Few things about...

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7. Contatti

Anesthesia

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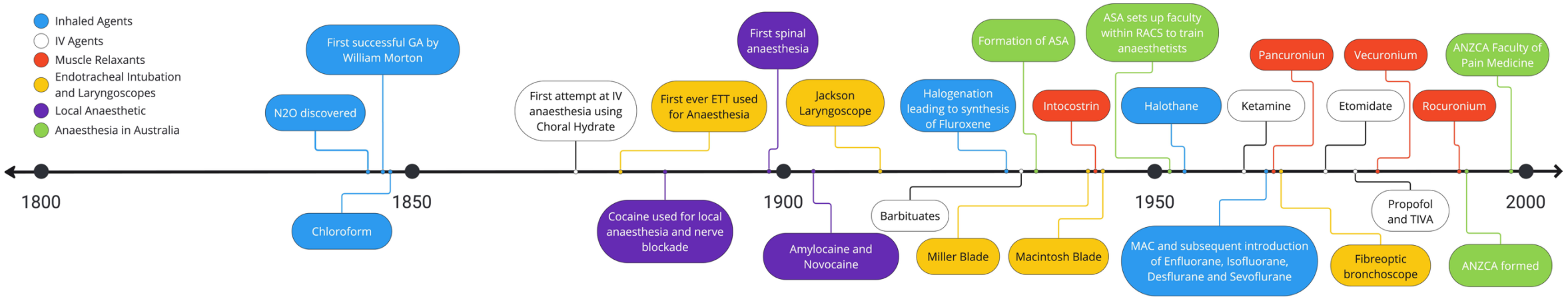
What is Anesthesia?

- Temporary, **controlled** and **reversible** depression of sensation ± consciousness
- Targets (“triad”): **hypnosis**, **analgesia**, **akinesia** (± autonomic control)
- Achieved with **single** or **combined** techniques (balanced anesthesia)
- Always paired with **physiological monitoring** and **support**

A Short History

- 1846: Morton’s public ether demo; rapid global adoption
- Chloroform era → toxicity lessons → safer agents
- Introduction of muscle relaxants (curare) & opioids
- Modern era: halogenated volatiles, propofol, regional anesthesia, ultrasound, safety culture



From Ether to Balanced Anesthesia (1846–1980s)

- 1846 Ether (Morton): first public surgical anesthesia → surgery becomes planned, humane
- 1847 Chloroform (Simpson): potent but toxic → early safety lessons
- 1884–1898 Local & Spinal: cocaine nerve blocks; Bier's spinal → anesthesia without unconsciousness
- 1900–1930s Airway & Machines: Magill intubation; Boyle machine → controlled delivery & ventilation
- 1934 Thiopental: reliable IV induction
- 1942 Curare: true muscle relaxation independent of depth → enables "balanced" anesthesia
- 1950s–70s Volatiles & Opioids: halothane → isoflurane; fentanyl family → smoother maintenance, better control

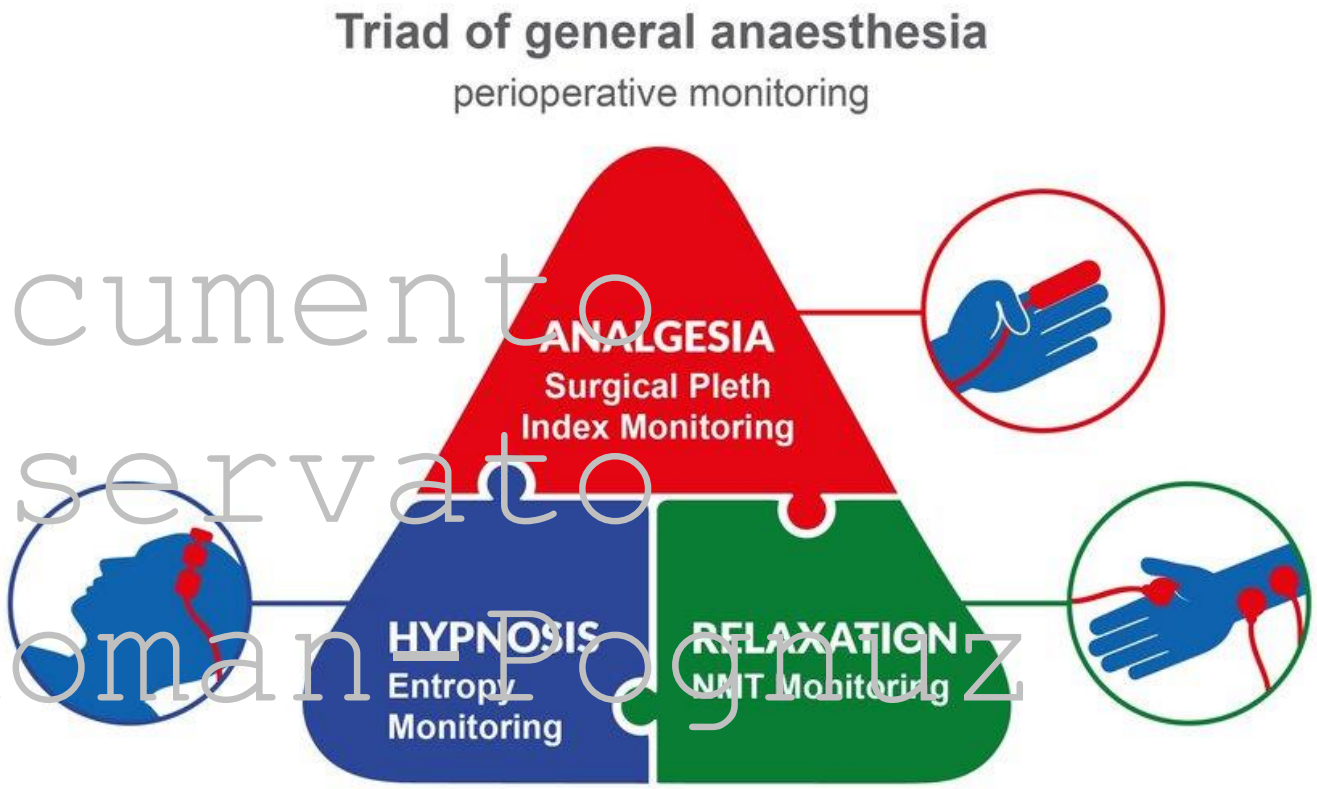
Monitoring, Safety, and Precision (1980s–Today)

