COMPUTED TOMOGRAPHY (CT)
PRINCIPLES OF CT
PHASES OF CT UROGRAPHY
PHASES OF CT ANGIOGRAPHY
CONTRAST-INDUCED NEPHROPATHY

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PRINCIPLES OF CT
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• Use of CT Scanning
  - CT allows acquisition of patient contour and inhomogeneities in a single procedure
  - It also gathers 3D attenuation data which is usable in treatment planning systems

• Advantages
  - Relatively inexpensive compared with MRI and PET scanning
  - Accurate, 3-D data including attenuation information
  - Rapid acquisition of data and no need for patients to remain for planning process
  - 4-D data acquisition is possible using gating technology

• Disadvantages
  - Relatively high amount of ionising radiation per scan (increased for 4-D imaging)
  - Subject to artefacts due to patient movement
  - Contrast required for certain structures, particularly vessels
  - Possibility of anaphylactic response to intravenous contrast, which may occasionally be fatal
PRINCIPLES OF CT

• Computed tomography (CT) scanning, also known as computerized axial tomography (CAT) scanning, is a diagnostic imaging procedure that uses X-rays in order to present cross-sectional images ("slices") of the body.
PRINCIPLES OF CT
4 Basic Steps of CT Scanning

• X-Ray Production
• Data Acquisition
• Data Processing
• Image Display
PRINCIPLES OF CT

• X-Ray Production:
  • In CT, an x-ray source and x-ray detector housed in a doughnut-shaped assembly move circularly around a patient who lies on a motorized table that is moved through the machine

• Data Acquisition
  • Data from the detectors essentially represent a series of x-ray images taken from multiple angles all around the patient

• Data Processing
  • The images are then sent to a computer

• Image Display
  • The computer will reconstruct these images into 2-D images (tomograms) representing a slice of the body in any plane desired
  • These images can also be used to construct detailed 3-D images
PRINCIPLES OF CT

• CT is based on the fundamental principle that the density of the tissue passed by the X-ray beam can be measured from the calculation of the attenuation coefficient

• Attenuation coefficient is quantified as the measure of how easily a material can be penetrated by the X-ray beam

• It quantifies how much the beam is "attenuated" - weakened by the material it is passing through
PRINCIPLES OF CT
HOUNSFIELD UNIT

• Attenuation coefficient is also known as radiodensity.

• Radiodensity (or radiopacity) refers to the relative inability of X rays to pass through a particular material.

• Radiodensity is quantified according to the Hounsfield unit (HU).

• Hounsfield chose a scale that affects the four basic densities, with the following values:
  • Air = -1000
  • Fat = -60 to -120
  • Water = 0
  • Compact bone = +1000
PHASES OF CT UROGRAPHY
The European Society of Urogenital Radiology defines CT urography as a diagnostic examination optimized for imaging the kidneys, ureters, and bladder with thin-slice MDCT, IV administration of contrast medium, and image acquisition in the excretory phase.

A typical CT urographic protocol has three phases that allow complete evaluation for the most common urologic causes of - unenhanced, nephrographic, and pyelographic phases.
CT UROGRAPHY

- **Unenhanced** phase can detect calculi, calcification, anatomy of kidney, ureter, bladder, haemorrhagic cyst, cyst/tumor/lesion/mass in kidneys/bladder

- **Nephrographic** phase imaging has the highest sensitivity in the detection of renal masses, and correlation with unenhanced images is required to show unequivocal enhancement

- **Pyelographic** phase images are acquired 5–15 minutes after contrast administration to evaluate the urothelium from the kidneys to the bladder
ADVANTAGES OF CT UROGRAPHY

• Three-dimensional reformations with coronal and sagittal maximum intensity projections of the kidneys and urinary collecting systems facilitate thorough examination for renal and urothelial malignancy. (Sensitivity (89 -100%) and specificity in the detection of pelvicaliceal and ureteric transitional cell carcinoma)

• Detection of urinary tract calculi are well established (sensitivity ranging from 98% -100% and specificity of 92 - 100%)

• CT urography for the evaluation of urinary tract calculi (stone protocol) does not require IV contrast administration, therefore the risk of nephrotoxicity associated with excretory urography is therefore eliminated
ADVANTAGES OF CT UROGRAPHY

• It is widely accepted that CT urography outperforms ultrasound, excretory urography, and radiography in the evaluation of renal parenchymal masses and urinary tract calculi.

