrombectomy
2. Percutaneous Mechanical Thrombectomy
Percutaneous Aspiration Thrombectomy

Diagram of PAT procedure.

a. Embolus is lodged at bifurcation of vessel.
b. Coaxial sheath and aspiration catheter pass distally in vessel. Catheter is advanced beyond the sheath; when catheter is in contact with embolus, negative pressure is applied with a 50-ml syringe.
c. Embolus is withdrawn toward the sheath, with a part of it extending into the lumen of the aspiration catheter.
d. Because it is soft, embolus remodels to shape of sheath as it is withdrawn proximally.
e. Small fragment of proximal portion of embolus has become separated and is free in the lumen of the aspiration catheter. Another part of the embolus remains engaged within the tip of the aspiration catheter. Another part has become separated and remains distal. After the engaged particles are removed the aspiration procedure will be repeated to remove the residual material.
Percutaneous Mechanical Thrombectomy

1. Hydrodynamic Device
2. Fragmentation Device
3. Ultrasound Device
4. Trellis Device
Percutaneous Mechanical Thrombectomy

1. Hydrodynamic Device
2. Fragmentation Device
3. Ultrasound Device
4. Trellis Device
Power Pulse™ Delivery

Mechanism of Action
Dual Functionality

Single-Catheter Option for Combination Therapy

INFUSION of physician-specified fluid (PSF)

REMOVAL of thrombus
## Hydrodynamic Device

<table>
<thead>
<tr>
<th>Series</th>
<th>Number of patients</th>
<th>Device used</th>
<th>Type of occlusion</th>
<th>Success rates</th>
<th>Limb salvage</th>
<th>Complication rates</th>
<th>Mortality rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silva et al 1998</td>
<td>22</td>
<td>AngioJet</td>
<td>Native arterial, multiple levels, bypass grafts</td>
<td>91%</td>
<td>89% at 6 months</td>
<td>Bleeding 9%</td>
<td>13.6%</td>
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<tr>
<td>Ansel et al 2002</td>
<td>99</td>
<td>AngioJet</td>
<td>Native arterial, multiple levels, bypass grafts</td>
<td>71%</td>
<td>96% at 6 months</td>
<td>Bleeding 5%</td>
<td>7.1%</td>
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<tr>
<td>Muller-Hulsbeck et al 2000</td>
<td>112</td>
<td>AngioJet</td>
<td>Native arterial, multiple levels, bypass grafts</td>
<td>75%</td>
<td>75% at 15 months</td>
<td>Acute renal failure</td>
<td>16%</td>
</tr>
<tr>
<td>Krajcer et al 2002</td>
<td>6</td>
<td>AngioJet</td>
<td>Aortic endografts</td>
<td>100%</td>
<td>100% at 2 years</td>
<td>Embolization N/A</td>
<td>0%</td>
</tr>
<tr>
<td>Kasirajan et al 2001</td>
<td>86</td>
<td>AngioJet</td>
<td>Native arterial, multiple levels, bypass grafts</td>
<td>84%</td>
<td>90% at 6 months</td>
<td>Embolization 0%</td>
<td>9.3%</td>
</tr>
</tbody>
</table>

Percutaneous Mechanical Thrombectomy

1. Hydrodynamic Device
2. Fragmentation Device
3. Ultrasound Device
4. Trellis Device
Fragmentation Devise

Rotarex

Techniques in Vascular and Interventional Radiology, Vol 6, No 1 (March), 2003: pp 22-34
Fragmentation Devise

- Success rate 71-75%
- Adjunctive success rate 95%
- 6 mo patency rate 43%
- No study in long term outcome
Percutaneous Mechanical Thrombectomy

1. Hydrodynamic Device
2. Fragmentation Device
3. Ultrasound Device
4. Trellis Device
Ultrasound devise
Percutaneous Mechanical Thrombectomy

1. Hydrodynamic Device
2. Fragmentation Device
3. Ultrasound Device
4. Trellis Device
Trellis device
Clinical and economic evaluation of the trellis thrombectomy device for arterial occlusions: Preliminary analysis