- Safety Monitoring: pulse oximetry + capnography become standards; ASA/Harvard guidelines → major mortality drop
- 1986 Propofol: rapid-on/off, antiemetic → cornerstone of TIVA and fast recovery
- Depth & Neuromuscular Monitoring: processed EEG (BIS/PSI), TOF → titration to effect, fewer complications
- Ultrasound-Guided Regional: visualized nerves, fewer failures/complications → wider adoption of blocks
- Perioperative Medicine: ERAS, multimodal analgesia, opioid-sparing pathways
- Precision Delivery: target-controlled infusions, advanced hemodynamics, POCUS, checklists, emerging AI/closed-loop systems

The Four Pillars of Modern Anesthesia

1. **Hypnosis (loss of awareness)**
2. **Analgesia (blunting nociception)**
3. **Muscle relaxation (surgical conditions)**
4. **Autonomic stability (control of reflexes & stress response)**

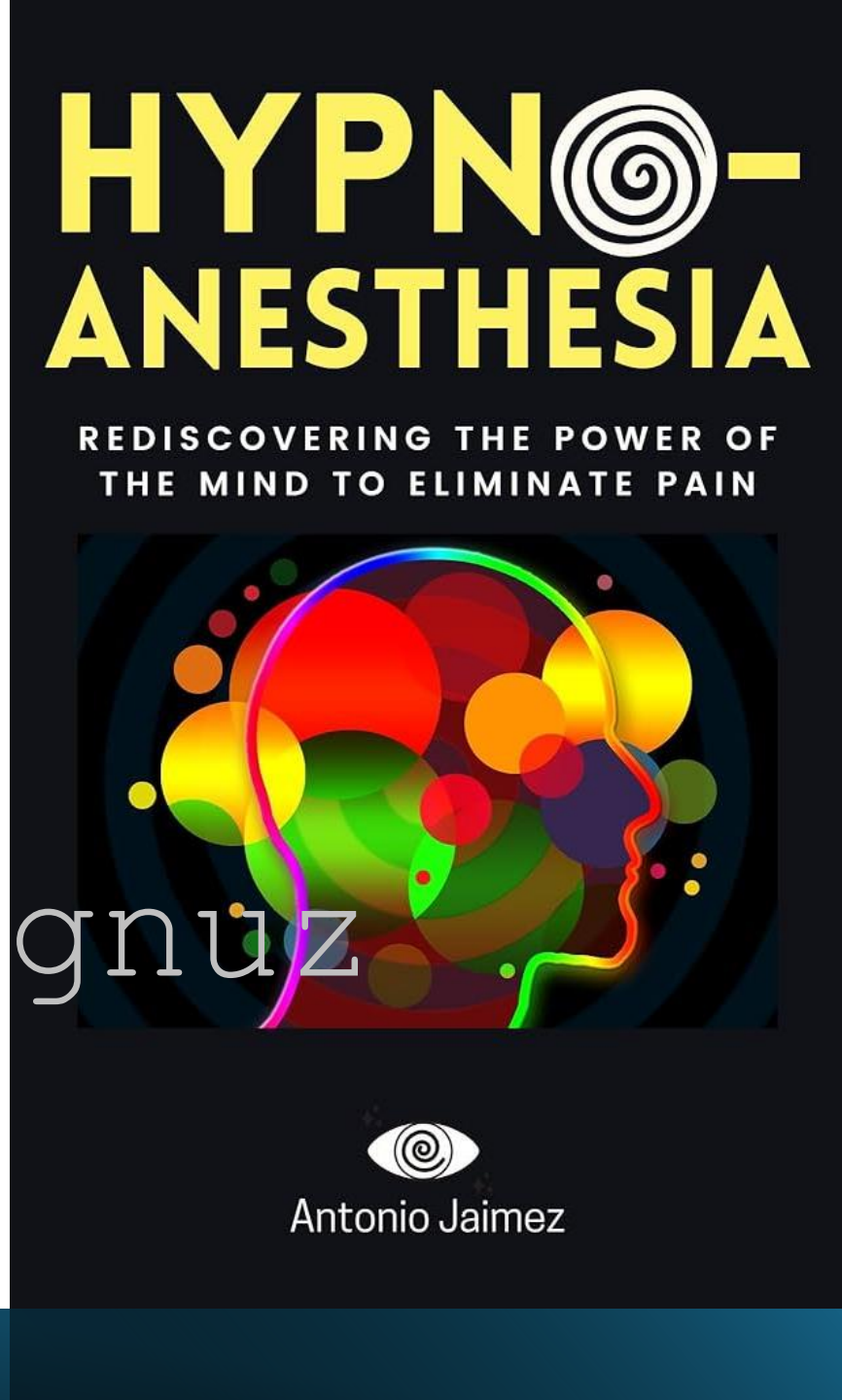
Delivered via balanced or TIVA strategies



Hypnosis (Loss of awareness & amnesia)

Goal: suppress cortical/thalamocortical connectivity → no awareness/recall

- Main agents: propofol (fast on/off), sevo/des/iso (volatiles), etomidate (CV stability), ketamine* (NMDA)
- Dosing approach: titrate to effect; reduce doses in frail/elderly/hypovolemic patients
- Monitoring: clinical signs + processed EEG (BIS/PSI target ~40–60 in GA); MAC 0.8–1.2 for volatiles
- Common pitfalls: hypotension (propofol/volatiles), delayed emergence, awareness if under-dosed
- Rescue: treat cause—fluids/vasopressors for BP, adjust depth, check infusion/rate/line patency
- Note: Ketamine preserves airway reflexes & BP; pair with midazolam if dysphoria is a concern.
- Delivery context: hypnosis via balanced anesthesia (volatile or IV) or TIVA (propofol ± adjuncts)



Analgesia (blunting nociception & stress response)

