INTERVENTIONAL RADIOLOGY

Questions

1. Introduction.
2. Determination of interventional radiology.
3. Vascular interventions.
4. Angiography.
5. Arterial angioplasty.
6. Thrombolysis.
7. Vascular embolization.
8. TIPS.
9. Nonvascular interventions.
10. Conclusion.

Didactic material, presentation:

1. Angiographic department.
2. Tools.
3. Percutaneous catheterization by Seldinger.
4. Main causes of vascular occlusion.
5. Atherosclerotic occlusion and acute thrombosis of the left common iliac artery.
6. Nonspecific aorto-arteriitis – multiple stenosis of intrarenal aortic part and artery of the left kidney.
7. Endarteriitis obliterans of lower limb arteries.
8. Aortic aneurism.
9. Traumatic arterial-venous shunt.
10. Drain insertion of liver.
11. Drain insertion of renal cyst.
12. Drain insertion of intrahepatic ducts.
13. Percutaneous drain insertion of the right liver duct.

Introduction

The advancements in the field of radiological imaging such as the Seldinger technique, together with innovations in instrumentation, led to a rapid development in interventional procedures in the 1970s.Cardiovascular procedures were found to be particularly well-suited for guided and minimally invasive operations, and catheterization remains as one of the main applications for interventional radiology.

Determination of interventional radiology

Interventional Radiology (abbreviated IR or sometimes VIR for vascular and interventional radiology) is a subspecialty of radiology in which minimally invasive procedures are performed using image guidance. Some of these procedures are done for purely diagnostic purposes (e.g., angiogram), while others are done for treatment purposes (e.g., angioplasty). Images are used to direct these procedures, which are usually done with needles or other tiny instruments like small tubes called catheters. The images provide road maps that allow the Interventional Radiologist to guide these instruments through the body to the areas containing diseases.

Vascular interventions

Vascular intervention contain next stages:

1. Angiography.
2. Catheter exchange.
3. Selective catheterization of vessel.
4. Angiographic control of catheter location.
5. Intervention.
6. Angiographic control of interventional quality.
7. Post-interventional period.

Angiography

Angiography or arteriography is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins and the heart chambers. This is traditionally done by injecting a radio-opaque contrast agent into the blood vessel and imaging using X-ray based techniques such as fluoroscopy. The word itself comes from the Greek words angeion, "vessel", and graphein, "to write or record". The film or image of the blood vessels is called an angiograph, or more commonly, an angiogram.

Although the term angiography is strictly defined as based on projectional radiography, the term has been applied to newer vascular imaging techniques such as CT angiography and MR angiography.

Depending on the type of angiogram, access to the blood vessels is gained most commonly through the femoral artery, to look at the left side of the heart and the arterial system or the jugular or femoral vein, to look at the right side of the heart and the venous system. Using a system of guide wires and catheters, a type of contrast agent (which shows up by absorbing the x-rays), is added to the blood to make it visible on the x-ray images.

The X-ray images taken may either be still images, displayed on a image intensifier or film, or motion images. For all structures except the heart, the images are usually taken using a technique called digital subtraction angiography (DSA). Images in this case are usually taken at 2 - 3 frames per second, which allows the radiologist to evaluate the flow of the blood through a vessel or vessels. This technique "subtracts" the bones and other organs so only the vessels filled with contrast agent can be seen. The heart images are taken at 15-30 frames per second, not using a subtraction technique. Because DSA requires the patient to remain motionless, it cannot be used on the heart. Both these techniques enable the radiologist or cardiologist to see stenosis (blockages or narrowings) inside the vessel which may be inhibiting the flow of blood and causing pain.

The Seldinger technique is a medical procedure to obtain safe access to blood vessels and other hollow organs. It is named after Dr. Sven-Ivar Seldinger (1921-1998), a Swedish radiologist from Mora, Dalarna County, who introduced the procedure in 1953.

The desired vessel or cavity punctured with a sharp hollow needle called a trocar, with ultrasound guidance if necessary. A round-tipped guidewire is then advanced through the lumen of the trocar, and the trocar is withdrawn. A "sheath" or blunt cannula can now be passed over the guidewire into the cavity or vessel. Alternatively, drainage tubes are passed over the guidewire (as in chest drains or nephrostomies). After passing a sheath of tube, the guidewire is withdrawn.

