CONTRAST AGENTS

CT Imaging and Tissue Contrast

- To distinguish adjacent tissues on a CT image, tissues must have **different densities (attenuation)**.
- Varying densities produce **distinct attenuation coefficients**, resulting in an image that clearly displays different tissues.

Inherent Tissue Contrast in the Body

- Some areas, like the **chest**, have inherently high subject contrast.
    - Example: Pulmonary vessels and ribs have significantly different densities from **aerated lung**, allowing easy identification on the image.
- Not all body areas have this level of inherent contrast.
    - Many tissues may have **similar attenuation coefficients**.
    - Tumors and disease processes may have attenuation coefficients **similar to surrounding tissues**, making detection harder.

Use of Contrast Agents

- **Purpose:** **Create a temporary, artificial density** difference between objects to make tissues with similar attenuation more visible.
- **Methods of administration in CT:**
    - **Oral or intravenous** (most common)
    - **Intravascular** (main category)
    - **Gastrointestinal** (main category)
    - Less common:
        - **Intrathecal** – into the **subarachnoid** space surrounding the **spinal cord**
        - **Intraarticular** – directly into a **joint** space
- **Contrast agents** fill a structure with a material of **different density than the structure**.

Types of Contrast Agents

- **Positive agents:** Higher density than the structure
    - Commonly contain **barium** or **iodine**
- **Negative agents:** Lower density than the surrounding structure
    - Examples: **Air**, **carbon dioxide**
- **Neutral agents:** Density similar to water, sometimes used in **gastrointestinal imaging**

Key Concept (BOX 12–1)

- **Contrast agents** **fill a structure with a material of different density**.
- **Positive agent:** Higher density than the structure.
- **Negative agent:** Lower density than the surrounding structure.

Intravascular Contrast Agents

- **Iodinated Agents**
    - Universally used in radiology due to:
        - Water solubility
        - Ease of intravascular administration
        - High safety index
    - Other agents (non-iodine) tested over the years were not adopted due to **unacceptable toxic side effects**.
- **Properties of Iodinated Agents**
    - **High attenuation** compared to human soft tissue → increases ability of enhanced structures to attenuate x-ray beam.
    - **Iodine** has **atomic number 53**, responsible for increased attenuation.
    - Adding iodinated agent to bloodstream temporarily **increases**

blood attenuation, making structures with adequate blood supply appear **lighter** on CT.
    - **Visible difference on CT:** Tissues must differ by at least **10 Hounsfield Units (HU)**.
        - Proper contrast administration can provide a **40–75 HU increase**, widening inherent differences and enhancing visibility of tissues, tumors, and disease processes.
- **Key Concept (BOX 12–2)**
    - Contrast agents **widen the difference in attenuation** between adjacent structures because:
        - Different tissues enhance differently
        - Normal vs abnormal tissue handles intravascular contrast differently
- **Contrast Administration vs Other Pharmaceuticals**
    - Not for therapeutic effect, only **distribution and elimination.**
    - Difference in dose and delivery:
        - **Therapeutic agents:** small doses at regular intervals (e.g., morphine 2–10 mg every 4 hours in 5–15 mL water)
        - **Iodinated contrast:** **large bolus doses (100–150 mL)** in **<1–2 minutes** with minimal physical effects
    - Guidelines for other drugs **do not apply** to IV contrast agents.

Osmolality

- **Definition:** **Number of particles in solution per unit liquid.**
- **Blood plasma osmolality:** **≈290 mOsm/kg water.**
- **Contrast media osmolality:**
    - Can be up to **7× blood plasma**.
    - Measured in **mOsm/kg**.
- **Key Concept (BOX 12–3)**
    - **High-osmolality contrast media (HOCM):** 4–7× blood osmolality **(≈1,300–2,140 mOsm/kg)**
    - **Low-osmolality contrast media (LOCM):** 2–3× blood osmolality **(≈600–850 mOsm/kg)**
    - **Isosmolar contrast media (IOCM):** Equal to blood osmolality **(≈290 mOsm/kg)**
- Most iodinated contrast agents are **hyperosmolar** (greater osmolality than blood plasma).
- **Historical context:**
    - Older HOCM used less due to higher osmolality
    - LOCM introduced later, initially more expensive, reserved for high-risk patients
    - **IOCM** (e.g., **Visipaque**, 1996) is isosmolar, more expensive, may benefit patients at risk of **renal complications**
- **Clinical relevance:**
    - Osmolality contributes to **nonallergic reactions.**
    - **Bolus injection** of hypertonic agents → rapid plasma osmolality increase → more pronounced effects.

Viscosity

- Viscosity = **thickness or friction** of fluid as it flows.
- Influences **injectability** through small-bore needles/IV catheters.
- Affected by:
    - Molecular structure
    - Concentration
    - Temperature (warming reduces viscosity, similar to maple syrup)

- Higher iodine concentration → **higher viscosity**
- **Key Concept (BOX 12–4)**
  - Viscosity depends on **brand, temperature, and iodine concentration**.

Ionicity

- Determines whether contrast molecules **dissociate into ions in solution**.
- **Ionic contrast agents:** molecules dissociate into ions.
- **Nonionic contrast agents:** molecules do **not** dissociate.
- Most nonionic agents also have low osmolality, but **nonionic ≠ low-osmolality**
  - Example: Hexabrix – low osmolality but ionic
- **Key Concept (BOX 12–5)**
  - Ionic → forms ions in solution
  - Nonionic → does not dissociate
  - Nonionic usually low osmolality, but not always synonymous

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Clearance

- Rapid distribution throughout **extracellular space**
- **Not metabolized**
- Excreted almost exclusively via **kidneys (glomerular filtration)**
- Half-life in patients with normal renal function: **≈2 hours**

Dose of Iodinated Contrast Agents

- **Factors Affecting Dose**
  - Both **iodine concentration** and **volume** must be considered.
  - Beam attenuation is **directly related** to iodine concentration.
  - **LOCM (Low-osmolality contrast media):** measured in **mgI/mL**.
  - **HOCM (High-osmolality contrast media):** usually labeled as **% weight/volume**, but mgI/mL can be found on the label or tables.
  - When comparing doses, calculate **total grams of iodine delivered**.

Clinical Examples of Total Iodine Delivered

- 125 mL of 240 mgI/mL → 125 × 240 = 30,000 mg = **30 gI**
- 100 mL of 300 mgI/mL → 100 × 300 = 30,000 mg = **30 gI**
- 150 mL of 370 mgI/mL → 150 × 370 = 55,500 mg = **55.5 gI**

CT Protocol Considerations

- Different CT protocols require **different iodine doses**.
- **Injection rate and delay from injection to scanning** affect dose selection.
- **Contrast enhancement** depends on iodine concentration in vasculature/tissues.
  - E.g., 400 mg/mL injected at 3 mL/s ≈ 300 mg/mL injected at 4 mL/s

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Safety and Overdose

- Adequate dose is essential for **high-quality imaging**.
- Dose must also be **safe for the patient**.
- **Overdose is rare**, but possible:
  - Deaths reported from **250–300 mL undiluted HOCM ionic media**.

    - Main adverse effects: **pulmonary and cardiovascular systems**.
- Most facilities set an **upper limit** on total volume for routine exams:
    - Typical guideline: **200 mL of 320 mgI/mL** → total **64 g iodine.**
    - **Patient-specific factors**, e.g., hydration, may necessitate adjustments.
- **Radiologist responsibility:** determine safe exceptions to guidelines.

Dose Principles

- Use **lowest dose** necessary for adequate visualization.
- Lower dose may reduce **risk of adverse reactions**, especially affecting **renal function**.
- CT procedures rarely require **maximum volume** or **highest concentration**.
- Dose selection should be **individualized** based on:
    - Age, body weight, vessel size
    - Anticipated pathology
    - Required degree/extent of opacification
    - Structures/areas to be examined
    - Disease processes affecting the patient
    - Equipment used

Pediatric Dosing

- Most pediatric doses calculated **by weight**: **2 mL/kg**.
- Adult practice often **uses uniform doses**, regardless of patient size:
    - E.g., 100-pound woman receives >3× dose per kg compared to 350-pound man.
- **Key Concept (BOX 12–6)**
    - Pediatric CT dose formula: **2 mL/kg**
    - Uniform adult dosing may **overdose smaller patients** and **underdose heavier patients**.
    - Studies show **weight-based dosing** provides same or better image quality than uniform dosing.
    - Example weight-based dose for **routine body CT: 1.5 mL/kg** (not to exceed 200 mL)
    - Weight-based dosing can also offer **cost savings** compared to standard 150 mL dose (if prefilled syringes not used).

Iodinated Contrast Media During Pregnancy

- **CT in Pregnancy**
    - CT is **seldom performed** during pregnancy due to concerns about **fetal exposure to ionizing radiation**.
    - Sometimes essential for **maternal health**.
- **Effects of Iodinated Contrast**
    - Studies in humans are **limited**; effects on embryo/fetus are **unknown**.
    - Animal/lab studies of **HOCM and LOCM**: no **mutagenic or teratogenic effects** observed.
    - **Iodinated contrast crosses the human placenta** and enters the fetus.
- **ACR Guidelines**
    - Reviewed extensively by **ACR Committee on Drugs and Contrast Media**.
    - **Key Concept (BOX 12–7):**
        - No proof that contrast agents are **harmful to the fetus**.
        - Insufficient evidence to confirm **zero risk**.

Iodinated Contrast Media During Lactation

- **Breastfeeding Considerations**
  - Patients may worry about **adverse effects on infants** from contrast in breast milk.
  - Facts known:
    - **<1%** of maternal dose excreted into breast milk.
    - **<1%** of that ingested by infant is absorbed from gastrointestinal tract.
    - Example: Maternal dose 150 mL → infant ingests ≈ **0.015 mL**.
- **Safety Recommendations**
  - **Breastfeeding is considered safe** after iodinated contrast administration.
  - **Key Concept (BOX 12–8):**
    - Very small fraction of contrast enters milk and is absorbed by infant.
    - Mothers can safely **continue breastfeeding** after receiving contrast.