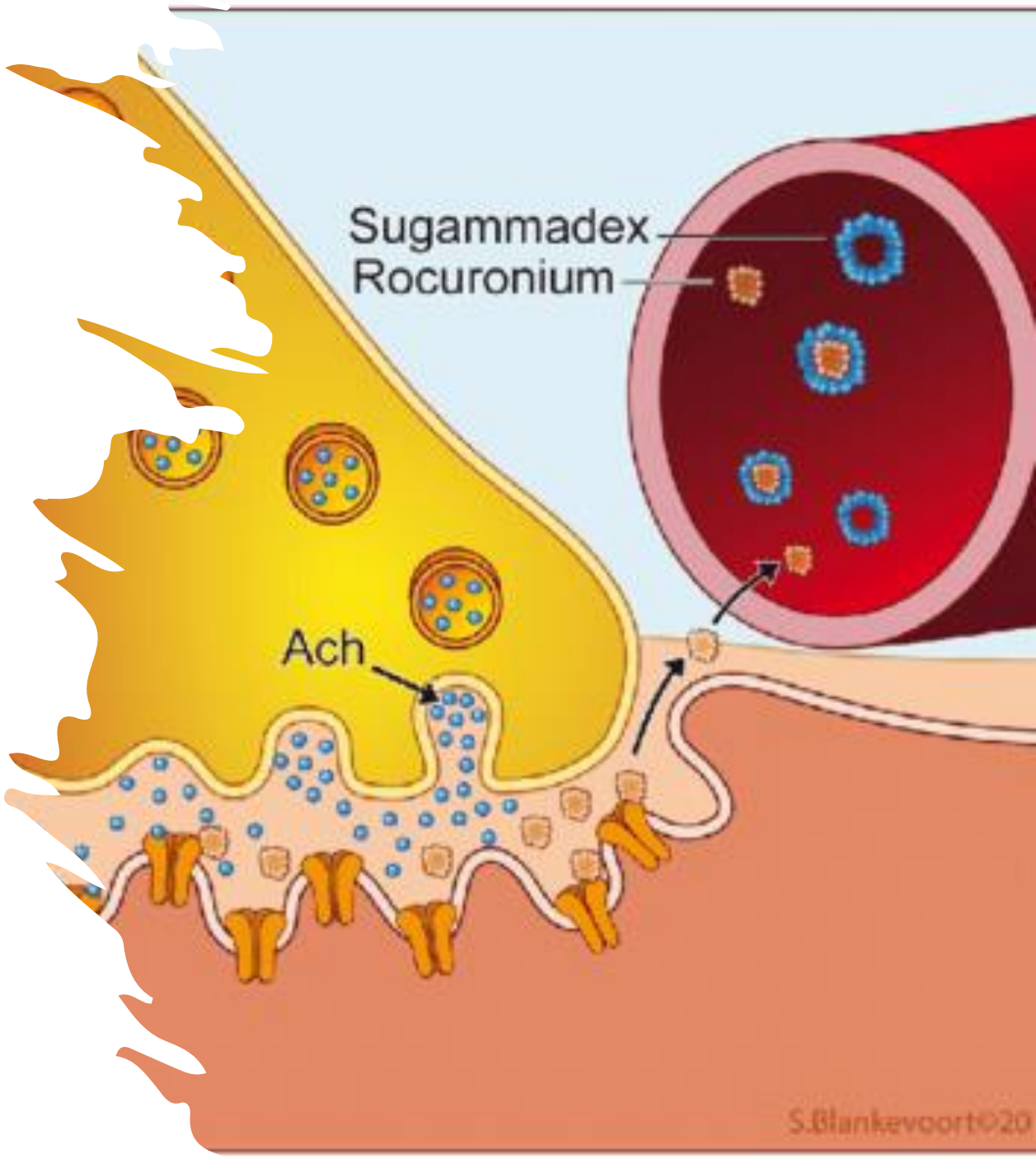
Physiology/target: block peripheral/central transmission and spinal wind-up.

- Main levers: opioids (fentanyl/remifentanil), multimodal (acetaminophen, NSAIDs, ketamine low-dose, lidocaine infusion, dexmedetomidine), regional/neuraxial blocks.
- Monitoring/proxies: hemodynamic responses (HR/BP), surgical pleth index, NOL index (if available), patient report post-op.
- Endpoint: minimal autonomic responses to surgical stimulus; low post-op pain scores with opioid sparing.
- Pitfalls: respiratory depression (opioids), bleeding/renal risk (NSAIDs).
- Rescue: titrate short-acting opioid (remi), add regional, non-opioids, adjust volatile

Muscle relaxation (optimal surgical conditions, immobility)

Physiology/target: neuromuscular junction blockade.

- Main levers: depolarizing (succinylcholine) for rapid sequence; non-depolarizing (rocuronium, cisatracurium) for maintenance.
- Monitoring: quantitative TOF (ulnar nerve/adductor pollicis); aim TOF 1–2 twitches intraop when needed.
- Endpoint: still field; no diaphragmatic/bucking during critical steps.
- Pitfalls: residual paralysis → airway risk.
- Reversal: sugammadex (for aminosteroids) or neostigmine + anticholinergic; extubate only if TOF ratio ≥0.9 (ideally ≥1.0).



Quantitative TOF Monitoring — Ulnar Nerve / Adductor Pollicis

Why quantitative? Objective block assessment; visual "fade" is unreliable.

- **Site & muscle:** Stimulate **ulnar nerve at the wrist**; measure **adductor pollicis** (thumb).
- **Device:** Acceleromyography or EMG preferred.
- **Calibration:** Establish baseline (TOF ratio ≈ **1.0**), ensure **supramaximal current**, good electrode contact.
- **Conditions:** Maintain **normothermia**, avoid arm compression/edema; secure hand/accelerometer.
- **Protocol:** Deliver **Train-of-Four (TOF)** = 4 stimuli at **2 Hz** (every 0.5 s), repeat every **12–20 s**.
- **When to use PTC:** If TOF = 0/4 and you need depth info, use **post-tetanic count** (profound block).
- **Onset vs recovery:** Facial nerve/orbicularis oculi tracks **laryngeal onset**; **adductor pollicis best for recovery** decisions.