• CT urography is more sensitive and specific than IVU in the detection of urothelial tumors.

• CT urography be performed as a first-line technique in the evaluation of hematuria when the risk of disease outweighs the risk of radiation exposure.
DISADVANTAGES OF CT UROGRAPHY

• CT urography more expensive than IVU or ultrasound

• CT urography uses radiation
PHASES OF CT ANGIOGRAPHY
CT ANGIOGRAPHY

• The purpose of contrast-enhanced CT (CECT) is to find pathology by enhancing the contrast between a lesion and the normal surrounding structures.

• Sometimes a lesion will be hypovascular compared to the normal tissue and in some cases a lesion will be hypervascular to the surrounding tissue in a certain phase of enhancement.

• Non-enhanced CT (NECT)
  • Early arterial phase
  • Late arterial phase
  • Hepatic or late portal phase
  • Nephrogenic phase
  • Delayed phase
CT ANGIOGRAPHY

• **Non-enhanced CT (NECT):** Detects calcifications, fat in tumors, fat-stranding as seen in inflammation, calculi

• **Early arterial phase:** immediately after bolustracking. This is the phase when the contrast is still in the arteries and has not enhanced the organs and other soft tissues

• **Late arterial phase:** 15-20 sec after bolustracking. Sometimes also called "arterial phase" or "early venous portal phase", because some enhancement of the portal vein can be seen. All structures that get their bloodsupply from the arteries will show optimal enhancement.
CT ANGIOGRAPHY

- **Hepatic or late portal phase** - 50-60 sec after bolustracking. Enhances liver parenchyma through bloodsupply by the portal vein and some enhancement of the hepatic veins can be seen.

- **Nephrogenic phase** - 80 sec after bolustracking. This is when all of the renal parenchyma including the medulla enhances. Only in this phase you will be able to detect small renal cell carcinomas.

- **Delayed phase** - 6-10 minutes after bolustracking. Sometimes called "wash out phase" or "equilibrium phase". There is wash out of contrast in all abdominal structures except for fibrotic tissue, because fibrotic tissue has a poor late wash out and will become relatively dense compared to normal tissue.
ADVANTAGES OF CT ANGIOGRAPHY

- Outline blood vessels – planning for surgery (transplant, malignancy)
- Identifying tumor (location, size)
- Able to reconstruct images – 3D
DISADVANTAGES OF CT ANGIOGRAPHY

- Requires arterial puncture – bleeding, haematoma at puncture site
- May dislodge arterial plug causing MI, PE, stroke
- Contrast nephropathy
- Contrast allergy
CONTRAST-INDUCED NEPHROPATHY
CONTRAST-INDUCED NEPHROPATHY

**DEFINITION:**

- Impairment of renal function within 48-72 hours of intravenous contrast administration

- It is measured as:
  - 25% increase in serum creatinine from baseline or
  - 44 µmol/L increase in serum creatinine from baseline
AETIOLOGY

• Contrast media act on distinct anatomic sites within the kidney and exert adverse effects via multiple mechanisms

• **Contrast media cause:**
  • direct cytotoxic effect on the renal proximal tubular cells
  • enhance cellular damage by reactive oxygen species (NO)
  • increase resistance to renal blood flow
  • exacerbate renal vasoconstriction (particularly in the deeper portions of the outer medulla)
  • decreases water reabsorption, leading to a buildup of interstitial pressure (the osmotic property of contrast media, especially in the tubular lumen)
  • increase resistance to blood flow by increasing blood viscosity and by decreasing red cell deformability (intravascular sludging generates local ischemia and causes activation of reactive oxygen species that result in tubular damage at a cellular level)
RISK FACTORS