Adverse Effects of Iodinated Contrast Medium

- **Safety Profile**
  - One of the **most widely used medications** in medicine.
  - Generally **very safe.**
  - **Fatal reactions** are extremely rare:
    - Estimated **0.9 per 100,000 (<0.001%)** for both HOCM and LOCM.
- **Predictability**
  - **Impossible to accurately predict** which patients will have an adverse reaction.
  - Staff must be **trained to respond quickly**, with drugs and equipment ready for acute reactions.
  - **Key Concept (BOX 12–9):**
    - Adverse reactions are unpredictable; rapid response capability is essential.

Administration During Pregnancy (Table 12–3 Summary)

- **Placental Transfer**
  - **Diagnostic iodinated contrast crosses the placenta** and enters the fetus at usual doses.
  - No **adequate, well-controlled teratogenic studies** in pregnant women.
- **Policies & Procedures**
  - Imaging facilities should attempt to **identify pregnant patients** before exams involving ionizing radiation.
  - Assess **medical necessity** for iodinated contrast.
  - Consider **radiation risk** and potential added risks from contrast.
- **ACR Recommendations**
  - Radiologist should **confer with referring physician** and document:
    - Information needed cannot be obtained by other means (e.g., ultrasound).
    - Information affects care of patient and fetus.
    - Referring **physician** believes it is **not prudent to wait** until after pregnancy.
  - Pregnant patients should provide **informed consent** documenting understanding of:
    - Risk-benefit of procedure
    - Alternative diagnostic options
    - Decision to proceed

Administration During Lactation (Table 12–4 Summary)

- **Excretion & Infant Exposure**
  - Plasma half-life: **≈2 hours**
  - Nearly 100% cleared from bloodstream within **24 hours**
  - **<1%** of maternal dose excreted into breast milk
  - **<1%** of that ingested by infant absorbed → <0.01% of maternal dose
  - Infant exposure is **far below recommended imaging dose (2 mL/kg)**
  - Potential risks (direct toxicity, allergic reaction) are **theoretical; not reported**
- **Recommendations**
  - Mothers should **decide whether to continue or temporarily abstain** from breastfeeding after contrast administration.
  - Data suggest **safe to continue breastfeeding**.
  - If concerned:
    - Abstain for **24 hours**
    - Actively express and discard milk during this period
    - Optionally, **use breast pump before study** to feed infant during 24 hours

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General Concepts

- **"Contrast reaction" definition**
  - Can describe **all undesired effects** (subjective or mild) such as:
    - Feeling of heat
    - Nausea
    - Mild flushing
  - Also used for **serious, potentially life-threatening reactions** requiring treatment.
- **Variation in literature**
  - Differences in reported incidence due to:
    - Lack of standard definition of adverse reaction
    - No universal system to classify severity
  - ACR Manual on Contrast Media provides a **severity-based classification**, widely used.

Categories of Reactions

1. **Chemotoxic Reactions**
   - Result from **physicochemical properties** of the contrast, dose, and injection speed.
   - Include **hemodynamic disturbances** and injuries to organs/vessels perfused by contrast.
   - Example: **Contrast-induced nephropathy**.
2. **Idiosyncratic Reactions**
   - Largely **unpredictable**, not dose-dependent.
   - Most occur **within 1 hour** of contrast administration.
   - Mechanism **not fully understood**; rarely "true allergy."
   - True allergy requires **antibody formation**, which is **not seen** with contrast agents.
   - Recurrent reaction risk:
     - **HOCM: 16–35%**
     - **LOCM: ≈7%**
   - Often called **"allergic-like"** or **"anaphylactoid" reactions**.

- **Key Concept (BOX 12–10)**
  - Contrast reactions can be broadly categorized as **chemotoxic** or **idiosyncratic**.

Pediatric Considerations

- **Lower frequency** of reactions than adults.
- Reactions, when present, are typically **idiosyncratic**.
- Infants/young children **cannot verbalize symptoms**, requiring careful monitoring.
- **Pediatric emergency equipment** must be available wherever IV contrast is administered.

Timing of Reactions

- Most adverse reactions occur **within minutes** of injection.
- **Delayed reactions** have been reported:
  - Poorly understood
  - May be **chemotoxic, idiosyncratic, or both**

Common, Expected Side Effects

- Not usually considered contrast reactions; **generally of no clinical consequence**:
  - Nausea, vomiting
  - Metallic taste
  - Perspiration, warmth, flushing
  - Anxiety
- Less common with **LOCM**.
- Mild side effects can **delay scanning** and affect image quality.

Idiosyncratic Reaction Severity

1. Mild Reactions

- Short duration, self-limiting
- Symptoms: cough, itching, hives, pallor, nasal congestion, mild facial/eye swelling, facial rash
- Monitor **20–30 min** as mild can progress

2. Moderate Reactions

- Not immediately life-threatening but **may progress**
- Symptoms:
  - **Respiratory difficulties** (bronchospasm, dyspnea, wheezing, mild laryngeal edema)
  - Pulse changes*, hypotension, hypertension
- Treatment may include:
  - **Diphenhydramine** for hives/bronchospasm
  - **Epinephrine** for laryngeal edema

3. ***Slow pulse with hypotension** may indicate **vasovagal reaction** (not allergic-like)

4. Severe Reactions

- Potentially or immediately life-threatening
- Symptoms:
  - Substantial **respiratory distress**
  - Unresponsiveness
  - Convulsions
  - Clinically significant arrhythmias
  - Cardiopulmonary arrest
- **Immediate response required**:
  - Cardiopulmonary resuscitation
  - Advanced life-support equipment
  - Trained personnel
- Presentation often mimics **acute anaphylaxis**; treat with **ABCs + ACLS**

Incidence of Idiosyncratic Reactions

- **HOCM (High-osmolality contrast media)**
  - Overall reaction rate: **5–12%**
  - **98–99%** of reactions are mild, non-life-threatening
- **LOCM (Low-osmolality contrast media)**
  - Reaction rates **4–5 times lower** than HOCM
- **Mortality**

- Death is **very rare** for both HOCM and LOCM
- Some data suggest **no significant difference**; others suggest **lower mortality with LOCM**

Risk Factors

1. **Previous Contrast Reaction**
   - Not true allergies; reactions are **allergic-like**
   - Repeat exposure does **not guarantee** reaction, unlike true allergens
   - Risk with prior HOCM reaction: **16–35%**, **11× higher** than nonreactors
   - Risk with prior HOCM reaction but now given LOCM: **≈5%**
   - **Most important predictor** of future reactions
2. **Asthma**
   - Increases risk:
     - **HOCM: ~8× higher**
     - **LOCM: ~5× higher**
3. **Allergies**
   - History of **food, drug, or other allergies** increases risk
   - Conditions like **hay fever or eczema** also increase risk (≈2×)
   - **Seafood allergy is NOT a risk factor**
     - Allergic reaction is to **proteins,** not iodine
   - **Topical iodine allergies** do not increase risk
4. **Medications**
   - **β-blockers** may impair response to treatment if a reaction occurs
   - No definitive evidence they increase incidence of reactions

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Prevention of Acute Reactions

- **High-risk patients**:
  - Consider alternative imaging **(ultrasound, MRI)**
  - If contrast is essential:
    - Monitor patient **for 1 hour** after injection
    - Use **LOCM** instead of HOCM
- **Test injections**
  - **Not predictive**; not recommended

Premedication

- **Steroid pretreatment** reduces reaction rates for HOCM
- Effectiveness for LOCM is **less certain**
  - May reduce **minor reactions**
  - Some believe moderate/severe reactions may also be reduced
- **Timing**:
  - Start steroids **≥6 hours**, preferably **12 hours** before injection
  - Oral administration preferred
  - **Prednisone and methylprednisolone** equally effective
  - **IV hydrocortisone (200 mg)** can be substituted if oral is not possible
- **H1 antihistamines** (e.g., diphenhydramine)
  - Reduce urticaria, angioedema, and respiratory symptoms
- **LOCM considerations**
  - Using a **different LOCM brand** after prior reaction may reduce risk (not scientifically proven)
- **Premedication regimens (Table 12–5)**
  - **Regimen 1: Corticosteroid + antihistamine**
    - 13 h before: prednisone 50 mg PO
    - 7 h before: prednisone 50 mg PO

        - 1 h before: prednisone 50 mg PO + diphenhydramine 50 mg PO
        - Use LOCM
    - **Regimen 2: Corticosteroid alone**
        - 12 h before: methylprednisolone 32 mg PO
        - 2 h before: methylprednisolone 32 mg PO
        - Use LOCM
- **Key Concept (BOX 12–14):**
    - **Steroid pretreatment** is effective for HOCM; unclear for LOCM.
    - Goal: **reduce risk**, not guarantee prevention.