If a sheath is used, it can be used to introduce catheters or other devices to perform endoluminal (inside the hollow organ) procedures, such as angioplasty. Fluoroscopy may be used to confirm the position of the catheter and to manoeuvre it to the desired location. Injection of radiocontrast may be used to visualize organs. Interventional procedures, such as thermoablation, angioplasty, embolisation or biopsy, may be performed.

Upon completion of the desired procedure, the sheath is withdrawn. In certain settings, a sealing device may be used to close the hole made by the procedure.

The Seldinger technique is used for angiography, insertion of chest drains and central venous catheters, insertion of PEG tubes using the push technique, insertion of the leads for an artificial pacemaker or implantable cardioverter-defibrillator, and numerous other interventional medical procedures.

Complications. The initial puncture is with a sharp instrument, and this may lead to hemorrhage or perforation of the organ in question. Infection is a possible complication, and hence asepsis is practiced during most Seldinger procedures. Loss of the guidewire into the cavity or blood vessel is a significant and generally preventable complication.

Angioplasty

Angioplasty is the technique of mechanically widening a narrowed or obstructed blood vessel; typically as a result of atherosclerosis. An empty and collapsed balloon on a guide wire, known as a balloon catheter, is passed into the narrowed locations and then inflated to a fixed size using water pressures some 75 to 500 times normal blood pressure (6 to 20 atmospheres). The balloon crushes the fatty deposits, so opening up the blood vessel to improved flow, and the balloon is then collapsed and withdrawn.

The word is composed of the medical combining forms of the Greek words αγγειος aggeîos meaning "vessel" and πλαστός plastós meaning "formed" or "moulded". Angioplasty has come to include all manner of vascular interventions typically performed in a minimally invasive or percutaneous method.

The first balloon angioplasty was performed interoperatively during bypass surgery in May, 1977 in St. Mary's Hospital in San Francisco, California. On

September 16, 1977 German surgeon Andreas Gruentzig (1939-85) performed the operation on an awake 37-year-old insurance salesman in Zurich, Switzerland.

Peripheral angioplasty refers to the use of mechanical widening in opening blood vessels other than the coronary arteries. It is often called percutaneous transluminal angioplasty or PTA for short. PTA is most commonly done to treat narrowings in the leg arteries, especially the common iliac, external iliac, superficial femoral and popliteal arteries. PTA can also be done to treat narrowings in veins, etc. coronary artery is the right branch.

A coronary angiogram (an X-ray with radio-opaque contrast in the coronary arteries) that shows the left coronary circulation. The distal left main coronary artery (LMCA) is in the left upper quadrant of the image. Its main branches (also visible) are the left circumflex artery (LCX), which courses top-to-bottom initially and then toward the centre-bottom, and the left anterior descending (LAD) artery, which courses from left-to-right on the image and then courses down the middle of the image to project underneath the distal LCX. The LAD, as is usual, has two large diagonal branches, which arise at the centre-top of the image and course toward the centre-right of the image.

Percutaneous coronary intervention (PCI), commonly known as coronary angioplasty is a therapeutic procedure to treat the stenotic (narrowed) coronary arteries of the heart found in coronary heart disease. These stenotic segments are due to the build up of cholesterol-laden plaques that form due to atherosclerosis. PCI is usually performed by an interventional cardiologist.

Treatment with PCI for patients with stable coronary artery disease does not reduce the risk of death, myocardial infarction, or other major cardiovascular events when added to optimal medical therapy.

Atherosclerotic obstruction of the renal artery can be treated with angioplasty of the renal artery (percutaneous transluminal renal angioplasty, PTRA). Renal artery stenosis can lead to hypertension and loss of renal function.

The SAPPHIRE trial also discloses that Jay Yadav was the inventor of the Angioguard embolic protection device used in the trial and held Angioguard stock at the time of purchase by Cordis, a sub-unit of Johnson and Johnson.

Stents.

Self-expandable metallic stents (SEMS) are cylindrical in shape, and are devised in a number of diameters and lengths to suit the application in question. They typically consist of cross-hatched, braided or interconnecting rows of metal that are assembled into a tube-like structure. SEMS, when unexpanded, are small enough to fit through the channel of an endoscope, which is meant for delivery of devices for therapeutic endoscopy. They expand through a deployment device which is placed at the end of the SEMS, and are held in place against the wall of the luminal surface by friction.