• Patient-related risk factors are as follows:
  • Multiple myeloma
  • Hypoalbuminemia
  • Renal transplant
  • Hypovolemia and decreased effective circulating volumes - As evidenced by congestive heart failure (CHF), an ejection fraction (EF) of less than 40%, hypotension, and intra-aortic balloon counterpulsation (IABP) use
  • Age
  • CKD
  • Diabetes mellitus
  • Anemia
  • Hypertension
  • Metabolic syndrome

• Procedure-related risk factors are as follows:
  • Urgent versus elective
  • Arterial versus venous
  • Diagnostic versus therapeutic

• Contrast-related risk factors are as follows:
  • Volume of contrast
  • Contrast characteristics, including osmolarity, ionicity, molecular structure, and viscosity

• Patients with CKD in the setting of diabetes mellitus have a 4-fold increase in the risk of CIN compared with patients without diabetes mellitus or preexisting CKD
Risk stratification scoring systems have been devised to calculate an individual patient’s risk of developing CIN.

This has mostly been done in patients undergoing percutaneous coronary intervention (PCI), especially those with preexisting risk factors. Mehran et al developed the following scoring system based on points awarded to each of 7 multivariate predictors:

- Hypotension = 5 points
- IABP use = 5 points
- CHF = 5 points
- SCr of greater than 1.5 mg/dL = 4 points
- Age greater than 75 years = 4 points
- Anemia = 3 points
- Diabetes mellitus = 3 points
- Contrast volume = 1 point for each 100 cc used

Based on the total calculated score, patients were divided into:

- low-risk (score of less than or equal to 5) – risk of HD 0.04%
- moderate-risk (score of 6-10) – risk of HD 0.12%
- high-risk (score of 11-15) – risk of HD 1.09%
- very-high-risk (score of greater than or equal to 16) – risk of HD 12.6%
MANAGEMENT

• **Hydration therapy:** is the cornerstone of contrast-induced nephropathy (CIN) prevention. Renal perfusion is decreased for up to 20 hours following contrast administration. Intravascular volume expansion maintains renal blood flow, preserves nitric oxide production, prevents medullary hypoxemia, and enhances contrast elimination.

• **NAC**: acetylated L-cysteine, an amino acid. It is an excellent antioxidant and scavenger of free oxygen radicals.

• **Statin:** A significantly lower incidence of CIN was found in patients treated with statins preoperatively (CIN incidence of 4.37% in the statin group vs 5.93% in the nonstatin group). However, prospective trials looking at statin use in patients undergoing noncardiac procedures are still required.
MANAGEMENT

- **Bicarbonate therapy**: alkalinizes the renal tubular fluid and, thus, prevents free radical injury

- **Dialysis**: less than 1% of patients with CIN ultimately go on to require dialysis, the number being slightly higher in patients with diabetes and severe renal failure (12%) and underlying renal impairment (3.1%)

- The best therapy for CIN is **prevention**. Physicians need to be increasingly aware that CIN is a common and potentially serious complication.

- Patients at risk should be identified early, especially those with CKD (GFR [eGFR] < 35 mL/min/1.73 m²)
PROGNOSIS

• CIN is normally a transient process, with renal functions reverting to normal within 7-14 days of contrast administration

• Less than one-third patients develop some degree of residual renal impairment

• Dialysis is required in less than 1% of patients, with a slightly higher incidence in patients with underlying renal impairment (3.1%)

• However, in patients with diabetes and severe renal failure, the rate of dialysis can be as high as 12%

• Of the patients who need dialysis, 18% end up on permanent dialysis therapy
THANK YOU