Documentation of Reactions

- Document at minimum:
    - **Amount and type of contrast** injected
    - **Signs and symptoms** of reaction
    - **Interventions/medications** and patient response
    - **Final outcome** (discharged or admitted)
- Patient/family should receive **instructions for future exams**:
    - Report prior reaction to **healthcare providers**
    - May require **alternative imaging** or **pretreatment**

Chemotoxic Reactions

- **Definition**
    - Reactions arising from the **pharmacologic properties** of contrast agents.
    - Mechanisms are **not fully understood**.
    - Effects are **multifactorial and variable**.
- **Proposed Mechanisms**
    - Molecular **binding to proteins**, inhibiting enzyme systems
    - Interference with **normal metabolic pathways** via binding to cell surface receptors
- **Examples**
    - **Pain at injection site**
        - Due to **hypertonicity and calcium binding,** causing **vasodilation**
- **Pharmacology**
    - Detailed pharmacology is beyond the scope of this text
    - Focus is on types of chemotoxic adverse reactions rather than underlying mechanisms

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Contrast Media-Induced Nephropathy (CIN)

- **Definition & Importance**
    - Iodinated contrast agents can **affect kidney function**, sometimes transient and asymptomatic
    - **Significant nephrotoxic effects** may occur in **high-risk patients**
    - **CIN** is the **third-leading cause of acute renal failure (ARF)** in hospitalized patients
    - ARF can be **treatable** but is associated with **high mortality**
- **Scope of the Problem**
    - Approx. **60 million doses** of contrast media used worldwide annually
- **Key Concept (BOX 12–15)**
    - **Intravascular contrast agents affect kidney function**
    - Most effects are **short-term and asymptomatic**

- Significant nephrotoxic effects can occur in **high-risk patients**

Renal Anatomy and Physiology

- **Function of Kidneys**
  - Maintain **homeostasis** (Greek: *homios* = same, *stasis* = standing)
  - Homeostasis = **minute-to-minute balance** of:
    - **Water**
    - **Electrolytes** (sodium, potassium, chloride, bicarbonate)
    - **pH**
- **Evolution & Adaptation**
  - Kidneys evolved in vertebrates to:
    - Eliminate **toxic nitrogenous wastes** (protein metabolism by-products)
    - Regulate **homeostasis**
  - Kidney function varies depending on species/environment:
    - **Saltwater fish:** kidneys conserve water and excrete salt
    - **Land animals:** kidneys prevent dehydration due to air exposure

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Renal Anatomy

- **Location & Protection**
  - Paired organs behind the **parietal peritoneum** along posterior abdominal wall, **~T12–L3 vertebrae.**
  - **Right kidney** slightly lower due to liver.
  - Cushioned by **fat** and anchored by **renal fasciae**.
- **Hilum & Capsule**
  - Medial concave notch: **hilum** – entry/exit for vessels, nerves, ureter.
  - Covered by tough **fibrous capsule**.
- **Internal Structure**
  - **Cortex**: outer layer
  - **Medulla**: inner portion, contains **renal pyramids** (triangular wedges)
    - Pyramid bases toward cortex, apices = **renal papillae** facing renal center.
- **Nephron**
  - **Basic functional unit** (~1–2 million per kidney).
  - Components:
    - **Bowman's capsule**
    - **Glomerulus**
    - **Proximal convoluted tubule**
    - **Loop of Henle**
    - **Distal convoluted tubule**
    - **Collecting tubule**
  - Function: filter blood, reclaim useful materials, excrete wastes as urine.
- **Blood Supply**
  - Kidneys = **0.5%** of body weight, but receive **20–25%** of cardiac output.

Renal Function

- **Clearance**
  - Ability of kidneys to **remove a substance** from blood.
- **Estimating Renal Function**
  - **Glomerular Filtration Rate (GFR)**
    - Measured with **inulin** (ideal, but cumbersome).
    - Normal adult GFR ≈ **120 mL/min.**
  - **Effective Renal Plasma Flow (ERPF)**
    - Measured with **hippuran**.
    - Normal ERPF **≈ 500 mL/min.**

- **Serum Creatinine (SeCr)**
  - Byproduct of **muscle metabolism;** excreted in urine.
  - **Advantages:** fast, inexpensive.
  - **Limitations:**
    - Secreted by **proximal tubules** → overestimates GFR by **10–40%.**
    - Varies with **muscle mass, sex, age, race**.
    - Affected by **diet** (e.g., cooked meat).
  - **Formulas:** **Cockcroft-Gault, MDRD for GFR estimation.**

Renal Dysfunction

- **Renal Failure**: inability to maintain homeostasis → **azotemia**
  - **Anuric:** <50 mL urine/24 h
  - **Oliguric:** <500 mL urine/24 h
  - **Nonoliguric:** 500–6,000 mL urine/24 h
  - **Polyuric:** >6,000 mL urine/24 h
- **Renal Insufficiency**: **abnormal renal function,** but sustains essential functions.
- **Nephropathy:** any kidney disease;
- **CIN** = **acute renal impairment** after contrast administration.

Contrast-Induced Nephropathy (CIN)

- **Definition**: **acute rise in serum creatinine >25% or 0.5 mg/dL within 48 h of contrast administration** (after excluding other causes).
- **Typical Course**
  - Rise in SeCr within **24–48 h,** peaks at **4–5 days,** returns to baseline in **7–10 days.**
  - Usually **nonoliguric**.
  - Urinalysis: coarse granular casts, renal tubular epithelial cells, low-grade proteinuria; hematuria absent; crystals (urate, calcium oxalate) may be present.
- **Incidence**
  - General population: **1–6%**
  - High-risk groups: **up to 50%**
- **Risk Factors**
  - **Renal impairment** (preexisting)
  - **Diabetes mellitus** (especially with renal insufficiency)
    - **Diabetes + normal kidney: ~0.6% risk**
    - **Renal insufficiency alone: ~6%**
    - **Diabetes + renal insufficiency: ~19.7%**
  - **Volume of contrast administered** – **higher** volumes increase risk
  - **Dehydration**
  - **Multiple myeloma** (risk mainly due to **dehydration**)
  - Other potential factors: age, male sex, atherosclerosis, low ejection fraction
- **Risk Stratification** (Table 12–8)
  - **High-Risk:** CrCl <25 mL/min; CrCl 25–50 mL/min + diabetes, CHF, large contrast volume, recent contrast exposure
  - **Moderate-Risk:** CrCl 25–50 mL/min; CrCl 50–75 mL/min + same risk factors
- **Prognosis**
  - Most recover within **7–10 days**
  - Some may require **temporary dialysis**
  - **Rarely** leads to chronic dialysis
  - CIN increases risk of mortality and complications (sepsis, bleeding, respiratory failure)

Factors Affecting Serum Creatinine Accuracy (Table 12–6)

Factor	Effect on SeCr	Mechanism
Kidney disease	↑	**Decreased GFR** (partially masked by tubular secretion & reduced creatinine generation)
Reduced muscle mass	↓	**Less creatinine generated** (children, women, elderly, malnourished)
Ingestion of cooked meat	↑	**Transient** creatinine increase
Malnutrition	↓	**Reduced** creatinine production
Cimetidine	↑	Inhibits tubular creatinine secretion
Flucytosine, some cephalosporins	↑	Assay interference
Ketoacidosis	↑	Assay interference

Prevention of Contrast-Induced Nephropathy (CIN)

CIN is **preventable** with appropriate strategies. Key interventions focus on minimizing renal insult:

1. Use of Low-Osmolar or Isosmolar Contrast Media

- **HOCM**: higher nephrotoxicity risk
- **LOCM**: **4–5× lower** risk than HOCM
- **Isosmolar agents**: may provide additional protection for high-risk patients, though studies vary

2. Hydration

- Oral or IV fluids **before and after contrast** significantly reduce CIN risk
- Particularly important for **high-risk patients**

3. Limit Contrast Volume

- Use **smallest** **effective dose**
- Consider **saline bolus** to improve enhancement and reduce contrast needed
- Allow **≥48 hours** **between contrast procedures** for renal recovery

4. Review Nephrotoxic Medications

- Temporarily **discontinue** medications like **NSAIDs or dipyridamole** before contrast in high-risk patients

5. Metformin

- Risk: CIN → impaired renal function → metformin accumulation → **lactic acidosis**
- **Recommendation**: stop metformin before contrast; **resume after 2 days** if kidney function normal

6. Dialysis Considerations

- **Acute renal failure patients:** **avoid** contrast if possible to prevent further renal damage
- **End-stage renal disease patients on hemodialysis:** routine contrast **can be used;** dialysis removes contrast efficiently
- **Immediate post-contrast dialysis** not proven to prevent complications

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Other Organ-Specific Considerations

Thyroid Function

- Normal thyroid: no significant effect
- **Hypothyroid:** slight temporary reduction, usually no treatment needed
- **Hyperthyroid:** iodinated contrast may **intensify thyrotoxicosis**, rarely precipitate **thyroid storm**
- **Precaution**: check thyroid history; notify radiologist

Pulmonary Effects

- Risks: bronchospasm, pulmonary arterial hypertension, pulmonary edema
- High-risk: asthma, pulmonary hypertension, heart failure
- **LOCM reduces risk**; steroids not protective

Pheochromocytoma

- HOCM may **increase catecholamines** → dangerous
- **LOCM is safe** in these patients

Central Nervous System

- Iodinated contrast does **not cross intact BBB**
- Disrupted BBB (brain metastases, tumors): risk of **seizures**
- **Prevention**: one-time oral **diazepam 5–10 mg 30 min prior**

Contrast Extravasation

- Leakage into subcutaneous tissue can occur; requires **preventive measures** (covered in Chapter 13)

Delayed Reactions

- Occur **1 hour to 1 week post-contrast**
- Common symptoms: **skin rash, itching, urticaria, maculopapular rash, angioedema**
- Other reactions: **iodide mumps**, **acute polyarthropathy**
- **High-risk populations**: renal dysfunction, interleukin-2 therapy
- **LOCM reduces frequency**
- Mechanisms: likely a mix of **chemotoxicity, idiosyncratic, or immune-mediated**

Key Concepts

- **CIN prevention:** LOCM/IOCM, hydration, minimal contrast dose, 48-hour gap between studies, review nephrotoxic meds
- **Metformin:** pause pre/post contrast if renal risk
- **Organ-specific risks:** thyroid, pulmonary, CNS, pheochromocytoma
- **Delayed reactions:** mainly skin-related; less frequent with LOCM