Timur P. Sarac, MD, a Daniel Hilleman, PhD, b Frank R. Arko, MD, c Christopher K. Zarins, MD, c and Kenneth Ouriel, MD, a Cleveland, Ohio; Omaha, Neb; and Stanford, Calif

- Success rate 92%
- Technical success rate for suprainguinal and infrainguinal occlusions was similar (90.7% +/- 11.7% vs 92.2% +/- 12.4%; P = .78).
- Thirty-day amputation-free survival rate was 96%
- No Bleeding complication
- Overall mean cost for patients with TIC treatment was $3216 +/- $1740
<table>
<thead>
<tr>
<th>Company</th>
<th>Device</th>
<th>Sheath Size</th>
<th>Guidewire Compatibility</th>
<th>Working Length</th>
<th>Mode of Operation</th>
<th>CE Mark</th>
<th>FDA Indicated Use</th>
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</thead>
<tbody>
<tr>
<td>Arrow International, Inc.</td>
<td>Arrow-Therola PTD (Percutaneous Thrombolytic Device)</td>
<td>5</td>
<td>N/A</td>
<td>65</td>
<td>Mechanical Thrombectomy</td>
<td>Yes</td>
<td>Used in combination with the rotator drive, permits mechanical declotting of synthetic dialysis grafts.</td>
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<tr>
<td></td>
<td>Arrow-Therola Over-The-Wire PTD (Percutaneous Thrombolytic Device)</td>
<td>7</td>
<td>.025</td>
<td>65, 120</td>
<td>Mechanical Thrombectomy</td>
<td>Yes</td>
<td>Used in combination with the rotator drive, permits mechanical declotting of native AV fistula and synthetic dialysis grafts.</td>
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<tr>
<td>Boston Scientific Corporation</td>
<td>Oasis Thrombectomy System</td>
<td>6</td>
<td>.018</td>
<td>60, 120</td>
<td>Venturi Effect With Fragmentation</td>
<td>Yes</td>
<td>AV Grafts</td>
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<tr>
<td>Boston Scientific Corporation</td>
<td>ProLumen</td>
<td>6</td>
<td>N/A</td>
<td>60</td>
<td>Wall Contact With Fragmentation</td>
<td>No</td>
<td>AV Grafts</td>
</tr>
<tr>
<td>Boston Scientific Corporation</td>
<td>ProLumen Plus</td>
<td>6</td>
<td>N/A</td>
<td>60</td>
<td>Wall Contact With Fragmentation</td>
<td>No</td>
<td>AV Grafts</td>
</tr>
<tr>
<td>Edwards Lifesciences, Inc.</td>
<td>Thrombix PNT System</td>
<td>6</td>
<td>.018</td>
<td>60, 120</td>
<td>Mechanical Necration and Aspiration</td>
<td>Yes</td>
<td>Indicated for removal of thrombus in synthetic hemodialysis access grafts.</td>
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<tr>
<td>ev3, Inc.</td>
<td>X-Sizer Catheter System</td>
<td>7, 8</td>
<td>.014</td>
<td>135</td>
<td>Enclosed Cutter With Aspiration</td>
<td>Yes</td>
<td>N/A (coronary registry ongoing dialysis graft 510(k) submitted)</td>
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<tr>
<td></td>
<td>Helix Clot Buster Thrombectomy Device (Amplatz Device)</td>
<td>7</td>
<td>N/A</td>
<td>75, 120</td>
<td>Impeller Device With Fragmentation</td>
<td>Yes</td>
<td>Dialysis graft and native fistula.</td>
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<tr>
<td></td>
<td>Castaneda Over-The-Wire Brush</td>
<td>6</td>
<td>.035</td>
<td>60</td>
<td>Wall Contact With Rotating Brush</td>
<td>Yes</td>
<td>Synthetic AV grafts.</td>
</tr>
<tr>
<td>Cardiometrics Technologies Inc.</td>
<td>Akiolyzer Eliminator</td>
<td>6</td>
<td>N/A (.018)</td>
<td>60</td>
<td>Combination of Manual Driven Axial, Rotational and/or Fusible Nocton</td>
<td>Yes</td>
<td>Indicated for use in the mechanical declotting of synthetic dialysis grafts.</td>
</tr>
<tr>
<td>Omnilignics Medical Technologies</td>
<td>Resolution 360 Therapeutic Wire</td>
<td>5</td>
<td>N/A</td>
<td>.025 X 95 cm total, 20 cm energy field</td>
<td>Low-Power Acoustic Energy</td>
<td>Yes</td>
<td>510(k) filed for the treatment of thrombosed synthetic dialysis access grafts.</td>