SEMS may be coated with chemicals designed to prevent tumour ingrowth; these are termed "covered" stents. Nitinol (a shape memory nickel-titanium alloy), polyurethane, and polyethylene are typically used as coatings for SEMS. Covered stents carry the advantage of preventing tumours from growing into the stent, although they run the risk of increased migration after deployment.

A plastic self-expanding stent (Polyflex, Boston Scientific) has also been developed for similar applications. It confers an additional advantage as it is designed to be removable, and may have a less traumatic insertion than metal stents. The Polyflex stent has shown benefit in palliation of esophageal malignancies.

The primary application of SEMS is in the palliation of tumours that obstruct the gastrointestinal tract. When they expand within the lumen, they are able to hold open the structure and allow passage of material, such as food, stool, or other secretions. The usual applications are for cancers of the esophagus, pancreas, bile ducts and colon that are not amenable to surgical therapy. SEMS may be used to treat additional complications of cancer, such as tracheoesophageal fistulas that may result from esophageal cancer, and gastric outlet obstruction which may result from stomach, duodenal or pancreatic cancer.

SEMS and self-expanding plastic stents have also been used for non-malignant conditions that cause narrowing or leaks of the esophagus or colon. These include peptic strictures caused by esophageal reflux and perforations of the esophagus. SEMS may also be placed in tandem fashion to treat ingrowth or overgrowth tumours, and fractures or migration of other SEMS. For the latter, the second SEMS in usually deployed within the lumen of the first.

SEMS are also sometimes used in the vascular system, usually in the aorta and peripheral vascular system. In the past they have been used for saphenous vein graft and native coronary artery percutaneous coronary interventions.

Self-expandable metallic stents are typically inserted at the time of endoscopy, usually with assistance with fluoroscopy or x-ray images taken to guide placement. Prior to the development of SEMS small enough to pass through the channel of the endoscopy, SEMS were deployed using fluoroscopy alone.

Esophageal SEMS are placed after a gastroscopy is performed to identify the area of narrowing. The area may need to be dilated in order to allow the gastroscope to pass. The tumour is usually better seen with the direct vision of endoscopy than on a fluoroscopic image. As a result, radio-opaque markers are usually placed on the surface of the patient in order to mark the area of narrowing on fluoroscopy. The SEMS is placed through the channel of the endoscope into the esophagus over a guidewire, marked on fluoroscopy, and mechanically deployed (using a device that sits outside of the endoscope) such that it expands when in position. Hypaque or other water-soluble dye may be placed through the passage to ensure patency of the stent on fluoroscopy. Enteric and colonic SEMS are inserted in a similar fashion, but in the duodenum and colon respectively.

Biliary SEMS are used to palliatively treat tumours of the pancreas or bile duct that obstruct the common bile duct. They are inserted at the time of ERCP, a procedure that uses endoscopy and fluoroscopy to access the common bile duct. The bile duct is cannulated with the assistance of a guidewire and the sphincter of Oddi that is located at its base is typically cut. A wire is kept in the bile duct, and the SEMS is deployed over the wire in a similar fashion as esophageal stents. The location of the SEMS is confirmed by fluoroscopy.

The complications of SEMS are related to a number of factors. The first is that the endoscopic procedure used to insert a SEMS involves the use of sedative medications, which may lead to oversedation, aspiration, or drug reaction. SEMS also expand and can lead to perforation of the bowel or compression of structures adjacent to the bowel.

Long-term complications of SEMS may be related to the underlying tumour being treated: the tumour may grow into the stent wall (tumour ingrowth) or over the end of the stent (tumour overgrowth), leading to obstruction. These complications may be limited by the use of coated stents. Tumour ingrowth or overgrowth can be additionally palliated by the placement of a second stent through the lumen of the first, through electrocautery or argon plasma coagulation of the tumour tissue in the stent, or through the use of photodynamic therapy.

Over time, SEMS may also migrate to a different position that does not help with treatment of the obstructed area. This may be treated with placement of a second SEMS, or endoscopic attempts to reposition or remove the first. Rarely, SEMS may fracture or intussescept after endoscopic intervention.

