Image Guided Therapy: Interventional Procedures and Clinical Issues

Filip Banovac, MD
Georgetown University Hospital
Imaging Science and Information Systems Center (ISIS)
Department of Radiology
Washington, DC, USA

Goals

• Describe Interventional Radiology (IR) – a medical subspecialty that utilizes imaging to perform minimally invasive procedures in treatment of disease

• Describe common interventional Radiology procedures and describe some of the technologies that are involved

• Examine the frontiers of technical innovation to improve and advance IR
What is Interventional Radiology (IR)?

• Targeted treatments with image guidance
• Less pain, less risk, faster recoveries than open surgery
• Interventional Radiologists are board certified physicians

What is Interventional Radiology (IR)?

• Diagnostic Radiology (5 years of postdoc training)
• Vascular and Interventional Radiology (1-2 additional years)
• Neurointerventional Radiology (2-3 additional years)
  • Similar to Interventional Radiology but deals with interventions in the brain, spine and head and neck
What is Interventional Radiology (IR)?

- Young Specialty
- Charles Dotter, MD - the “father of interventional radiology” was nominated for the Nobel Prize in medicine in 1978

- Unrecognized specialty
  - Society of Interventional Radiology poll on name recognition
  - One of technologically most advanced specialties
  - Most recognized specialty – PEDIATRICS (92%)
  - Most unrecognized specialty – Interventional radiology (2%)

What are the advantages of interventional radiology?

- Most procedures can be performed on an outpatient basis or require only a short hospital stay
- General anesthesia usually is not required
- Risk, pain and recovery time are often significantly reduced
- The procedures are usually less expensive than surgery or other alternatives
What procedures are done by IR?

- Vascular interventions
- Non-vascular interventions

Additional procedures:
- Angiography
- Balloon Angioplasty
- Blood vessel Stenting
- Catheter delivered chemotherapy for cancer
- Endovascular embolization
- Endovascular recanalization and thrombolysis
- TIPS
- Long term venous access for dialysis and drug administration
What procedures are done by IR?

- Non-vascular interventions
  - Abscess drainage
  - Bile drainage for obstructed liver bile ducts
  - Percutaneous nephrostomies and stenting
  - Radiofrequency ablation (RFA) of tumors
  - Gastrostomy for feeding
  - Gastrojejunostomy for feeding
  - Image guided needle biopsy

Technologies

**Multidetector Fluoro-CT**

Advantages:
- Combines the advantages of fluoroscopy with CT cross sectional imaging
- Considerable improvement from standard CT and even High Speed multi-detector CT
Technologies

● CT
  ● Good contrast
  ● Not real time (Fluoro-CT is real time, but limited availability)
  ● High radiation dose to the operator

Technologies

● Ultrasound
  Real time
  ● Excellent for soft tissue interventions
  ● Limited windows, 2 dimensional
    ● 3D US exists but image hard to display useful data in interventions
    ● Limited by poor penetration of bone and air filled structures
  ● Hard to see your instruments
Technologies

- Fluoroscopy
  - Real time
  - Overwhelming use and long clinical experience
  - Limited contrast and poor organ/structure definition
Angiography

- Radiologic exam of the arteries and veins to diagnose blockages and other blood vessel problems
- Uses a catheter to access the blood vessel and a contrast agent to make the artery or vein visible

Angiography

- Enabling Technology:
  - Digital Subtraction Angiography (DSA)
  - Subtracts the bones and soft tissues out to only display blood vessels once radiographic contrast is injected
Angiography

- Limitation of present technology:
  - DSA images are temporary – contrast washes out with blood
  - Intervention based on knowledge of anatomy and memory of what was just seen.

Balloon Angioplasty

- Opens blocked or narrowed blood vessels by inserting a small balloon into the vessel and inflating it
- Used to unblock narrowed arteries in the legs, kidneys, liver or elsewhere in the body
**Balloon Angioplasty**

- **Enabling Technology:**
  - Balloons delivered over thin catheters to function at the location of disease without having to surgically "open" the patient.