</tr>
<tr>
<td>Posat Medical Inc.</td>
<td>XMI</td>
<td>4</td>
<td>.014</td>
<td>135</td>
<td>Venturi Effect With Micro Fragmentation and Removal</td>
<td>Yes</td>
<td>Removing thrombus in the treatment of patients with symptomatic coronary artery or saphenous vein graft lesions in vessels &gt;2 mm in diameter prior to balloon angioplasty or stent placement.</td>
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<tr>
<td></td>
<td>XMI-4X</td>
<td>4</td>
<td>.014</td>
<td>135</td>
<td>Venturi Effect With Micro Fragmentation and Removal</td>
<td>Yes</td>
<td>Removing thrombus in the treatment of patients with symptomatic coronary artery or saphenous vein graft lesions in vessels &gt;2 mm in diameter prior to balloon angioplasty or stent placement.</td>
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<td></td>
<td>XVG</td>
<td>6-8</td>
<td>.014</td>
<td>140</td>
<td>Venturi Effect With Micro Fragmentation and Removal</td>
<td>Yes</td>
<td>Breaking apart and removing thrombus from infragluteal peripheral arteries &gt;3 mm in diameter.</td>
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<tr>
<td></td>
<td>Xspeedor 120</td>
<td>6</td>
<td>.035</td>
<td>120</td>
<td>Venturi Effect With Micro Fragmentation and Removal</td>
<td>Yes</td>
<td>Breaking apart and removing thrombus from infragluteal peripheral arteries &gt;3 mm in diameter.</td>
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<tr>
<td></td>
<td>AVX</td>
<td>6</td>
<td>.035</td>
<td>50</td>
<td>Venturi Effect With Micro Fragmentation and Removal</td>
<td>Yes</td>
<td>Breaking apart and removing thrombus from AV access conduits.</td>
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<tr>
<td>Strauss Medical</td>
<td>Rotaxa Catheter</td>
<td>6-8</td>
<td>.018</td>
<td>88 to 110</td>
<td>Detachment, Suction, Fragmentation and Transport</td>
<td>Yes</td>
<td>N/A</td>
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<td>Category</td>
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<td>Company</td>
<td>Mechanism</td>
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<tr>
<td>Clot Aspiration Devices</td>
<td>AngioJet</td>
<td>Possis Medical, Inc</td>
<td>High-pressure fluid injection, Bernoulli principle</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Trellis, Fino</td>
<td>Bacchus Vascular</td>
<td>Combination mechanical fragmentation/aspiration</td>
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<tr>
<td></td>
<td>Oasis</td>
<td>Boston Scientific</td>
<td>Venturi effect with fragmentation</td>
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<td></td>
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<td></td>
<td>Thrombex PMT</td>
<td>Edwards Lifesciences</td>
<td>Maceration and aspiration</td>
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<td>Clot fragmentation Devices</td>
<td>Arrow-Trerotola</td>
<td>Arrow International</td>
<td>Mechanical maceration of clot</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Helix Clot Buster (Amplatz device)</td>
<td>ev3</td>
<td>Impeller device with fragmentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Casteneda Brush</td>
<td>Micro Therapeutics, Inc</td>
<td>Wall contact with rotating brush</td>
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<tr>
<td>Ultrasound Devices</td>
<td>Resolution 360 wire</td>
<td>Omnisonics Medical Technologies, Inc</td>
<td>Acoustic energy clot disruption</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Lysus Infusion system</td>
<td>EKOS Corp.</td>
<td>Low energy ultrasound to increase lytic dispersion into thrombus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Complications for percutaneous intervention
Complications