Thrombolysis

Thrombolysis is the breakdown (lysis) of blood clots by pharmacological means. It is colloquially referred to as clot busting for this reason. It works by stimulating fibrinolysis by plasmin through infusion of analogs of tissue plasminogen activator (tPA), the protein that normally activates plasmin.

Thrombolysis requires the use of thrombolytic drugs, which are either derived from Streptomyces species, or, more recently, using recombinant biotechnology whereby tPA is manufactured by bacteria, resulting in a recombinant tissue plasminogen activator or rtPA.

Some commonly used thrombolytics are

- streptokinase
- urokinase
- alteplase (rtPA)
- reteplase
- tenecteplase

Formation of blood clots lies at the basis of a number of serious diseases (see below). By breaking down the clot, the disease process can be arrested, or the complications reduced. While other anticoagulants (such as heparin) decrease the "growth" of a clot, thrombolytic agents actively reduce the size of the clot.

All thrombolytic agents work by activating the enzyme plasminogen, which clears the cross-linked fibrin mesh (the backbone of a clot). This makes the clot soluble and subject to further proteolysis by other enzymes, and restores blood flow over occluded blood vessels.

Diseases where thrombolysis is used:

- Myocardial infarction

- Stroke (ischemic stroke)
- Massive pulmonary embolism
- Acute limb ischaemia

Apart from streptokinase, all thrombolytic drugs are administered together with heparin (unfractionated or low molecular weight heparin), usually for 24-48 hours.

Thrombolysis is usually intravenous. It may also be used during an angiogram (intra-arterial thrombolysis), e.g. when patients present with stroke beyond three hours.

In some settings, emergency medical technicians may administer thrombolysis for heart attacks in prehospital settings. (Although in the UK it is more common for a Paramedic to administer thrombolysis - rather than technicians)

There are absolute and relative contraindications to thrombolytic therapy.

Absolute

- Previous intracranial bleeding at any time, stroke in less than a year, active bleeding, uncontrolled high blood pressure (>180 systolic or >100 diastolic).
- Streptokinase is contraindicated in patients who have been previously treated with streptokinase, as there is a risk of anaphylaxis, a life-threatening allergic reaction, due to the production of antibodies against the enzyme.

Relative

- Current anticoagulant use, invasive or surgical procedure in the last 2 weeks, prolong cardiopulmonary resuscitation (CRP) defined as more than 10 minutes, known bleeding diathesis, pregnancy, hemorrhagic or diabetic retinopaties, active peptic ulcer, controlled severe hypertension.

Inferior vena cava filter

An inferior vena cava filter, also IVC filter a type of vascular filter, is a medical device that is implanted into the inferior vena cava to prevent fatal pulmonary emboli (PEs).

IVC filters are used in case of contraindication to anticoagulation, failure of anticoagulation or complication to anticoagulation in patients who have a venous thromboembolic disease or in prophylactic use for patients with a high risk of pulmonary embolism.

IVC filters are placed endovascularly, meaning that they are inserted via the blood vessels. Historically, IVC filters were placed surgically, but as designs changed they could be placed via the groin through a thin tube or catheter. With modern filters which can be compressed into much thinner catheters, however, access to the venous system can be obtained either via the femoral vein (the large vein in the groin),the internal jugular vein (the large vein in the neck.) or via the arm veins with one design. Choice of route depends mainly on the amount and location of blood clot within the venous system. To place the filter, a catheter is guided into the IVC using fluoroscopic guidance, then the filter is pushed through the catheter and deployed into the desired location, usually just below the junction of the IVC and the lowest renal vein.

Review of prior cross-sectional imaging or a venogram of the IVC is performed before deploying the filter to assess for potential anatomic variations, thrombi within the IVC, or areas of stenoses, as well as to estimate the diameter of the IVC. Rarely, ultrasound-guided placement is preferred in the setting of contrast allergy, renal insufficiency, and when patient immobility is desired. The size of the IVC may affect which filter is deployed, as some (such as the Birds Nest) are approved to accommodate larger cavas. There are situations where the filter is placed above the renal veins (e.g. pregnant patients or women of childbearing age, renal or gonadal vein thromboses, etc.). Also, if there is duplication of the IVC, the filter is placed above the confluence of the two IVCs or a filter can be placed within each IVC.