**Limitation of present technology:**

- Balloons displace the disease, they don't remove it.
- Complications:
  - Plaque embolization
  - Blood vessel dissection
  - Disease recurrence
Biliary Drainage and Stenting

- Uses a stent (tube) to open blocked ducts and allow bile to drain from the liver

Nephrostomy tube placement

- Insertion of a tube into the kidney
- Used in patients whose kidney or ureters are obstructed from kidney stones or cancer
Nephrostomies and Biliary duct Drainage

Limitation of present technology:

- We don’t have good technology to insert our needles into these targets if the targets are small.

Liver Cancer

- 14,000 cases of primary liver cancer are diagnosed each year (HCC is most common type)
- Due to the increase of hepatitis C, the incidence of HCC is on the rise

Chemoembolization for liver cancer

- Liver Cancer
Liver Cancer

- Surgical removal of liver tumors offers the best chance for a cure
- Surgical removal is not possible for more than 75% with primary and 90% with secondary (metastases) liver cancer

Chemoembolization for liver cancer

- Delivers a high dose of cancer-killing drugs directly to the tumor while depriving the tumor of its blood supply by blocking (embolizing) the arteries feeding the tumor
Chemoembolization for liver cancer

- Delivery of cancer-fighting agents directly to the site of a liver tumor
- Currently being used mostly to treat cancers of the liver and endocrine tumor metastases to the liver

Courtesy of Elliot Levy, MD, Georgetown University Hospitals

Chemoembolization for liver cancer

- Ethiodol
  - Poppyseed Oil
  - Accumulates preferentially in HCC

Courtesy of Elliot Levy, MD, Georgetown University Hospitals
Chemoembolization for liver cancer

Using imaging, a catheter is fed through the femoral artery to the blood vessels feeding the tumor.

- Small embolic particles are injected to block the blood vessel.
Chemoembolization for liver cancer

The drugs and lack of blood supply cause the tumor to shrink.
Chemoembolization

For liver cancer

53 year old male

May, 2002               September, 2003                              March, 2004

Chemoembolization courtesy of Elliot Levy, Georgetown University Hospitals
Chemoembolization for liver cancer
58 year old male

July, 2003

Courtesy of Elliot Levy, Georgetown University Hospitals

Chemoembolization for liver cancer
58 year old male

August, 2003

Courtesy of Elliot Levy, Georgetown University Hospitals
Radiofrequency Ablation (RFA) of tumors

• Using radiofrequency (RF) energy to cook and kill cancerous tissue
• Alternative to surgical resection
• Only option in most patients with metastasis from colon cancer to liver

Clinical Application
Radiofrequency Probe
Coaxial needle system

Allows for biopsy before or during ablation, may also track easier
Radiofrequency Ablation

- At 46°C malignant cells will die after 8 minutes
- At 51°C as little as 2 minutes are required
- At temperatures above 60°C intracellular proteins denature
- Thermal coagulation begins at 70°C
- Tissue desiccation occurs at 100°C

- So if you cook it – you kill it!

RF 3000 generator
Evolution of a Complete Thermal Lesion

1. Thermal Lesion begins at site array tips
2. Thermal Lesion expands laterally along the lines back toward the center of the array
3. Thermal Lesion expands outward and between lines
4. Complete Thermal Lesion

Starburst electrode
Radiofrequency Ablation (RFA)

- Using imaging, an interventional radiologists guides a small needle into the tumor
- From the tip of the needle, radiofrequency energy is transmitted into the targeted tissue, where it produces heat and kills the tumor
Radiofrequency Ablation (RFA)

- Nonsurgical, localized treatment that kills the targeted tissue with heat, while sparing the healthy tissue
- Usually few side effects
Radiofrequency Ablation (RFA)

PRE-RFA

POST

Courtesy of Elliot Levy, Georgetown University Hospitals

Radiofrequency Ablation (RFA)