Targets, Interpretation & Actions (Aim: TOF 1–2 Twitches Intraop)

- Induction/intubation: Target TOF 0/4 (consider PTC 1–2 for profound block).
- Intraoperative relaxation: Aim TOF 1–2/4 twitches when paralysis is required; titrate to surgical need.
- Recovery/extubation: Require TOF ratio ≥0.9 (ideally ≥1.0) plus clinical readiness (ventilation, airway reflexes).
- Pitfalls: Hypothermia, poor electrodes, tucked arms; drug interactions (e.g., magnesium, aminoglycosides); residual block risk.

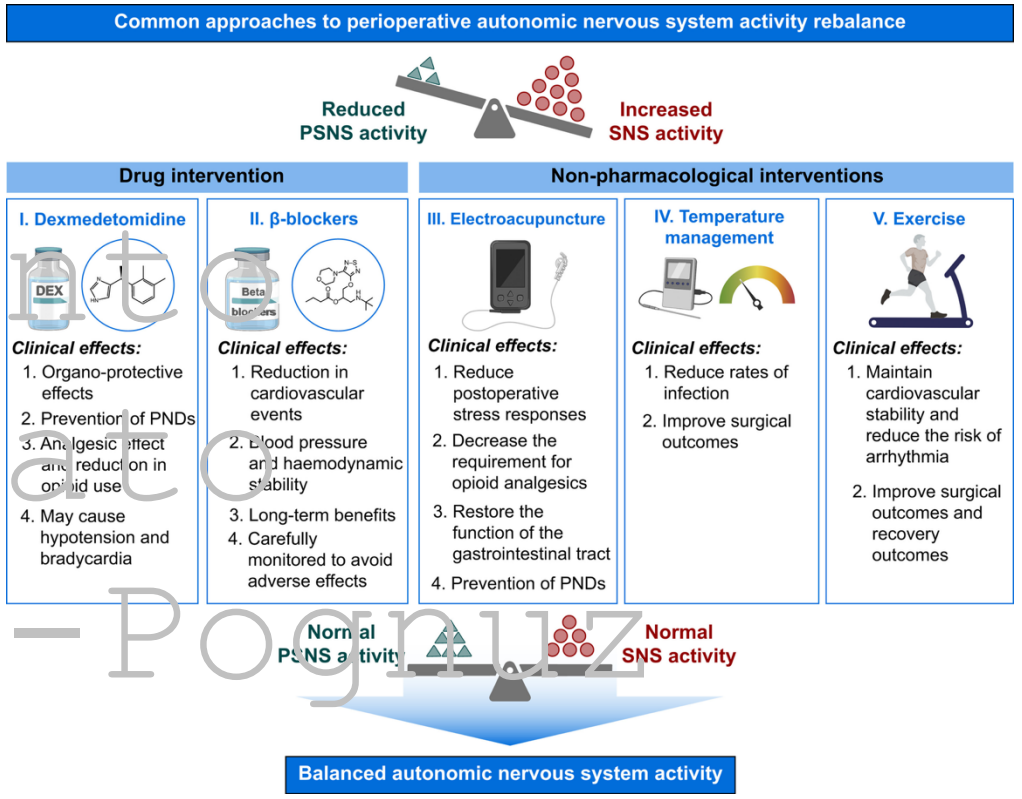
Actions:

- Inadequate relaxation → check TOF, then top up NMBA judiciously.
- Excess block → hold dosing, ventilate, plan reversal.
- Reversal: Sugammadex for aminosteroids (dose by depth/TOF/PTC) or neostigmine 0.04–0.07 mg/kg + glycopyrrolate.

Autonomic stability (control of reflexes & stress response)

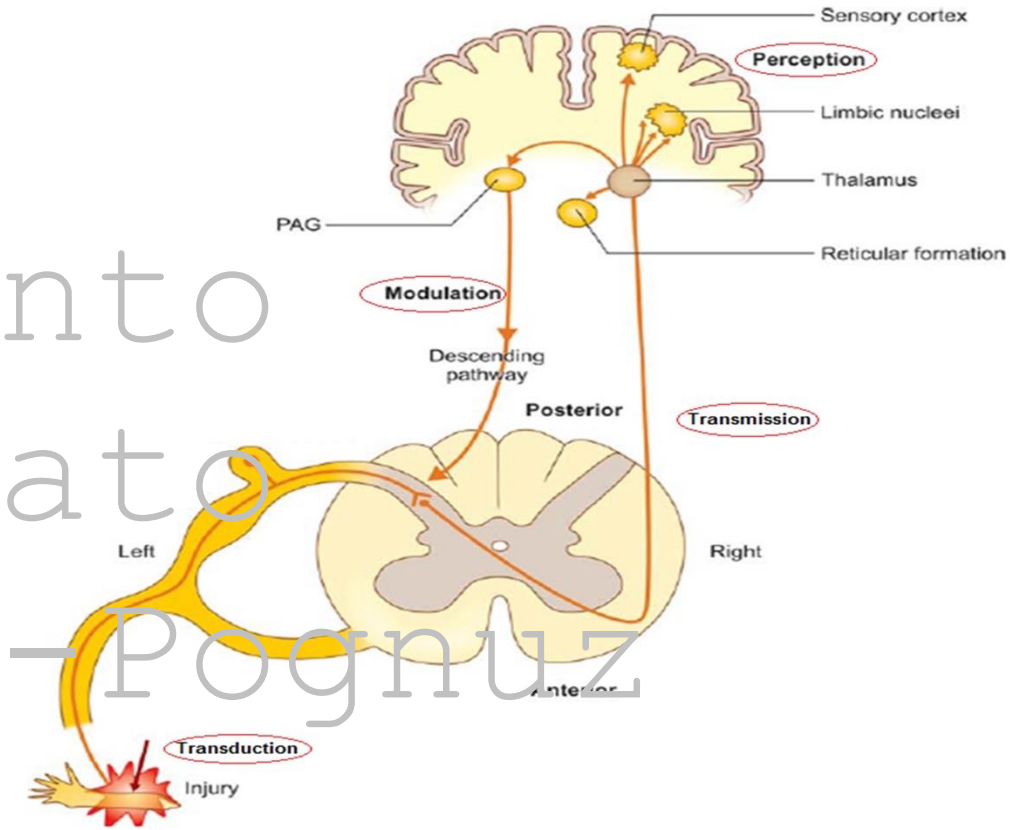
Physiology/target: temper sympathetic/parasympathetic swings; maintain perfusion.