Puncture site (total) 4.0%
  Bleeding 3.4%
  False aneurysm 0.5%
  Arteriovenous fistula 0.1%

Angioplasty site (total) 3.5%
  Thrombus 3.2%
  Rupture 0.3%

Distal vessel (total) 2.7%
  Dissection 0.4%
  Embolization 2.3%
Complications

Systemic (total) 0.4%
Renal failure 0.2%
Myocardial infarction (fatal) 0.2%
Cerebrovascular accident (fatal) 0.55%

Consequences
Surgical repair 2.0%
Limb loss 0.2%
Mortality 0.2%

Complications of Endovascular Procedures Requiring Surgical Intervention

- Pseudoaneurysm 61.2%
- Hematoma 11.2%
- Arteriovenous fistula 10.2%
- External bleeding 6.1%
- Retroperitoneal hematoma 5.1%
- Arterial thrombosis 3.1%
- Groin abscess 2%
- Mycotic aneurysm 1.0%
Reperfusion

- Compartment syndrome
- Myocardial stunning & arrhythmias
- Central nervous system
- Gastrointestinal system
- Lung
- Kidney
- Multiorgan dysfunction
Prevention

- Hydration
- Diuretic
- Alkalinizing urine
- Mannitol
- Inotropic drugs
- Anti arrhythmic drugs
Medication that may help

- N-acetylcysteine
- angiotensin-converting enzyme inhibitors
- Mannitol
- iron-chelating compounds
- Catalase
- superoxide dismutase
- Allopurinol
- calcium-channel antagonists
- vitamin E
Scope

• Etiology
• Ischemia
• Reperfusion
• Compartment syndrome
Definition:
An increased pressure within enclosed osteofascial space that reduces capillary perfusion below level necessary for tissue viability; the underlying mechanism is:
- increased volume within space
- decreased space for contents
- combination of both
Pain

• Classically out of portion to injury
• Exaggerated with passive stretch of the involved muscles in compartment
• Earliest symptom but inconsistent
• Not available in obtunded patient
Paresthesia

• Also early sign
  – Peripheral nerve tissue is more sensitive than muscle to ischemia
  – Permanent damage may occur in 75 minutes
• Difficult to interpret
• Will progress to anesthesia if pressure not relieved
Paralysis

• Very late finding
  – Irreversible nerve and muscle damage present

• Paresis may be present early
  – Difficult to evaluate because of pain
Compartment Pressure

• When?
  – Confirm clinical exam
  – Obtunded patient with tight compartments
  – Regional anesthetic
  – Vascular injury

• Technique
  – Whiteside infusion
  – Stick technique: side port needle
  – Wick catheter
  – Slit catheter
Whiteside Technique

- Simple technique
- Readily available supplies
- With 18 gauge needle least accurate
- More accurate if use side port needle
- Considered "gold standard"
- Need a catheter
- Can use the measuring unit for Stick system
- Can leave indwelling for continuous monitoring
Stryker Stic System

Unique design with unique benefits

- Side ported, non-coring needle for tissue fluid pressure equilibration
- Diaphragm chamber maintains sterile fluid pathway
- One way valve prevents backflow of fluid
- Automatic zero balance button eliminates manual zeroing adjustments
- Digital display (with low battery indicator) to quantify pressure reading
- Pre-filled syringe for rapid, convenient utilization

Easy to use
Can check multiple compartments
Different areas in one compartment

(Not actual size)
Forearm
Leg Anatomy
Leg Two Incision Technique
Hand Compartments
Foot Compartments
Wound Care

- Soft tissue coverage by 5-7 days
- Delayed closure
  - Vascular loop ‘lace technique’
- Split thickness skin graft
- Flaps or free tissue transfer
Prophylactic Fasciotomy

- Prolonged ischemia ( >4-6 hrs )
- Prolonged hypotension
- Swelling extremity
- Extensive soft tissue damage
- Combined venous/arterial injury
- Combined bony/arterial injury
- Intracompartment pressure > 25 mmHg
Anticoagulants

- Unfractionated heparin
- LMWH
- Activated protein C
- Anti thrombin III
Bad anastamosisis
Management of postoperative extremity ischemia