Gastrointestinal (GI) Contrast Medium

- **Purpose:** **Distinguish bowel loops** from cysts, abscesses, or neoplasms; used **orally or rectally.**
- **Classification:**
  - **Positive agents:** appear bright (barium sulfate, iodinated solutions)
  - **Negative agents:** appear dark (water, air, CO_2)
  - **Neutral definition:** based on HU relative to bowel wall (e.g., water)

Oral Contrast

- **Barium Sulfate:**
  - Special CT formulations **(1–3%)** resist settling.
  - **Dosage: ≥500 mL 45 min–2 hr before scan; +200 mL before scan.**
  - **High-viscosity** paste for **esophagus.**
  - **Disadvantages:** may obscure mucosa after IV contrast, can cause **streak artifacts.**
  - **Low-HU barium (VoLumen 0.1%):** acts as negative/neutral agent, better **bowel wall visualization.**
  - **Contraindication:** suspected **perforation** → risk of barium **peritonitis** (high mortality).
  - **Allergic reactions:** very rare, mostly due to additives.
- **Iodinated Agents:**
  - HOCM and LOCM can be diluted orally; stimulate peristalsis → **diarrhea.**
  - HOCM cheaper, **LOCM** safer in infants/children or risk of aspiration/perforation.
  - **Rectal: 150–200 mL dilute solution for rectosigmoid studies.**
- **Comparison:**
  - Barium sulfate and water-soluble agents provide comparable bowel opacification.
  - **Small amounts: barium clings to wall; water-soluble absorbed.**
- **Water:** negative/neutral; poor distention; rapid transit.
- **Air / CO_2:**
  - Negative contrast for CT colonography.
  - CO_2 advantages: absorbed, less spasm, better tolerated.
  - **Room air may cause cramping; CO_2 preferred.**
  - Optional **IV glucagon** improves distention.

Intrathecal Contrast

- **Rare** in CT.
- Only specific iodinated agents safe.
- Serious adverse reactions if wrong agent used: death, seizures, coma, brain edema, rhabdomyolysis, cardiac arrest, etc.
- FDA requires non-intrathecal agents to be labeled “not for intrathecal use.”
- **Post-myelogram CT:** scan **1–3 hr after injection;** head elevated **~30°;** roll patient to mix contrast and reduce streak artifacts.

Intraarticular Contrast

- Direct injection into **joint** for soft tissue visualization.
- **CT arthrography** evaluates both **bone and soft tissue.**
- Injection performed by **radiologist,** usually under **fluoroscopy.**

Summary / Key Points

- **Contrast agents** are essential for CT imaging to differentiate structures and pathology.
- They carry potential risks; technologists must understand:
  - Characteristics of agents
  - Dosing guidelines
  - Possible adverse effects

RADIATION DOSIMETRY IN CT

Radiation Dosimetry in CT – Basic Dose Concepts

- **Responsibility of Imaging Professionals:**
  - Understand the **benefit vs. risks** of procedures.
  - Maximize diagnostic value while minimizing harm.
- **Rational Use of CT:**
  - **Two key components:**
    1. Appropriate patient selection (guided by ACR guidelines; enforced primarily by radiologists).
    2. Minimization of radiation dose without compromising image quality (main focus of this chapter).

Measurement Terminology

- **X-ray Energy:**
  - Maximum energy: **120–140 keV**
  - Average energy: **~70 keV**
- **Exposure in Air:**
  - Unit: **Roentgen (R)**
- **Absorbed Dose:**
  - Unit: **rad** (radiation absorbed dose) – energy absorbed per unit mass
  - SI unit: **Gray (Gy)** → 1 Gy = 100 rad
  - **Centigray (cGy):** 1 cGy = 1 rad
- **Quality Factor (Q):**
  - Accounts for **different biologic effects** of different types of radiation
  - For diagnostic x-rays used in **CT: Q = 1**
- **Dose Equivalent:**
  - Absorbed dose × Q
  - Unit: **rem** (roentgen equivalent man)
  - SI equivalent: **sievert (Sv)** → 1 Sv = 100 rem
- **Equivalent Dose (H):**
  - Absorbed dose × radiation weighting factor **(wR)**
  - wR analogous to Q
  - Unit: **rem or Sv**
- **Effective Dose / Effective Dose Equivalent:**
  - Accounts for **tissue-specific sensitivity to radiation**
  - Weighted average of organ doses (weights set by ICRP Publication 60)
  - Unit: **rem or Sv**
  - Uses data from **Japanese atomic bomb survivors**
  - Accurate calculation depends on ability to estimate dose to radiosensitive organs; challenging in practice

Key Concepts – BOX 14-1

- **Unit of Radiation Dose:**
  - **Roentgen (R):** exposure in air
  - **Radiation absorbed dose (rad):** unit of absorbed dose
  - **Gray (Gy):** SI unit; 1 cGy = 1 rad
  - **Quality factor (Q) / Radiation weighting factor (wR):** accounts for different types of radiation
  - **Roentgen equivalent man (rem):** rad × Q
  - **Sievert (Sv):** SI unit for rem

Dose Geometry in CT

- **Conventional Radiography:**
  - **Skin at the entrance** plane receives **100%** of the radiation.
  - Radiation falls rapidly as the beam passes through tissue.
  - **Exit dose** is often only **~1% of entrance dose.**
- **CT Scans:**
  - Dose at the center of the slice is closer to the dose at the periphery.
  - **Reasons for more uniform dose in CT:**
    - Beam is **heavily filtered** at the x-ray tube → fewer low-energy photons remain → beam is "harder" → less absorption/scatter.
    - Exposure comes from **all directions (360° rotation)** → more uniform distribution.
- **Uniformity Differences:**
  - **Dose uniformity decreases with increased scan field of view and patient thickness.**
  - Body scans are **less uniform** than head scans.
    - **Central dose in body scans ≈ 1/3 to 1/2 of peripheral dose.**
  - Organ doses are **higher in children** than adults:
    - Organ near x-ray source receives similar dose in both adults and children on proximal side.
    - On distal side, body tissue provides partial shielding → **thinner children get less shielding → higher organ dose.**

Z-Axis Dose Variations (Radiation Profile)

- **Z-Axis Dose Distribution:**
  - Refers to dose variations along the **length of the patient** (head-to-foot).
- **Traditional Axial Scan (Contiguous Slices):**
  - **Slice thickness** = table increment → no gaps, no overlaps.
  - If no scatter:
    - Single slice dose = **1 cGy**
    - Total dose for 30 contiguous slices = **1 cGy** (each area exposed only once).
  - Scatter exists, but low and travels short distances **(1–10 mm).**
- **Effects of Scatter:**
  - Scatter spreads radiation to adjacent tissue outside designated slice → called **tails**.
  - Multiple scans increase total dose due to scatter overlap.
    - Example: single slice chest dose = 4 cGy → 30 contiguous slices → total dose 5–5.6 cGy (4 + 1–1.6 cGy from tails).
- **Multiple Scan Average Dose (MSAD):**
  - Accounts for **central slice dose + scatter from tails.**
  - Measured with **phantoms** at center and periphery.
  - MSAD increases if **slices overlap; decreases if there are gaps** between slices.

Key Observations

- **Head scans:** central dose ≈ peripheral dose.
- **Body scans**: central dose < peripheral dose due to **thicker tissue and reduced uniformity.**

- **Children receive higher organ doses** for a given machine setting than adults due to **thinner body → less shielding.**

Calculating Exposure from Multiple Slices

- **Total Exposure Formula:**
  - **Single slice dose + scattered dose = total exposure**
- **MSAD (Multiple Scan Average Dose):**
  - Dose calculated from multiple scans, including scatter from adjacent slices.
- **CTDI (Computed Tomography Dose Index):**
  - Dose reported to the **FDA.**
  - Requires **contiguous slices** (no gaps or overlap).
  - When slices are **contiguous** → **MSAD = CTDI.**
  - If there is **overlap or gaps** → **CTDI × (slice thickness ÷ slice increment) = actual MSAD.**
- **Purpose:**
  - **Allows an estimate of MSAD with a single scan.**
  - Manufacturers report CTDI to FDA and prospective customers.
  - Typical doses reported for head and body CT protocols.
- **Measurement Method:**
  - **Pencil ionization chamber: 100-mm-long cylindrical dosimeter.**
  - Spans width of **14 contiguous 7-mm slices** → better estimate of MSAD for thin slices.
  - Measurement with this device → called **CTDI100**.

Adjusting for Dose Variations

- **Body scans:** dose not uniform; **periphery > center.**
- **CTDIw (Weighted CTDI):**
  - **Weighted average of dose** at center and peripheral slice locations **(x and y dimensions).**
- **CTDIvol (Volume CTDI):**
  - Accounts for **exposure variation along the z-axis.**
  - For **helical scans:** CTDIvol = CTDIw ÷ pitch.
  - **Preferred expression of radiation dose in CT dosimetry.**
  - **Measures exposure per slice, independent of scan length.**
- **Dose-Length Product (DLP):**
  - Accounts for **irradiated length of scan: DLP = CTDIvol × scan length.**
  - Reflects **total radiation dose** for a specific CT exam.
  - Influenced by patient **anatomy** → **less useful** for cross-protocol comparison.