- Main levers: adequate depth/analgesia; vasopressors (phenylephrine, norepinephrine), anticholinergics, beta-blockers; regional techniques reduce afferent input.
- Monitoring: continuous ECG, NIBP/arterial line, $EtCO_2$, temperature; consider advanced CO/PPV/echo in high-risk cases.
- Endpoint: MAP within target (often ≥65 mmHg; individualized), stable HR, normocarbia, normothermia.
- Pitfalls: hypotension from volatiles/propofol or high neuraxial; hypertension/tachycardia from inadequate analgesia.
- Rescue: treat cause first (depth/analgesia/fluids), then vasoactive drugs.



Nociception Pathway: From Stimulus to Perception

- **Transduction (periphery):** Nociceptors (free endings) convert thermal/mechanical/chemical stimuli via **TRPV1/2**, **ASICs**, **Nav** channels.
- **Primary afferents:**
  - **Aδ fibers** (thin, myelinated) → **fast, sharp** pain.
  - **C fibers** (unmyelinated) → **slow, burning/aching** pain.
- **First synapse (spinal cord):** Dorsal horn **laminae I/II (substantia gelatinosa) & V**.
  - Neurotransmitters: **glutamate** (AMPA/NMDA), **substance P**, **CGRP**.
- **Ascending tracts:**
  - **Spinothalamic (lateral):** location/intensity (→ **thalamus** VPL/VPM → **S1/S2**).
  - **Spinoreticular/spinomesencephalic:** arousal/affect (→ **insula**, **ACC**, **amygdala**).
- **Perception (brain):** Sensory-discriminative (**S1/S2**), affective-motivational (**ACC/insula**), cognitive-evaluative (**PFC**).



Pain ≠ nociception alone—cortical networks shape what the patient "feels."

Modulation, Sensitization & Where Anesthetics Act

- **Segmental modulation (spinal "gate"):**
  - Inhibitory interneurons (**GABA**, **glycine**, **enkephalins**) dampen input in dorsal horn.
- **Descending control: PAG → RVM → dorsolateral funiculus**; transmit **5-HT**, **NE (α2)**, endogenous opioids.
  - Can be **inhibitory** or **facilitatory** (context-, stress-, and disease-dependent).
- **Peripheral sensitization:** Inflammatory soup (**PGE_2, bradykinin, histamine**, **TNF-α/IL-1, NGF**) lowers nociceptor thresholds → **primary hyperalgesia**.
- **Central sensitization ("wind-up"):** Repetitive C-fiber input → **NMDA activation**, Ca^{2+} influx, microglial **BDNF/cytokines**, disinhibition → **secondary hyperalgesia/allodynia**.
- **Therapeutic targets (multimodal):**
  - **Peripheral: NSAIDs/COX-2**, steroids (↓inflammation); **local anesthetics** block **Nav**.
  - **Spinal: Epidural/spinal LA**, **opioids** (μ pre/post-synaptic), **α2-agonists** (dex/clonidine), **ketamine**(NMDA), **Mg^{2+}** (NMDA), **gabapentinoids** (α2δ Ca^{2+}).
  - **Supraspinal: Propofol/volatiles** (↑GABAergic tone), **acetaminophen** (central), **opioids**.
- **Clinical implications:** Prevent/treat sensitization with **pre-emptive** and **multimodal** analgesia; watch for **opioid-induced hyperalgesia** in high-dose remifentanil contexts.

Spinal gate (Control theory)

A **functional inhibitory "checkpoint" in the dorsal horn** of the spinal cord (mainly **lamina II, substantia gelatinosa**) that **regulates how much nociceptive (Aδ/C) input is allowed to reach projection neurons** (lamina I/V "wide-dynamic-range" cells) and ascend to the brain.

How it works (circuit logic)

- **Closes the gate (↓ pain transmission):** Low-threshold **Aβ touch fibers** activate **inhibitory interneurons** (GABA, glycine, enkephalin) → **pre-synaptic inhibition** of Aδ/C terminals (↓ glutamate/Substance P release) and **post-synaptic inhibition** of projection neurons (hyperpolarization).
- **Opens the gate (↑ pain transmission):** Strong or persistent **Aδ/C nociceptive activity** and **descending facilitatory** signals suppress these inhibitory interneurons → more excitatory drive to projection neurons.

Modulators

- **Descending inhibitory pathways** (PAG → RVM; **noradrenergic α_2**, serotonergic) help **close** the gate.
- **Inflammation/central sensitization** (NMDA activation, microglial BDNF/cytokines, disinhibition) tend to **open** it → hyperalgesia/allodynia.
- **Clinical corollaries**
- Rubbing the skin/TENS activates **Aβ** input → **closes** the gate (less pain).
- **Spinal/epidural local anesthetics**, **spinal opioids**, **α_2-agonists** enhance dorsal horn inhibition → close the gate.
- **Neuropathic pain** often reflects **gate failure** (loss of inhibition/disinhibition).

DRUGS

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Hypnotics (Part 1: Mechanisms & Dosing)