Indications for use

- Most filters are placed for the following reasons.
- Failure of anticoagulation; eg development of deep vein thrombosis (DVT) or pulmonary emboli (PE) despite adequate anticoagulation.
- Contraindications to anticoagulation; eg a patient at risk of PE who has another condition that puts them at risk of bleeding, such as a recent bleed into the brain, or a patient about to undergo major surgery
- Large clots in the vena cava or iliac veins
- Patients at high risk of having a PE

Embolization

Embolization is a non-surgical, minimally-invasive procedure performed by an interventional radiologist and interventional neuroradiologists. It involves the selective occlusion of blood vessels by purposely introducing emboli.

Embolisation is used to treat a wide variety of conditions affecting different organs of the human body.

Hemorrhage

The treatment is used to occlude:

- Arteriovenous malformations (AVMs)
- Cerebral aneurysm
- Gastrointestinal bleeding
- Epistaxis
- Primary post-partum hemorrhage

Growths

- The treatment is used to slow or stop blood supply thus reducing the size of the tumour:
- Liver lesions, typically hepatocellular carcinoma (HCC). Either by partical infarction or transcatheter arterial chemoembolization (TACE).
- Kidney lesions
- Uterine fibroids

Other

- Portal vein

The procedure is a minimally-invasive alternative to surgery. The purpose of embolization is to prevent blood flow to an area of the body, which effectively can shrink a tumour or block an aneurysm.

The procedure is carried out as an endovascular procedure, by a consultant radiologist in an interventional suite. It is common for most patients to have the treatment carried out with little or no sedation, although this depends largely on the organ to be embolized. Patients who undergo cerebral embolization or portal vein embolization are usually given a general anesthetic.

Access to the organ in question is acquired by means of a guidewire and catheter(s). Depending on the organ this can be very difficult and time consuming. The position of the correct artery or vein supplying the pathology in question is located by digital subtraction angiography (DSA). These images are then used as a map for the radiologist to gain access to the correct vessel by selecting an appropriate catheter and or wire, depending on the 'shape' of the surrounding anatomy.

Once in place, the treatment can begin. The artificial embolus used is usually one of the following:

- Coils: Guglielmi Detachable Coil or Hydrocoil
- Particles
- Foam
- Plug

Once the artificial emboli have been successfully introduced, another set of DSA images are taken to confirm a successful deployment.

Agents:

1. liquid embolic agents - used for AVM. these agents are able to flow through complex vascular structures so the surgeon does not need to target his catheter to every single vessel.
2. nbca - n-butyle-2-cyanoacrylate: this agent is a permanent rapidly acting liquid that will polymeraize immediately on contact with ions. aka superglue. it also has an exothermic reaction which destroys the vessel wall. since the polymerization is so rapid, it requires skill of the surgeon when using. during the procedure, the surgeon must flush the catheter before and after injecting the nbca or the agent will polymerize within the catheter. also the catheter must be withdrawn quickly or it will be stuck to the vessel. oil can be mixed with nbca to slow the rate of polymerization
3. ethiodol - made from iodine and poppyseed oil, this is a highly viscous agent. it is usually used for chemembolizations, especially for hepatomas. this is because these types of tumors have a characteristic of absorbing iodine. half life is 5 days so it only temporarily embolizes vessels
4. sclerosing agents - these will harden the endothelial lining of vessels. they have been around for a long time and need more time to react than the liquid embolic agents. therefore you can't use them for high flow vessels or large vessels.
5. ethanol - this permanent agent is very good for treating AVM. the alcohol does need some time to denaturize proteins of the endothelium and activate the

coagulation system which causes a blood clot. therefore, some surgeons will use a balloon occlusion catheter to stop the blood flow and allow time for ethanol to work. the disadvantage of this is that it is toxic to the system in large quantities and may cause compartment syndrome. also the injections are painful