Key Concepts

- **MSAD:** Total dose from multiple scans including scatter.
- **CTDI:** Dose reported by manufacturers; equals MSAD for contiguous slices.
- **CTDIw:** Adjusts for dose variation across slice (center vs periphery).
- **CTDIvol:** Adjusts for z-axis variation; preferred measure of CT dose.
- **DLP:** Accounts for scan length; reflects total exam dose.
- **BOX 14–3 Key Concept:**
  - **CTDIvol is the preferred expression of radiation dose in CT dosimetry.**

Comparison of Dose: CT vs. Conventional Radiography

- **Modalities are different:**
  - CT and conventional film-screen radiography differ in principle, purpose, and imaging requirements.
  - Simple numerical comparison is not accurate, but general dose awareness is important.
- **Image quality and contrast resolution:**
  - **CT** is an excellent **low-contrast discriminator** due to highly collimated x-ray beams and low scatter.
  - **Film-screen systems** cannot discriminate objects with **<10%** contrast.
  - CT can resolve **differences as low as 0.1%–0.5%,** allowing visualization of soft tissue masses unseen on film-screen.
- **Dose trade-off:**
  - **High radiation dose** is required to suppress noise for good low-contrast CT images.
  - Skin dose in CT **~ 10× higher** than film-screen; average absorbed dose **~ 100× higher**.
  - **Special procedures** (angiography, interventional radiography) may approach or **exceed CT doses.**
- **Background for perspective (BEIR VII):**
  - **Average annual background radiation (U.S.) ~ 3 mSv.**
  - **Chest x-ray ~ 0.1 mSv.**
  - **Whole-body CT scan ~ 10 mSv.**

Factors Affecting Radiation Dose in CT

Radiation Beam Geometry

- **Theoretical minimum: 180° rotation arc** for most reconstruction algorithms.
- Most scanners use **360° tube arc**:
  - Compensates for beam divergence and patient motion.
  - Extra information **improves image quality but increases dose.**
- **Overscanning:**
  - Using **>360° tube arc,** often in **fourth-generation CT** or for helical interpolation.
  - **Increases radiation dose.**

Filtration

- **Removes soft (low-energy) x-rays.**
- Low-energy x-rays absorbed quickly and increase patient dose without image benefit.
- **Metal filters** reduce dose while maintaining acceptable contrast.

Detector Efficiency

- **Less-efficient detectors** → require **higher** radiation for adequate image.
- **Solid-state detectors: 90–100% efficient.**
- **Older xenon gas detectors: significantly less efficient.**

Slice Width and Spacing

- **Thicker slices** → slightly **higher** dose to adjacent slices.
- **Thinner, contiguous slices** → **increased MSAD** due to more scatter.
- **Overlapping slices** → higher dose; **gapped slices** → lower dose.
- **Multi-detector CT (MDCT):** beam collimation impacts dose via **overbeaming** (extra x-ray penumbra outside active detectors).

Pitch

- **Pitch = table movement per rotation ÷ collimated beam width.**

- **Pitch = 1** → adjacent slices, dose similar to axial CT if kVp and mAs constant.
- **Pitch > 1** → spreads radiation over slices → less dose per point.
- **MDCT pitch** calculation differs due to multiple simultaneous slices.
- **Early MDCT models:** doses **30–50% higher** due to overbeaming, tube positioning, and scatter.

Scan Field Diameter

- **Smaller phantoms (16 cm, head)** absorb **higher dose** than **larger phantoms (32 cm, body)** with same parameters.
- **Smaller patients** → more uniform dose (**higher** absorbed dose).
- **Larger patients** → more tissue attenuates exit radiation → **lower** dose at exit.

Radiographic Technique

- **mAs and kVp affect dose:**
  - **Dose ∝ mAs** (doubling mAs → dose doubled; halving mAs → dose halved).
  - **Halving dose increases noise** by **~41%.**
  - **kVp increase from 120 → 140 → dose increase ~30–45%** (non-linear).

Patient Size / Body Part Thickness

- **Larger/thicker patients** → **higher** dose to maintain image quality.
- **Increased scatter** with larger body parts.

Repeat Scans

- Additional scans (e.g., multiple contrast phases) → **cumulative dose increase.**

Collimation

- **Lead collimators near x-ray tube** control beam size, reduce scatter, and prevent unnecessary patient dose.
- Collimators **near detectors** reduce scatter and control aperture.

Localization (Scout) Scans

- Scout images deliver **very low dose** compared to cross-sectional slices.

BOX 14–4 Key Concept

- **Excellent low-contrast resolution** of CT comes at the cost of **relatively high radiation dose**.

Why the Growing Concern About CT Radiation?

- **Historical context:**
  - Radiation dose and image quality management in CT has been a concern since the first clinical scanners in the early **1970s.**
  - Importance has increased due to:
    - Expanded clinical applications
    - Modern **MDCT technology**
    - Increased **CT-guided procedures**
    - Early trends toward **screening studies**
    - Concerns about **pediatric CT and cancer risk**

CT as a High-Dose Procedure

- CT contributes **disproportionately** to overall radiologic radiation:

- Represents **~11% of all diagnostic radiologic procedures.**
- Accounts for **~67% of the effective dose** from all diagnostic procedures.

- Dose comparison:
  - **One abdominal CT ≈ 100–250 chest radiographs** in radiation exposure.

BOX 14–5 Key Concept

- CT scanning is **relatively high-dose** and contributes disproportionately to overall radiation from radiologic sources.

Impact of Modern MDCT Technology

- **High-speed MDCT** creates **more-defined images** in shorter scan times.
- Enables **new indications**, e.g., CT angiography.
- Faster scans reduce the need for **sedation in pediatric patients**, increasing CT use in children.
- Dose implications:
  1. **Effective radiation dose with MDCT is ~27–35% higher** than older single-detector row helical scanners.
  2. **Organ doses** (kidneys, uterus, ovaries, pelvic bone marrow) are estimated to be **92–180% higher**.
- **Key concerns with new CT technology:**
  1. More studies are performed due to expanded technology.
  2. Higher radiation doses are associated with newer scanners.

Effects of Low-Dose Radiation

- **New research (2000):**
  - Studies on Japanese atomic bomb survivors irradiated as children show that **low-dose radiation from diagnostic CT is comparable** to the doses these survivors received.
  - Small but statistically significant **increased risk of developing cancer** observed.
  - Prediction: Pediatric CT may lead to **1 in 1,000 children** eventually developing cancer from the radiation exposure.

Need for Education

- Many healthcare professionals, including **parents, pediatricians, technologists, and radiologists**, often lack awareness of CT radiation doses.
- Education on dose management is **critical**, particularly in pediatric care.

Inappropriate Scanning Parameters in Pediatrics

- **2001 study (Paterson et al.):**
  - Pediatric patients were routinely imaged using **adult CT parameters** (tube current/mA, pitch).
  - No adjustment for age or size; infants sometimes exposed to **higher mA than adolescents**.
  - Mean tube current in study: **213 mA**, without size adjustment.
  - Result: Pediatric patients received **unnecessarily high radiation doses**.
- **Impact:**
  - Using adult protocols in neonates/young children can result in **up to 50% higher effective dose**.

- **2003 study (Hollingsworth et al.):**
  - Pediatric radiologists in children's/university hospitals mostly practice **age-adjusted helical CT**.
  - Trends:
    - **Increased tube current** with age
    - **Lower mA** for chest CT than abdominal CT in each age group
  - Still, **11–26% of CTs in children <9 years used >150 mA.**
  - **20–25%** of radiologists did not know their specific scanning parameters.
  - Conclusion: Need **continued size-based scanning** and **education on radiation dose in pediatric CT**.
- **BOX 14–6 Key Concept:**
  - Using adult protocols in neonates/young children increases **effective dose by up to 50%**.
  - Technologists **must adjust scan parameters for patient size**.

Extra Images

- **Definition:** Images acquired **beyond the desired anatomic area of interest**.
- **Impact on dose:**
  - Effective dose is **directly proportional to scan volume**.
  - Extra images can add **~10% to patient radiation dose**.
  - Most extra images provide **no additional diagnostic information**; affected diagnosis in **<1%** of cases.
- **Justifications for extra images:**
  - Ensure **entire liver and spleen** included in one contrast phase.
  - For **uncooperative or breathless patients,** sometimes needed.
- **Risks:**
  - **Infrapubic extension** (pelvis) without clinical indication adds unnecessary gonadal exposure.
  - Radiologists and technologists **share responsibility** to limit scanning to the area of interest.
- **BOX 14–7 Key Concept:**
  - **Extra images increase patient dose without adding useful diagnostic information**.

Lack of Awareness Regarding CT Radiation Dose

- **Study by Lee et al.:**
  - Purpose: **Assess awareness of radiation dose and risks from CT scans** among **patients, ED physicians, and radiologists**.
  - Survey asked respondents to estimate radiation dose for **one CT scan versus one chest radiograph (CR)** using categories:
    1. ≤ 1 CR
    2. 1 but <10 CR
    3. 10 but <100 CR
    4. **100–250 CR** (**accurate range**)
    5. ≥ 500 CR

Key Findings

- **Patients:**
  - Only **7% reported being informed** of risks/benefits before CT.
  - **None estimated dose accurately**; all underestimated radiation dose.
- **Emergency Department (ED) Physicians:**
  - **22%** estimated dose accurately.

    - **4% overestimated**, **73% underestimated**.
    - No significant correlation between **years of practice** and dose accuracy.
- **Radiologists:**
    - **13% estimated dose accurately**.
    - **10% overestimated**, **76% underestimated**.
    - Experience level did not affect accuracy.

Conclusion

- **Patients are not adequately informed** about CT risks and radiation dose.
- **Physicians and radiologists also lack accurate knowledge** regarding CT dose.

Summary of Main Factors Driving Concern About CT Radiation

1. **Higher use of CT scans** in clinical practice.
2. **New CT scanners** often deliver **higher radiation doses**.
3. **Evidence linking low-dose radiation to increased lifetime cancer risk**.
4. **Lack of knowledge** among radiologists, technologists, physicians, and patients about CT radiation dose.
5. **Insufficient adjustment of scanning parameters for pediatric patients**, leading to **higher-than-necessary doses** in infants and children.