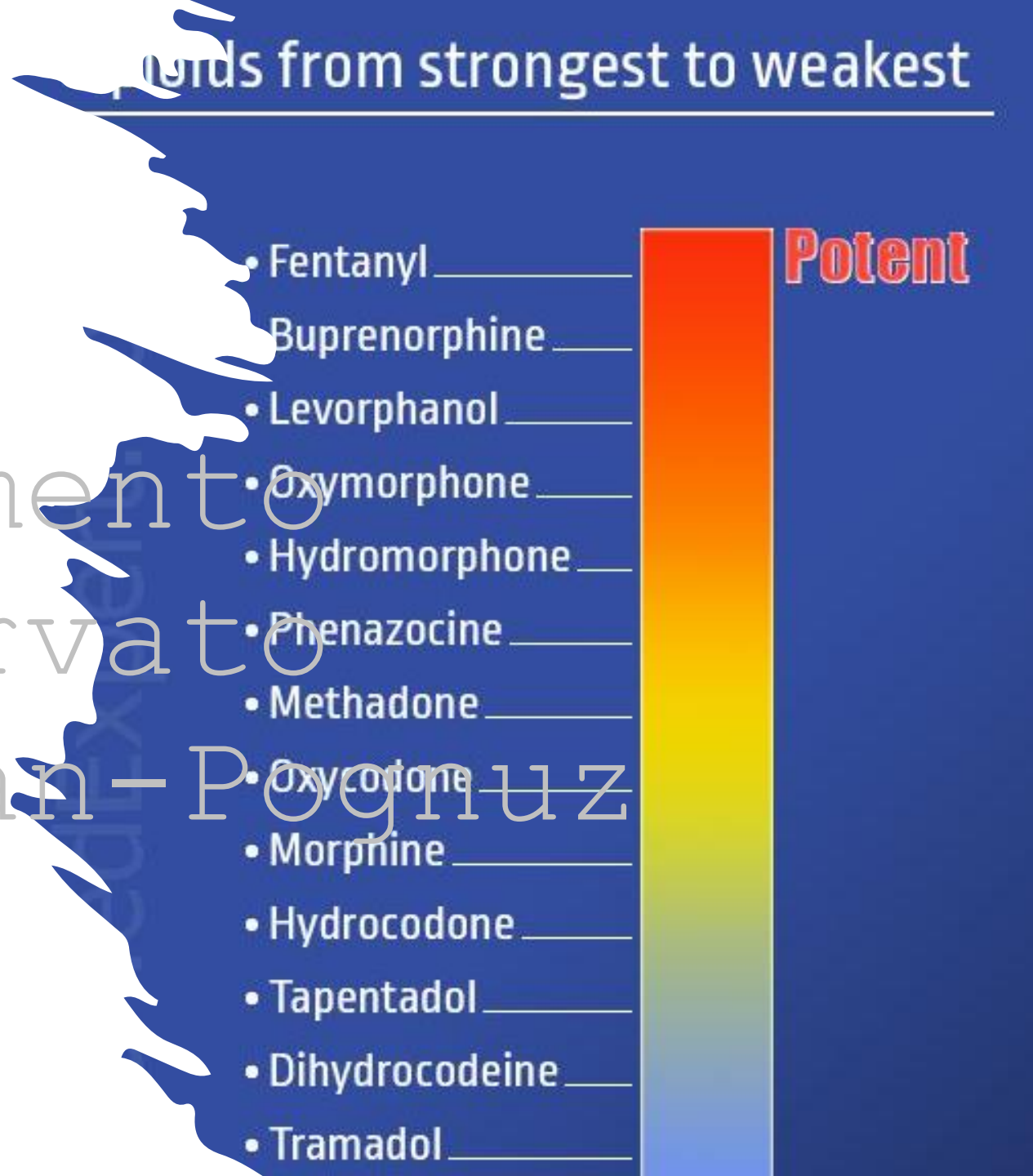
- **Mechanisms**
  - **Propofol:** ↑GABA_A → cortical/thalamic depression (rapid on/off)
  - **Etomidate:** ↑GABA_A; minimal CV depression
  - **Ketamine: NMDA antagonism** → dissociative anesthesia; analgesic at low dose
- **Adult IV dosing (typical)**
  - **Propofol:** induction **1.5–2.5 mg/kg**; maintenance **50–200 µg/kg/min**
  - **Etomidate:** induction **0.2–0.3 mg/kg** (bolus; avoid prolonged infusions)
  - **Ketamine:** induction **1–2 mg/kg**; analgesic **0.1–0.3 mg/kg** bolus → **0.1–0.4 mg/kg/h**
- **Adjuncts**
  - Lidocaine (reduce propofol injection pain); midazolam with ketamine to limit dysphoria
- **Titrate to effect**
  - Reduce doses in **elderly, frail, hypovolemic**, or with severe valvular/cardiac disease

Hypnotics (Part 2: Effects, Use Cases, Pitfalls, Monitoring)

- **Physiologic effects**
  - **Propofol:** ↓SVR/contractility → **hypotension**; respiratory depression; antiemetic
  - **Etomidate:** hemodynamic stability; **myoclonus**; transient **adrenal suppression**
  - **Ketamine:** ↑BP/HR, bronchodilation; preserves airway reflexes/resp drive; salivation; emergence phenomena
- **Use cases**
  - **Propofol:** TIVA, neuro (↓$CMRO_2$/CBF), day surgery
  - **Etomidate:** tenuous **cardiac function**, shock
  - **Ketamine:** trauma/hypovolemia, bronchospasm, opioid-sparing
- **Pitfalls & monitoring**
  - Treat hypotension (fluids/vasopressors), capnography for hypoventilation
  - **Context-sensitive half-time:** propofol short (good for TIVA); ketamine intermediate; etomidate for bolus use
  - Depth: clinical signs + **processed EEG** (BIS/PSI target ~40–60 in GA)

Opioids (Part 1: Mechanism, Agents, Dosing, Kinetics)

- **Mechanism: μ-receptor agonists** → ↓nociceptive transmission (spinal & supraspinal)
- **Key agents & adult dosing**
  - **Fentanyl:** bolus **1–2 μg/kg**; infusion **1–5 μg/kg/h**
  - **Remifentanil: 0.05–0.2 μg/kg/min** (TCI ~1–6 ng/mL); **ultra-short** (esterase metabolism)
  - (PACU context: **Morphine 0.05–0.1 mg/kg**, **Hydromorphone 0.01–0.02 mg/kg**)
- **Pharmacokinetics**
  - **Remifentanil:** context half-time **~3–5 min** (constant even after long infusions)
  - **Fentanyl:** context half-time **increases** with duration (tissue accumulation)
- **Role intraop:** Blunt stress response (HR/BP), allow lower hypnotic/volatile dose



Fentanyl (clinical essentials)