6. ethanolamine oleate - this permanent agent is used for sclerosing esophageal varices. it is made of 2% benzyl alcohol so it is less painful than ethanol. however it does cause hemolysis and renal failure in large doses.
7. sotradecol - is used for superficial lower extremity varicose veins. it has been around for a very long time and is a proven remedy. however, it does cause hyperpigmentation of the region in 30% of patients. it is less painful than ethanol.
8. particulate embolic agents - only used for precapillary arterioles or small arteries. these are also very good for AVM deep within the body. the disadvantage is that they are not easily targeted in the vessel. none of these are radioopaque so it makes radiologic imaging difficult to see them unless they were soaked in contrast prior to injection.
9. gelfoam - temporarily occludes vessels for 5 weeks. they work by absorbing liquid and plugging up the vessel. these are water insoluble gelatin so the particles may travel distally and occlude smaller capillaries. a way to localize the injection of gelfoam is to make a gelfoam sandwich. a coil is placed at a precise location. then gelfoam is injected and lodged into the coil.
10. polyvinyl alcohol (PVA) - these are permanent agents. they are tiny balls 50-1200 um in size. the particles are not meant to mechanically occlude a vessel. instead they cause an inflammatory reaction. unfortunately they have a tendency to clump together since the balls are not perfectly round. the clump can separate a few days later failing as an embolic agent.
11. acrylic gelatin microspheres - this is a superior form of permanent particulate embolic agent. they are similar to PVA but they are perfectly round. thus they do not clump together. the balls are fragile so they may crack inside small catheters.
12. mechanical occlusion devices - these fit in all vessels. they also have the advantage of accuracy of location (they are deployed exactly where the catheter ends).
13. coils - used for AVF, aneurysms, or trauma. they are very good for fast flowing vessels because they immediately clot the vessel. made from platinum or stainless steel. they induce clot because of the dacron wool tails around the wire. the coil itself will not cause mechanical occlusion. because it is made of metal, it is easily seen in radiographic images. the disadvantage is that large coils can disrupt the radiographic image. the coil may also lose its shape if the catheter is kinked. also there is a small risk of dislodging from the deployed location.
14. detachable balloon - treat AVF and aneurysms. these balloons are simply implanted in a target vessel then filled with saline through a one-way valve. the blood stops and endothelium grows around the balloon until the vessel fibroses.

unfortunately, the balloon may be hypertonic relative to blood and cause the balloon to rupture and fail. or the balloon may be hypotonic and cause the balloon to shrink and migrate somewhere else.

Advantages

- Minimally invasive
- No scarring
- Minimal risk of infection
- No or rare use of general anesthetic
- Faster recovery time
- High success rate compared to other procedures

Disadvantages

- User dependent success rate
- Risk of emboli reaching healthy tissue
- Not suitable for everyone
- Recurrence more likely

Chemoembolization is a procedure in which the blood supply to the tumor is blocked surgically or mechanically and anticancer drugs are administered directly into the tumor. This permits a higher concentration of drug to be in contact with the tumor for a longer period of time.

In chemoembolization, anti-cancer drugs are injected directly into the blood vessel feeding a cancerous tumor. In addition, synthetic material called an embolic agent is placed inside the blood vessels that supply blood to the tumor, in effect trapping the chemotherapy in the tumor.

TIPS

A transjugular intrahepatic portosystemic shunt (commonly abbreviated as TIPS or TIPSS) is an artificial channel in the liver from the portal vein to a hepatic vein (for blood). It is created endovascularly (via the blood vessels) by physicians via the jugular vein.

It is used to treat portal hypertension (which is often due to scarring of the liver (liver cirrhosis)) which frequently leads to intestinal bleeding (esophageal varices) or the buildup of fluid within the abdomen (ascites).

A TIPS decreases the effective vascular resistance of the liver. The result is a reduced pressure drop over the liver and a decreased portal venous pressure. This, in turn, lessens the pressure on the blood vessels in the intestine so that future bleeding is less likely to occur. The reduced pressure also makes less fluid develop, although this benefit may take weeks or months to occur.

Transjugular intrahepatic portosystemic shunts are typically placed by interventional radiologists under fluoroscopic guidance. Access to the liver, as the name transjugular suggests, is gained via the jugular vein in the neck. Once access to the jugular vein is confirmed, a guidewire and introducer sheath are typically placed to facilitate the shunt's placement. This enables the interventional radiologist to gain access to the patient's hepatic vein via the vena cava. The shunt is created by advancing a special needle through the sheath system to connect the hepatic vein to the large portal vein, near the center of the liver. The channel for the shunt is next created by inflating an angioplasty balloon within the liver along the tract created by the needle. The shunt is completed by placing a special mesh tube known as a stent or endograft to maintain the tract between the higher pressure portal vein and the lower pressure hepatic vein. After the procedure, fluoroscopic images are made to show placement. Pressure measurements in the portal vein and inferior vena cava are often done.