Perception of Risk in Pediatric CT

- **Increased Cancer Risk:**
    - CT in childhood leads to a **small but statistically significant increase in lifetime cancer deaths**.
    - **Estimated mortality: 1 in 1,000 children scanned during childhood**.
    - Cancer incidence (including nonfatal cases) is likely **more than double the mortality figure**.
- **Importance of Perspective:**
    - Effective communication with patients/families requires understanding **how risk is perceived differently by scientists and the public**.
    - **Scientists:** Risk defined by nature of harm, probability, and number of people affected.
    - **General public:** Concerned with qualitative aspects such as:
        - Voluntary vs. imposed risk
        - Distribution of risk and benefits
        - Controllability
        - Necessity and availability of safer alternatives

Factors Influencing Public Perception of Risk

- **Catastrophic potential:** Fear of mass fatalities (e.g., airplane crashes) vs. scattered deaths (e.g., car accidents).
- **Familiarity:** Concern higher for unfamiliar risks (e.g., radiation) than familiar ones (e.g., household accidents).
- **Understanding:** Poorly understood risks are more concerning (e.g., radiation exposure).
- **Scientific uncertainty:** Unknown or uncertain risks raise concern (e.g., GMOs).
- **Controllability:** Risks outside personal control are more feared (e.g., pesticides in food).

- **Voluntariness of exposure:** Imposed risks more concerning than voluntary ones (e.g., smoking).
- **Impact on children:** Risks affecting children disproportionately are more alarming.

General Principles of Risk

- Risk perception is often **not rational**; people overestimate rare catastrophic events and underestimate common risks.
- Example: Fear of flying (1 in 1,000,000 risk) vs. driving (100x higher risk).
- **Risk levels:**
  - 1 in 1,000,000 per year → generally ignored (e.g., lightning strike).
  - 1 in 100 per year → unacceptable (e.g., historical coal mining accidents).
  - Pediatric CT risk → intermediate; **acceptable if three conditions are met**:

BOX 14-8 Key Concept: Acceptable Risk in CT

A **CT risk** can be considered acceptable if:

1. **The individual is aware of the risk.**
2. **The individual receives commensurate benefit.**
3. **All reasonable steps are taken to reduce the risk.**

Application to Pediatric CT

- **Communication:** Parents (or child, if appropriate) should be informed of the **small risk** involved.
- **Indication:** CT should only be used when **specifically indicated** and offers a **diagnostic benefit not easily obtained otherwise**.
- **Dose Reduction:** Adjust **kVp and mAs** to suit the child's size; **"one size fits all" is no longer acceptable**.

Special Considerations for Pediatric CT

1. Increased Sensitivity

- **Children are much more radiosensitive than adults.**
- Example: A **1-year-old infant** is **~6 times more likely** than a 50-year-old adult to develop malignancy from the same radiation dose.
- Reasons for increased sensitivity:
  - **Longer time to develop cancer** due to latency (10–30 years for CT dose ranges).
  - **Cumulative exposure:**
    - **30%** of patients have ≥3 CT scans
    - **7%** have ≥5 scans
    - **4%** have ≥9 scans
  - **More dividing cells** → greater adverse effects.
- Recent research: Children are **4–6 times more sensitive** than middle-aged adults.
- **BOX 14-9 Key Concept:**
  - **Children** are more radiosensitive than adults.
  - **Girls are more radiosensitive than boys.**

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2. Higher Effective Dose

- Even with **individualized machine parameters** (mAs and kVp), **organ doses are larger in children** compared to adults.

- Cause: **Absence of partial shielding** by intervening tissues (as discussed in dose geometry).

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3. Increasing Use of CT in Children

- **Helical CT use is growing faster in children than adults**.
- Reasons:
  - Improved scanner capabilities
  - Increased reliance on imaging
  - Malpractice environment pressures
- Risk: Temptation to use CT as a **screening procedure**, which is discouraged.

Radiation Dose to the Fetus

- **Fetal radiosensitivity:** Greatest from **conception to 3 months' gestation** (organ and neural crest development).
- **ACR recommendations:**
  - Prefer **nonionizing imaging** (ultrasound or MRI) in pregnant women.
  - CT is sometimes necessary for **pulmonary embolism (PE), appendicitis, renal colic, or trauma**.
- **BOX 14-10 Key Concept:**
  - **Radiosensitivity of the fetus** is highest from **conception to 3 months**.

Fetal Dose Findings

- Fetal doses measured for:
  - Conventional axial CT
  - Single-detector helical CT
  - 16-slice MDCT
  - **64-slice MDCT:** Not yet reported
- Major concerns: **neurologic and carcinogenic effects**
  - Standard 16-slice body protocols → **no significant neurologic impairment**
  - Carcinogenesis risk less clear; some protocols **could double the chance of childhood cancer**
    - Example: Fetal CT of maternal appendix → **~2 in 600 risk**, **vs 1 in 600** for general pediatric population
- CT protocols **not directly exposing the fetus** (e.g., thoracic CT for PE) → **lower dose**
  - **Older studies:** Single-detector CT dose < ventilation-perfusion scan
  - **Newer MDCT research:** Fetal dose ≥ ventilation-perfusion scan
- **Clinical principle:** Risk-benefit ratio for **first-trimester maternal** CT must be **carefully weighed**.
- Accurate assessment requires knowledge of **fetal dose and associated risk estimates**.

Strategies for Reducing Radiation Dose in CT

General Strategies

A combination of methods should be used to **reduce patient dose while maintaining diagnostic image quality**:

1. **Adjusting mAs (tube current × time)**
   - **Small patients** → lower mAs; **large patients** → higher mAs.
   - mAs can be adjusted using **patient weight or diameter**, both effective.
2. **Automatic Tube Current Modulation**
   - Some CT systems adjust mA along the patient's body based on **attenuation estimates** from scout images or prior slices.

    - Reduces dose without compromising image quality.
3. **Avoid Increasing kVp**
    - Higher kVp → higher radiation dose.
    - Keep **≤120 kVp** unless imaging **obese patients**.
    - If kVp is increased, tube current (mA) can be reduced to offset dose.
4. **Increase Pitch in Helical CT**
    - **Increasing pitch** (table movement per rotation ÷ collimated beam width) **reduces dose.**
    - Example: **Pitch 1 → 1.5** → dose decreases **~33%** without diagnostic loss.
5. **Limit Thin Slices**
    - Thin slices → **30–50% more radiation** than fewer, thicker slices.
    - Avoid thin slices unless clinically required.
    - Thin slices → **higher** radiation dose to **compensate for increased noise,** which occurs because thinner slices **contain fewer X-ray photons**
6. **Limit Repeat Scans**
    - Repeat or multiphase scans are **cumulative**.
    - Use multiphase scans only when **clinically indicated** (e.g., **liver lesions**).
    - **Triple-phase kidney studies** should be reserved for cases with unresolved findings.
7. **New Reconstruction Methods**
    - **Iterative reconstruction** can reduce dose **up to 50%** compared with standard filtered back-projection.

Strategies for Pediatric Patients

Children require special consideration due to **increased radiosensitivity**:

1. **Appropriate Patient Selection**
    - Confirm CT is **necessary**.
    - Consider **alternatives** (ultrasound, MRI) to avoid ionizing radiation.
    - Avoid CT as a **screening tool** unless justified.
2. **Customize the CT Examination**
    - Limit scan region to the **area of interest**.
        - Example: Avoid routine pelvic scans if not clinically needed → protects gonads.
    - Limit multiphase studies; every additional phase multiplies dose.
        - Routine multiphase scans used in ~30% of children; can often be reduced.
3. **Technical Parameters**
    - **mAs adjustment** based on:
        - Patient size
        - Region scanned (lungs → lower mA; bone → slightly higher acceptable)
        - Clinical indication
    - **Patient shielding:**
        - Limited benefit due to narrow collimation and internal scatter.
        - Can still protect **breast and thyroid tissue** and improve **perception of safety**.
    - **Increase pitch, avoid unnecessary thin slices, and use iterative reconstruction when available.**

Summary / Key Principles

- CT is a **high-value but high-dose** imaging modality.
- Risks are **outweighed by benefit** when CT is clinically indicated.
- **Avoid excessive radiation** by:
    - **Appropriate patient selection**
    - **Tailored scan protocols** to answer the clinical question

    - **Adjustment of technical parameters** for patient size and clinical need
- **Pediatric patients** need particular attention due to:
    - Greater radiosensitivity
    - Higher effective doses
    - Increasing use of CT

Relationship	Value
1 Gy	= 100 rad
1 cGy	= 1 rad
1 Sv	= 100 rem
Dose Equivalent	= Absorbed Dose × Q
Equivalent Dose (H)	= Absorbed Dose × wR

Measurement Terminology (Highly Organized Table)

Concept	Definition / Description	Units	Conversions / Notes
X-ray Energy	**Energy** of x-ray photons	keV	**Maximum:** 120–140 keV **Average:** ~70 keV
Exposure in Air	Measurement of **ionization in air** caused by x-rays	Roentgen (R)	—
Absorbed Dose	Energy absorbed **per unit mass**	rad	SI unit: **Gray** (Gy) 1 Gy = **100 rad** 1 cGy = **1 rad**
Quality Factor (Q)	Adjusts for **biologic effect** of radiation type	—	For diagnostic x-rays (CT): **Q = 1**
Dose Equivalent	Absorbed dose **adjusted for radiation type** (Dose × Q)	rem	SI: **Sievert (Sv)** 1 Sv = **100 rem**
Equivalent Dose (H)	Absorbed dose **× radiation weighting factor** (wR)	rem or Sv	wR is **analogous** to Q
Effective Dose / Effective Dose Equivalent	Accounts for **tissue sensitivity;** weighted average of **organ doses**	rem or Sv	Based on ICRP Publication 60 Derived from **Japanese atomic bomb survivor data** Difficult to calculate accurately in practice