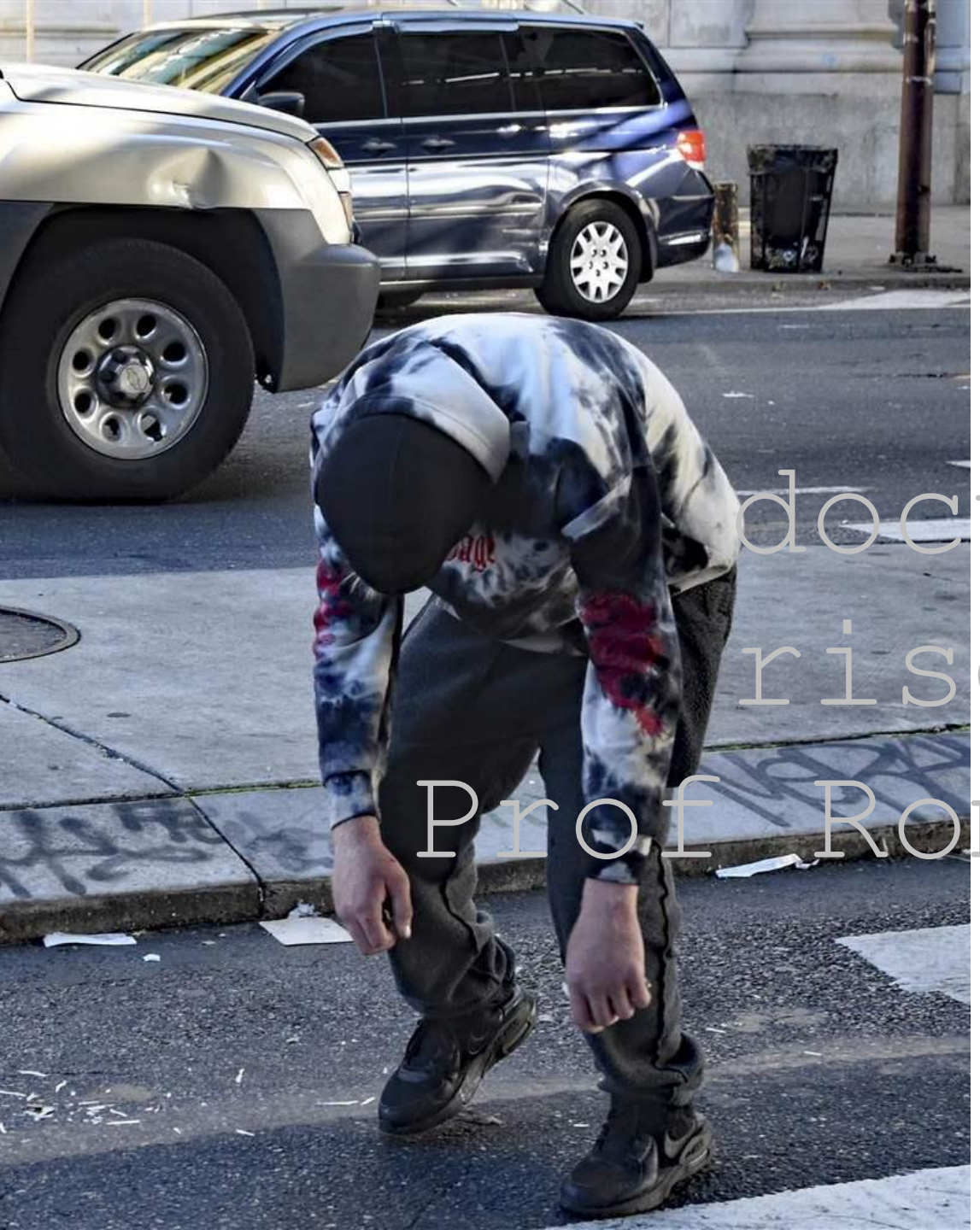
Class & mechanism: synthetic **μ-opioid receptor agonist**; **50–100×** morphine potency → profound analgesia, rapid CNS penetration.

- **Formulations (medical):** IV bolus/infusion, transdermal patch (chronic pain), transmucosal (breakthrough cancer pain).
- **Typical intra-op dosing (adults):** bolus **1–2 μg/kg**; infusion **1–5 μg/kg/h** (titrate to effect).
- **PK/PD pearls:** very **lipophilic** → fast onset; redistribution determines offset after bolus; **context-sensitive half-time increases** with long infusions (plan emergence accordingly).

Pros: potent analgesia; blunts sympathetic responses; hemodynamically stable at modest doses.

Adverse effects: respiratory depression, chest wall rigidity (rapid/high dose), bradycardia, pruritus, **PONV**.

- **Interactions/risks:** synergy with sedatives/hypnotics; caution in OSA/obesity; naloxone reverses but may require infusion for renarcotization.
- **Contrast with remifentanil:** remi has **ultrashort, infusion-independent** context half-time (~3–5 min) → exquisite moment-to-moment control but **no residual analgesia** (plan postop meds).



Why fentanyl dominates the U.S. drug crisis

- **Extreme potency → easy trafficking:** micro-doses deliver effects; **tiny shipments** supply large markets; **low cost to produce** synthetically (vs. plant opioids). **Fentanyl ≈100× morphine; ≈50× heroin** (analgesic potency). DEA
- **Counterfeit pill & contamination market:** illicitly manufactured fentanyls (IMFs) are **pressed to look like oxycodone/benzodiazepines**; also **mixed into heroin, cocaine, meth**, driving unintentional exposure. DEA+1
- **Sheer scale of supply: >60 million** fentanyl-laced fake pills and **~8,000 lb** powder seized by DEA in **2024** (**≈380 million** "potentially lethal doses"). DEA
- **Overdose toll (recent): ~105k** U.S. overdose deaths in **2023**; **~76%** involved opioids. About **70%** of 2023 overdose deaths involved **IMFs**. (Provisional 2024 data show a **decline**, but levels remain very high.) CDC+2CDC+2
- **Why people keep using despite risk:** high **reinforcement** (potency), **unpredictable dose** in illicit pills/powders, **tolerance** & withdrawal cycles; barriers to treatment access. National Institute on Drug Abuse

Public-health responses (what works):

- **MOUD** (buprenorphine/methadone), **naloxone** distribution, **fentanyl test strips**, safer-supply strategies, and **settlement-funded** prevention/recovery—expansions linked with recent mortality improvements but require sustained investment