A complication of umbilical hernia has been recently reported. In addition, hepatic encephalopathy may develop due to the shunting of blood past the liver.

Nonvascular interventions

Common nonvascular IR procedures are:

- Cholecystostomy: placement of a tube into the gallbladder to remove infected bile in patients with cholecystitis, an inflammation of the gallbladder, who are too frail or too sick to undergo surgery
- Drain insertions: placement of tubes into different parts of the body to drain fluids (e.g., abscess drains to remove pus, pleural drains)
- Biopsy: taking of a tissue sample from the area of interest for pathological examination from a percutaneous or transjugular approach.

  A biopsy is a medical test involving the removal of cells or tissues for examination. It is the medical removal of tissue from a living subject to determine the presence or extent of a disease. The tissue is generally examined under a microscope by a pathologist, and can also be analyzed chemically. When an entire lump or suspicious area is removed, the procedure is called an excisional biopsy. When only a sample of tissue is removed with preservation of the histological architecture of the tissue’s cells, the procedure is called an incisional biopsy or core biopsy. When a sample of tissue or fluid is removed with a needle in such a way that cells are removed without preserving the histological architecture of the tissue cells, the procedure is called a needle aspiration biopsy.
- Radiofrequency ablation (RF/RFA): localized destruction of tissue (e.g., tumours) by heating.

  Radio frequency ablation (RFA) is a medical procedure where part of the electrical conduction system of the heart, tumor or other dysfunctional tissue is ablated using high frequency alternating current to treat a medical disorder. An important advantage of RF current (over previously used low frequency AC or pulses of DC) is that it does not directly stimulate nerves or heart muscle and can therefore often be used without the need for general anaesthetic. RFA has become increasingly accepted in the last 15 years with promising results. RFA procedures are performed under image guidance (such as X-ray screening, CT scan or ultrasound) by an interventional radiologist or a cardiac electrophysiologist, a subspecialty of cardiologists.

  RFA is performed to treat tumors in lung, liver, kidney, bone and (rarely) in other body organs. Once the diagnosis of tumor is confirmed, a needle-like

RFA probe is placed inside the tumor. The radiofrequency waves passing through the probe increase the temperature within tumor tissue that results in destruction of the tumor. Generally RFA is used to treat patients with small tumors that started within the organ (primary tumors) or that spread to the organ (metastasis). The suitability of a patient to receive RFA is decided by doctors based on multiple factors. RFA has also been shown to have success in use with selective reduction procedures of multiple fetuses.

- Cryoablation - localized destruction of tissue by freezing.

  Cryoablation is a process that uses extreme cold (cryo) to remove tissue (ablation).

  Cryoablation is used in a variety of clinical applications using hollow needles (cryoprobes) through which cooled, thermally conductive, fluids are circulated. Cryoprobes are inserted into or placed adjacent to tissue which is determined to be diseased in such a way that ablation will provide correction yielding benefit to the patient. When the probes are in place, the cryogenic freezing unit removes heat ("cools") from the tip of the probe and by extension from the surrounding tissues.

  Ablation occurs in tissue that has been frozen by at least three mechanisms: (1) formation of ice crystals within cells thereby disrupting membranes, and interrupting cellular metabolism among other processes; (2) coagulation of blood thereby interrupting bloodflow to the tissue in turn causing ischemia and cell death; and (3) induction of apoptosis, the so-called programmed cell death cascade.

  The most common application of cryoablation is to ablate solid tumors found in the lung, liver, breast, kidney and prostate. The use in prostate and renal cryoablation are the most common. Although sometimes applied through laparoscopic or open surgical approaches, most often cryoablation is performed percutaneously (through the skin and into the target tissue containing the tumor).

- Vertebroplasty: percutaneous injection of biocompatible bone cement inside fractured vertebrae.

  Vertebroplasty is a medical spinal procedure where bone cement is injected through a small hole in the skin (percutaneously) into a fractured vertebra with the goal of relieving the pain of osteoporotic compression fractures. It has been found to be ineffective in treating compression fracture of the spine.