Quantity Measured	Traditional Unit	SI Unit	What It Measures	Key Notes / Conversion
Exposure	Roentgen (R)	—	Ionization produced in **air** by x-rays/gamma rays	Measures radiation in air only
Absorbed Dose	rad	Gray (Gy)	Energy absorbed **per unit mass** of tissue	1 Gy = 100 rad
Dose Equivalent	rem	Sievert (Sv)	**Biological effect** of radiation (accounts for radiation type)	Dose × Quality Factor (Q) 1 Sv = 100 rem
Effective Dose	rem	Sievert (Sv)	Overall risk considering **sensitivity of different organs**	Uses tissue weighting factors (ICRP)

Unit	Focus	Formula	Purpose
Roentgen (R)	Air	—	Measures exposure in air
rad / Gy	Tissue	—	Measures absorbed energy
rem / Sv	Biological effect	Dose × Q	Accounts for radiation type
Effective Dose (Sv/rem)	Whole body risk	Weighted organ doses	Estimates overall harm

R → Air
rad/Gy → Absorbed energy
rem/Sv → Biological effect
Effective dose → Whole body risk

PATIENT PREPARATION

General Overview

- Many steps occur **before the patient arrives** at the imaging facility:
  - Scheduling the examination
  - Selecting the appropriate protocol
  - Obtaining medical history
  - Preparing the CT examination room
- These tasks involve:
  - Technologists
  - Clerical staff
  - Radiologists
- Notes:
  - Order and responsibility vary by facility
  - Focus is on tasks **before scanning the patient**

EXAMINATION INITIATION

Who Initiates the Exam

- Must be ordered by a **clinician** with appropriate credentials:
  - **Physicians**
  - **Nurse Practitioners (NP)**
  - **Physician Assistants (PA)**

Outpatient Process

- Clinician writes order in **private office**
- **Clerical staff:**
  - Call imaging facility
  - Schedule appointment
- Scheduling staff:
  - Send appointment to CT department

Risks

- Multiple steps → risk of **transcription errors**

Recommendation

- Original requisition should be:
  - **Faxed OR**
  - **Electronically transmitted**

Technologist Responsibility

- Must have access to **original order requisition**
- Must verify:
  - Correct examination is planned

Patient Screening (at Scheduling Stage)

- **Helps improve efficiency**
- Identifies issues such as:
  - **Contrast media allergies**
  - **Claustrophobia**

KEY CONCEPT (Box 11-1)

- Before CT exam:
  - Review physician's order
  - Read all clinical data
  - Resolve discrepancies between:
    - **Written order**
    - **Scheduled exam**
    - **Patient's understanding**

Inpatient Process

- Different from outpatient workflow
- Also prone to **transcription errors**

Best Method

- **Computerized Physician Order Entry (CPOE):**
  - Clinician enters order directly
  - Eliminates transcription errors
  - Ensures legibility

When CPOE Not Available

- Orders may be transcribed by:
  - **Clerk**
  - **Nurse**
- Final step required:
  - **Technologist verifies:**
    - Original order vs scheduled exam
- Often done by:
  - Reviewing patient chart

PROTOCOL SELECTION

Responsibility

- Primarily:
  - **Radiologist**
- With input from:
  - **Technologist**

Goal

- Answer clinical question with **least patient risk**

Possible Risks

- Radiation exposure
- Contrast media reactions
- Complications:
  - Bleeding
  - Infection
  - (e.g., biopsies, fluid drainage)

KEY CONCEPT (Box 11-2)

- **Protocol** must:
  - Answer clinical question
  - Minimize risk to patient

Protocol Selection Methods

1. Radiologist-Driven

- **Radiologist:**
  - **Reviews request**
  - **Considers medical history**
  - **Assigns protocol**
- Technologist:
  - Executes protocol
  - Raises concerns if needed

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2. Algorithm-Based (Technologist-Driven)

- Predefined protocols based on:
  - Clinical indications
- Example:
  - CT Head + facial droop → routine CT without contrast
- **Requires review of:**
  - **Medical history**
  - **Lab values (renal function)**
  - **Allergies**
- Radiologist consulted if uncertain

Technologist Responsibilities

- Understand protocol selection criteria
- Review requisition carefully
- Identify possible errors (patient safety safeguard)

ROOM PREPARATION

Before Patient Enters

- Perform:
  - **Scanner calibration**
  - **Tube warm-up**

Room Setup

- Ensure:
  - Cleanliness
  - Removal of previous patient items
  - Supplies stocked and organized

Equipment Preparation

- Attach necessary equipment:
  - Head holder
  - Foot extension
- Ensure availability of:
  - Positioning devices (e.g., angle sponges)
  - Safety equipment:
    - Thyroid shields
    - Breast shields

Additional Safety

- If someone stays in room:
  - Provide:
    - **Lead apron OR**
    - **Lead shield**

MEDICAL HISTORY

Importance

- Ensures:
  - **Patient safety**
  - **Proper protocol selection**
  - **Diagnostic accuracy**

KEY CONCEPT (Box 11-3)

- **CT history** questions aim to:
  - Ensure safety
  - Select correct protocol
  - Provide diagnostic information

PATIENT IDENTIFICATION

Requirements

- Must use **at least two identifiers**

Examples

- **Full name**
- **Birth date**

Alternative Methods

- **Armband check**
- **Family verification** (if patient cannot communicate)

Do NOT Use

- **Room number**
- **Bed label**
- **Door label**

KEY CONCEPT (Box 11-4)

- At least **two methods of identification required**

PATIENT SAFETY (CONTRAST MEDIA)

Assessment Areas

- **Renal function**
- **Allergies**
- **Thyroid conditions** (e.g., hyperthyroidism)

Purpose

- Determine if IV contrast can be safely given
- Prepare for possible adverse reactions

KEY CONCEPT (Box 11-5)

- History questions assess:
  - **Renal function**
  - **Allergies**
  - **Thyroid conditions**

LABORATORY VALUES

Kidney Function Tests

- **BUN (Blood Urea Nitrogen):**
  - Normal: **7–25 mg/dL**
- **Creatinine:**
  - Normal: **0.6–1.7 mg/dL**

Clinical Use

- Assess **safety for IV contrast**

Consult Radiologist If:

- BUN **> 30 mg/dL**
- Creatinine **> 2 mg/dL**

KEY CONCEPT (Box 11-6)

- **BUN & Creatinine** → assess renal function

Coagulation Tests

- **PT (Prothrombin Time):**
  - **11–14 sec**
- **PTT (Partial Thromboplastin Time):**
  - **25–35 sec**
- **Platelet count:**
  - **150,000–400,000/mm³**

Importance

- Needed for procedures with **bleeding risk:**
  - **Biopsy**
  - **Fluid drainage**

Anticoagulant Medications

- Examples:
  - **Warfarin (Coumadin)**
  - **Heparin**
  - **Plavix**
  - **Aspirin**
- Often **temporarily stopped** before procedures

PREGNANCY CONSIDERATION

- Fetus is **highly sensitive** to radiation

Actions

- Ask all women of **childbearing age**
- If uncertain:
  - **Delay exam**
  - **Confirm pregnancy status**

If Pregnant

- **Risk-benefit analysis involving:**
  - Patient
  - Referring physician
  - Radiologist

PROTOCOL SELECTION (PATIENT INPUT)

- When information is **lacking:**
  - Use **patient interview**

Key Questions

- **Symptoms**
- **Onset (new or chronic)**

Other Considerations

- Previous examinations:
  - May guide protocol
  - Used for comparison

DIAGNOSTIC INFORMATION

- **Medical history** helps:
  - **Differentiate diseases with similar CT findings**

Example

- Radiation scarring vs lung disease

Important History

- Past surgeries
- Medical conditions
- Current symptoms

PATIENT EDUCATION & INFORMED CONSENT

Technologist Responsibility

- **Educate patient about procedure**
- Improve:
  - Compliance
  - Image quality

Minimum Information to Provide

- Procedure steps
- Duration
- Contrast use:
  - Method (oral/IV)
  - Side effects
- Patient instructions:
  - Breath-holding
  - Staying still
  - Remove metals
  - Wear gown
- Post-exam instructions

CONSENT

- **Patient's legal and ethical right to decide**

Without Consent

- May result in:
  - **Battery** (nonconsensual touching)
  - **Malpractice claims**

KEY CONCEPT (Box 11-7)

- **Basic consent:**
  - **Explain procedure**
  - **Ask for agreement**

Written Consent

- **Common for:**
  - **IV contrast use**

Pros

- Documents **discussion** of risks

Cons

- May increase **anxiety**
- Limited **legal protection**

INFORMED CONSENT ELEMENTS

- Nature of procedure

- Alternatives
- Risks & benefits
- Patient understanding
- Patient agreement

When Required

- **Invasive procedures** (e.g., biopsy)

Requirements for Valid Consent

- Patient must be:
  - **Competent**
  - **Voluntary**
- Must be signed:
  - **Before sedation** or pain medication

Special Cases

- **Pediatric patients:**
  - Consent signed by **parent/guardian**

IMMOBILIZATION AND PATIENT RESTRAINT DEVICES

- Purpose:
  - Ensure **patient safety**
  - Improve **CT image quality**
- Common devices:
  - **Straps:** prevent falls, remind patient to remain still
  - **Bean bags:** placed alongside lower limbs to prevent motion
- Technologist responsibilities:
  - Be sensitive to patient feelings
  - Explain device purpose and usage to patient or guardian
  - Obtain **basic consent** whenever possible
- Special situations:
  - **Consent may not be possible for:**
    - **Unaccompanied patients**
    - **Unconscious patients**
    - **Delirious patients**
    - **Mentally disabled patients**
  - **Clinician's order** technically required for **restraint use**
  - Short-term use to complete exam sometimes done without consulting physician
- **Rules for restraint use:**
  - Allow as **much mobility** as safely possible
  - Pad areas where immobilizers are applied to protect skin
  - Maintain **normal anatomic position**
  - Avoid **knots that tighten** with movement
  - Immobilizer must be **easy to remove** quickly
  - Circulation and respiration **must not be impaired**
  - If **leg immobilizers** are used, apply **wrist immobilizers** to prevent patient from unfastening device or accidentally harming themselves