PRE-RFA

Courtesy of Elliot Levy, Georgetown University Hospitals
Radiofrequency Ablation (RFA)

Angiogram performed and tumor was embolized first

Courtesy of Elliot Levy MD, Georgetown University Hospitals

Radiofrequency Ablation (RFA)

Angiogram performed and tumor was embolized first

Courtesy of Elliot Levy, Georgetown University Hospitals
Radiofrequency Ablation (RFA)

Post RF Ablation

Courtesy of Elliot Levy MD, Georgetown University Hospitals
Stent-graft Insertions for Aneurisms

- For thoracic (TAA) and abdominal aortic aneurisms (AAA)
- Stent-graft reinforces a ruptured or ballooning section of an artery (an aneurysm) with a covered stent
- Alternative to open surgery which carries high morbidity and mortality

Thrombolysis and Venous Filters

- Dissolves blood clots by injecting clot dissolving drugs at the site of the clot (Urokinase, Alteplase, Tenectaplace)
- Reopens blood flow without surgery
Thrombolysis and Venous Filters

- Dissolves blood clots by injecting clot dissolving drugs at the site of the clot (Urokinase, Alteplase, Tenecteplase)
- Reopens blood flow without surgery

Thrombolysis and Venous Filters

- Mechanical filter prevents clots from flowing to the lung (pulmonary embolism)
Thrombolysis and Venous Filters

- Mechanical filter prevents clots from flowing to the lung (pulmonary embolism)

TIPS (transjugular intrahepatic portosystemic shunt)

- A procedure to prevent fatal hemorrhage in patients with liver disease
- Usually awaiting transplant
Arterial embolization for obstetric bleeding

- Embolization procedure of uterine arteries to stop life-threatening post delivery bleeding
- Usually preventing hysterectomy
- Preserves fertility
Uterine Artery Embolization for Fibroid Tumors

- An embolization procedure of uterine arteries to shrink painful, benign tumors in the uterus.
- Alternative to surgical hysterectomy or myomectomy
Uterine Artery Embolization for Fibroid Tumors

- An embolization procedure of uterine arteries to shrink painful, benign tumors in the uterus.
- Alternative to surgical hysterectomy or myomectomy

Stroke

- Carotid artery narrowing is a common cause of stroke
- The vessel can close and brain is deprived of blood = stroke
- Small plaque can break from the arterial wall and embolize to the brain = stroke
Stroke

- Every 45 seconds someone in the U.S. has a stroke
- Stroke is the 3rd leading cause of death in the U.S. behind high blood pressure and cancer

Preventing Stroke

- treating “hardening of the arteries” in the carotid artery in the neck with stenting
- FDA approved for high-risk patients

Information provided by the Society of Interventional Radiology. www.SIRweb.org © 2004
Why Interventional Radiologists need good technology?

- Our image guidance is only as good as the imaging equipment
- Our limitations are largely due to our inability to see or precisely localize the focus of disease we want to treat
For More Information

- Web site
  - www.SIRweb.org
- Doctor Finder

Acknowledgements

- Clinicians
  - Elliot Levy, MD, Radiology
  - Vance Watson, MD, Radiology
- Scientists / Researchers
  - Kevin Cleary, Ph.D. / ISIS Center
  - David Lindisch, RT, Radiology / ISIS Center
  - Daigo Tanaka, MA, ISIS Center
  - John Tang, BS, ISIS Center
  - Seong K. Mun, PhD, Radiology / ISIS Center
  - Sheng Xu Ph.D., Johns Hopkins ERC CISST
- Collaborators
  - Dan Stoianovici, PhD, Johns Hopkins Urology / ERC CISST
  - Russell Taylor, PhD, Johns Hopkins ERC CISST
  - Gabor Fichtinger, PhD, Johns Hopkins ERC CISST
  - Charles Nguyen, PhD, Catholic University
  - Brad Wood, MD, NIH Radiology
- Funding
  - US Army Medical Research and Materiel Command
  - RSNA Holman Pathway Resident Grant