  Two studies published in The New England Journal of Medicine found no benefit to vertebroplasty:

  In a multicenter, randomized, double-blind, placebo-controlled trial involving 131 participants who were patients with one or two painful osteoporotic vertebral fractures, vertebroplasty did not result in greater improvement than a sham procedure in overall pain, physical functioning, or quality of life at 3 or 6 months after treatment. Jeffrey Jarvik of the University of Washington said his study, funded by the National Institutes of

Health, found vertebroplasty had no detectable benefit when compared with procedures that only mimicked such procedures. He advises that "vertebroplasty should not be done any longer, unless it's in the setting of a study.

In a randomized trial involving 78 participants with osteoporotic vertebral compression fractures, patients who underwent vertebroplasty had improvements in pain and disability measures that were similar to those in patients who underwent a sham procedure. University of Virginia radiologist Avery Evans said his study, which was funded by the Australian government and Cook Medical Inc., found vertebroplasty and sham procedures offered patients nearly identical pain relief.

Several earlier case reports and unblinded studies had suggested that vertebroplasty provided effective relief of pain, and many vertebroplasty practitioners continue to advocate for the procedure. However, none of the other studies had the benefit of double-blind comparisons against placebos and randomized samples of patients.

The main goal of vertebroplasty is to reduce pain caused by the fracture by stabilizing the bone. Vertebroplasty is typically performed by a spine surgeon or interventional radiologist. It is a minimally invasive procedure and patients usually go home the same day as the procedure. Patients are given local anesthesia and light sedation for the procedure, though it can be performed using only local anesthetic for patients with severe lung disease who cannot tolerate sedatives well.

During the procedure, acrylic cement is injected with a biopsy needle into the collapsed or fractured vertebra. The needle is placed with x-ray guidance. The acrylic cement quickly dries and forms a support structure within the vertebra that provide stabilization and strength. The needle makes a small puncture in the patient's skin that is easily covered with a small bandage after the procedure.

Some of the associated risks that can be produced are from the leak of acrylic cement outside of the vertebral body. Although severe complications are extremely rare, it is important to know that infection, bleeding, numbness, tingling, headache, and paralysis may ensue due to misplacement of the needle or cement. This particular risk is decreased by the use of x-ray or other radiological imaging to ensure proper placement of the cement. When the cement has leaked into blood vessels, heart and lung damage and some deaths have occurred.

- Nephrostomy placement: Placing a catheter directly into the kidney to drain urine in situations where normal flow of urine is obstructed. NUS catheters are nephroureteral stents which are placed through the ureter and into the bladder.

  A nephrostomy is an artificial opening created between the kidney and the skin which allows for the drainage of urine directly from the upper part of the urinary system (renal pelvis).

A nephrostomy is performed whenever a blockage keeps urine from passing from the kidneys, through the ureter and into the urinary bladder. Without another way for urine to drain, pressure would rise within the urinary system and the kidneys would be damaged.

The most common cause of blockage necessitating a nephrostomy is cancer, especially ovarian cancer and colon cancer. Nephrostomies may also be required to treat pyonephrosis and kidney stones.

Nephrostomies are created by surgeons or interventional radiologists and typically consist of a catheter which pierces the skin and rests in the urinary tract. It is performed under ultrasound guidance, CT fluoroscopy or under image intensifier. Local anesthetic infiltration is used to numb the area where the needle would pass through to make the puncture on the kidney.

Newer technologies such as 3D fluoroscopy are being developed to aid in placement of these types of drainage tubes.

Urine is collected in an external bag which can be emptied as often as necessary.

- Radiologically Inserted Gastrostomy or RIG: Placement of a feeding tube percutaneously into the stomach and/or jejunum.
- Biliary intervention - Placement of catheters in the biliary system to bypass biliary obstructions and decompress the biliary system. Also placement of permanent indwelling biliary stents.

Conclusion

As in most medical specialties, training varies depending on varying regulations from country to country. In the United States, interventional radiologists are physicians who have completed a college degree, four years of medical school, a preliminary year of training (internship), a four year diagnostic radiology residency program, and then a one or two year fellowship in vascular & interventional radiology.