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ASSESSMENT AND MONITORING

Vital Signs

- Begin assessment upon **first patient contact:**
  - **Observe breathing, skin color, overall health**
- Monitor throughout **CT exam:**
  - Visual observation
  - Frequent communication via **intercom**
- Special monitoring devices usually **not required** for routine CT on stable patients
- Inpatient or unstable patients:
  - May arrive with monitors or respirators
  - Must be accompanied by nurse or trained health professional for monitoring
- **Key points**:
  - Adverse reactions to contrast are random and unpredictable
  - Early indicators of problems are **vital signs**:
    - Body temperature
    - Pulse
    - Respirations
    - Blood pressure
  - Other indicators:
    - Pain
    - Pulse oximetry
    - Pupil size, equality, reactivity
- **Box 11-8 Key Concept**:
  - **Vital signs** are the **best early indicators** of physiologic changes

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Body Temperature

- Common measurement sites:
  - **Oral**
  - **Ear (tympanic)**
  - **Axilla**
  - **Rectum**
- Thermometer types:
  - **Electronic** with disposable sheaths
  - **Tympanic** with disposable sheaths
  - **Disposable chemical strip** thermometers (e.g., 3M Tempa-Dot)
  - **Mercury-free glass thermometers**
    - **Blue tip = oral**
    - **Red tip = rectal**
- Notes:
  - **Oral, rectal, tympanic readings higher than axillary**
  - Table 11-2: Average and normal ranges

Route	Average	Normal Range
Oral	98.7°F **(37.0°C)**	96.8–100.4°F **(36.0–38.0°C)**
Rectal	99.1°F **(37.7°C)**	97.2–100.8°F **(36.7–38.7°C)**
Axillary	97.7°F **(36.4°C)**	95.8–99.4°F **(35.4–37.4°C)**
Tympanic	Calibrated to oral/rectal	Accuracy inconclusive

Pulse

- **Expansion and recoil of an artery with each heartbeat**
- Measurement:
  - **Count expansions** per unit time
  - Felt where **superficial artery** lies over firm tissue/bone
- Common pulse locations (Fig. 11-3):
  - **Temporal:** anterior to ear
  - **Facial:** lower mandible, 1/3 anterior to angle
  - **Carotid:** neck, right or left of midline
  - **Radial:** thumb side of wrist

    - **Brachial:** medial elbow (between biceps & triceps), infants
    - **Femoral:** groin
    - **Popliteal:** behind knee
    - **Pedal (tibialis posterior):** posterior ankle
    - **Pedal (dorsalis pedis):** top of foot
- Factors affecting **palpability**:
    - **Low systolic BP:**
        - **<90 mm Hg** → **radial** not palpable
        - **<80 mm Hg** → **brachial** not palpable
        - **<60 mm Hg** → **carotid** not palpable (usually **cardiac arrest)**
- **Normal pulse rates:**
    - **Adults: 60–100 bpm** (athletes 45–60 bpm)
    - **Children: 95–110 bpm**
    - **Infants: 100–160 bpm**
- When measuring pulse, note:
    - **Rate**
    - **Rhythm**
    - **Volume/strength**
        - **Full/bounding:** regular, good force
        - **Weak/thready:** irregular, difficult to palpate

Respirations

- **Respiratory rate = breaths per minute**
- Measured at rest by counting chest rises for **1 minute**
- Normal ranges by age:
    - **Adults: 14–20**
    - **Adolescent youth: 18–22**
    - **Children: 22–28**
    - **Infants: 30+**
- **Respiration to pulse ratio ≈ 1:4**

Blood Pressure

- **Pressure of circulating blood on vessel walls**
- Measured in **arteries** (arterial pressure)
- Determined by:
    - **Blood volume and force**
    - **Size and elasticity of arteries**
- Measurement:
    - **Sphygmomanometer** (mercury or modern digital)
    - Cuff around upper arm at heart height
    - Inflate to occlude artery **(~180 mm Hg)**
    - Listen with stethoscope at brachial artery
        - **First sound = systolic**
        - **No sound = diastolic**
- **Normal adult BP:**
    - **120/80 mm Hg (systolic/diastolic)**
    - Broad normal ranges:
        - **Adults: 90–140 / 60–90 mm Hg**
        - **Children: 65–130 / 45–85 mm Hg**
- Notes:
    - **Hypertension** = abnormally high BP
    - **Hypotension** = abnormally low BP
    - Influenced by **age, sex, race, activity, medications**
- **Box 11-9 Key Concept**:
    - **Systolic = peak pressure**
    - **Diastolic = resting phase**
    - **Typical adult: 120/80 mm Hg** (“one twenty over eighty”)

SUMMARY: PATIENT PREPARATION AND MONITORING STEPS

Critical steps before first CT image:

1. **Prepare the room:**
    - Clean, stock, set up equipment
    - Calibrate scanner
    - Warm-up tube
2. **Verify order:**
    - Ensure correct exam
    - Reconcile any discrepancies
3. **Verify patient identity:**
    - Use at least **two** identifiers
    - Examples: name, birth date, armband, family confirmation
4. **Obtain medical history:**
    - Contrast allergies
    - Renal function (BUN, Creatinine)
    - Thyroid status
    - Coagulation (PT, PTT, Platelet count)
    - Pregnancy status
5. **Explain examination & obtain consent:**
    - Procedure steps
    - Duration
    - Contrast use & side effects
    - Patient instructions
    - Follow-up requirements
6. **Continually assess patient:**
    - Vital signs: temperature, pulse, respirations, blood pressure
    - Monitor visually and via intercom
    - Watch for adverse reactions
    - Special monitoring for unstable or inpatient cases
7. **Immobilization and restraint devices (if needed):**
    - Straps, bean bags
    - Pad and maintain normal anatomy
    - Ensure safety of circulation and respiration
    - Explain to patient/guardian and obtain consent if possible

Patient Consent Summary

<<Facility Name>>

- **Understanding & Authorization**
  - I have discussed my diagnosis and condition with my doctors.
  - I understand the recommended procedures, their benefits, and risks of having or not having them.
  - I understand the approximate location of the procedure and how sites are categorized:
    - **Operative Field** – procedures with right/left or multiple structure distinction (e.g., fingers, toes, skin lesions).
    - **Specific Surgical Site** – procedures needing site verification (e.g., lymph nodes, breast masses, cochlear implants).
    - **Intraoperative Surgical Site** – procedures requiring intraoperative verification (e.g., spinal level, plastic reconstructive surgery).
    - **Excluded Sites** – do not require marking (e.g., midline sternotomy, C-sections, laparoscopy without left/right distinction, endoscopic procedures, genital or dental procedures).
- **Additional Procedures**
  - I authorize the facility and providers to perform any necessary additional procedures discovered during surgery.
- **Anesthesia & Sedation**
  - I consent to the use of anesthesia or sedation as deemed necessary by my doctors or anesthetists.
  - I understand additional risks may include: blood loss, infection, nerve or eye damage, drug reactions, cardiac arrest, permanent disability, or death.
- **Alternatives**
  - I have been informed of possible alternatives and their risks and have chosen to proceed.
- **Tissue & Specimen Use**
  - I authorize the facility to handle, preserve, analyze, or dispose of any excess tissues or specimens for lawful purposes, including education and anonymous research.
- **Participation of Personnel**
  - I authorize doctors, nurses, trainees, technicians, and other assigned staff to participate in my care.
  - I understand the facility is a teaching institution and medical or other students may participate, including examinations under anesthesia.
- **Acknowledgment**
  - I understand that medicine and surgery are not exact sciences.
  - I have been informed of the probability of success but understand that no guarantees or promises have been made.

NEUROANATOMY – HEAD

BRAIN

- Routine scans:
  - Start at **base of the skull**
  - Continue **superiorly**
- Depending on clinical indication:
  - Without IV contrast
  - With IV contrast
  - Both without and with IV contrast
- Note:
  - Images in this section include **IV contrast enhancement**

SINUSES

- Purpose of sinus screening:
  - Inexpensive
  - Accurate
  - Low radiation dose
  - Detect **inflammatory sinonasal disease**
- If disease is confirmed:
  - **Coronal images** act as a **"roadmap" for surgery**
- For **chronic/recurrent sinusitis:**
  - **No IV contrast used**
  - Scanning in **coronal plane**
- Other cases:
  - May require:
    - IV contrast
    - Axial scans

TEMPORAL BONES

- Contain organs for:
  - Hearing
  - Balance
- Located in:
  - **Petrous ridge of temporal bone**
- Imaging characteristics:
  - Use **thin slices** (structures are very small)
- Post-processing:
  - Petrosal bones reconstructed separately
  - Reduced field of view → better resolution
- Protocols usually include:
  - **Coronal and axial planes**
  - IV contrast depends on clinical indication

NECK

- CT exams:
  - Usually performed with **IV contrast**
- Challenges:
  - **Dental artifacts** may obscure structures
- Solutions:
  - Split data acquisition
  - Angle gantry to reduce artifacts
- Limitation:
  - Some MDCT systems:
    - Cannot angle gantry in **helical mode**

SPINE

- CT of the spine:
  - Usually done **without IV contrast**
- Exception:
  - May be done **after intrathecal contrast**
  - Used in **myelography studies**