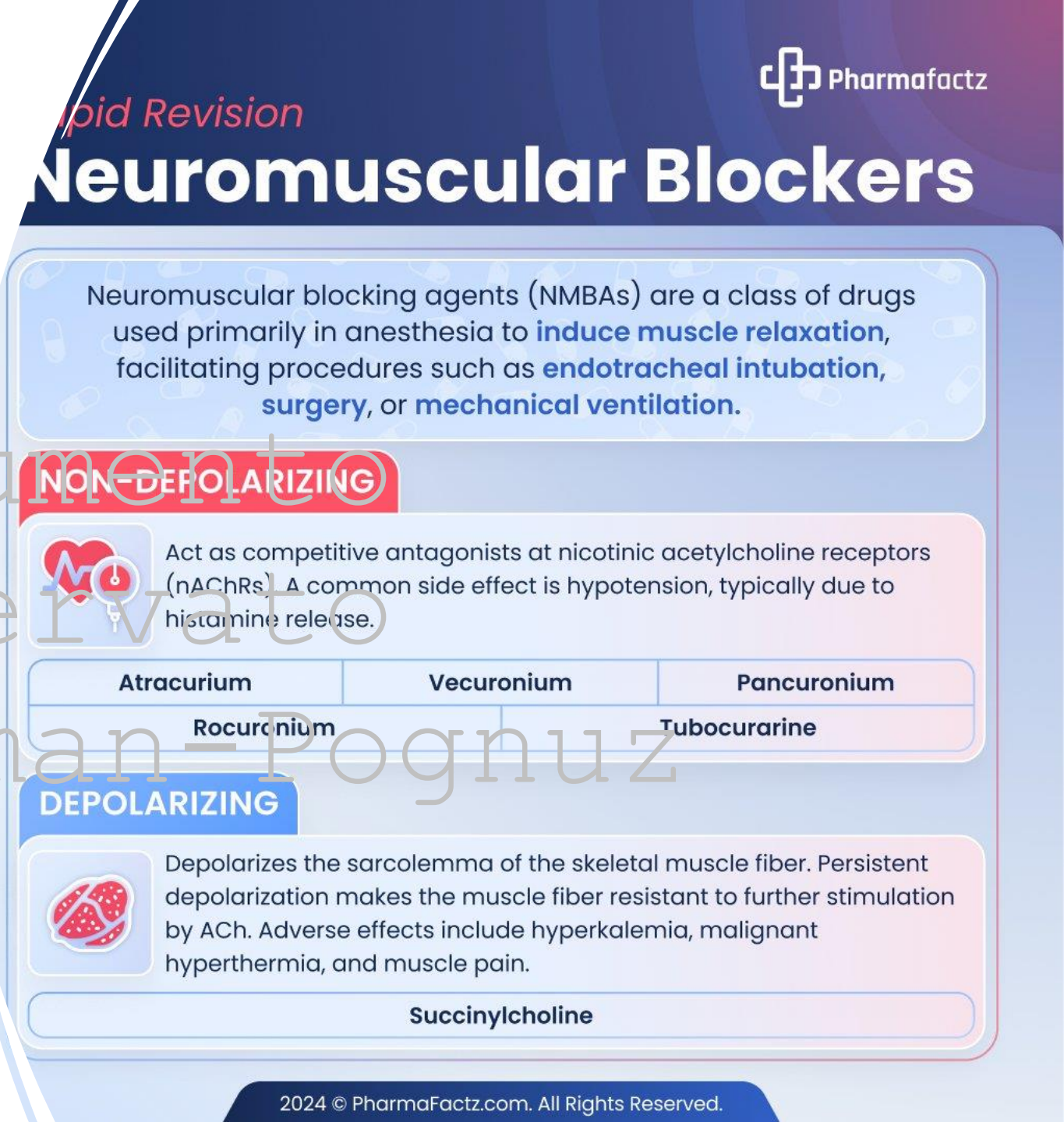
Opioids (Part 2: Effects, Risks, Reversal, Pearls)

- **Adverse effects**
  - **Respiratory depression**, chest wall rigidity (rapid/high dose), bradycardia
  - **PONV**, pruritus; **opioid-induced hyperalgesia (OIH)** with high-dose remifentanil
- **Reversal & mitigation**
  - **Naloxone** 20–40 µg IV increments; consider infusion to prevent renarcotization
  - **Multimodal analgesia** (acetaminophen, NSAIDs/COX-2, ketamine, lidocaine, dexmedetomidine, regional)
- **Clinical pearls**
  - **Remifentanil:** superb moment-to-moment control but **no residual analgesia** → plan PACU/ward analgesia
  - **Fentanyl/Hydromorphone:** useful when some **postop** analgesia is desired
  - Reduce opioid load in **OSA/elderly**; anticipate PONV prophylaxis per risk (e.g., Apfel)

NMBAs
(Part 1: Classes, Dosing, Indications, Contra)

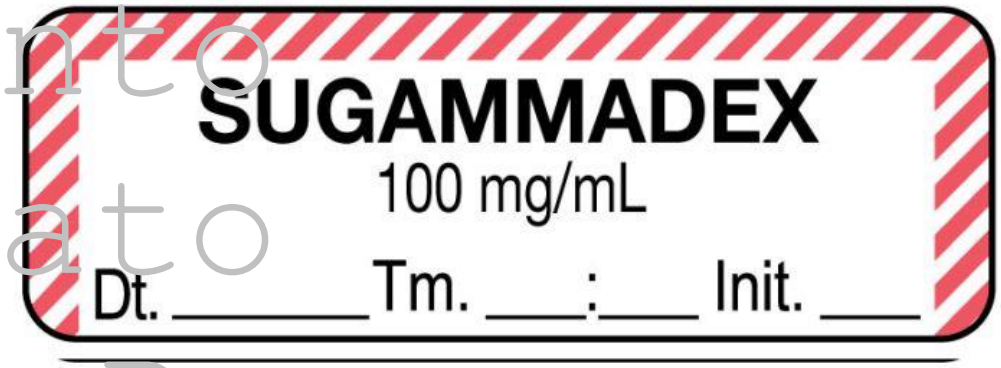
Purpose: paralysis for intubation/surgical conditions (**not** hypnosis/analgesia)

- **Depolarizing**
  - **Succinylcholine 1–1.5 mg/kg** (onset 30–60 s; duration 5–10 min)
  - Pros: fastest RSI; Cons: **↑K^+ 0.5–1.0 mEq/L**, myalgia, masseter spasm, ↑IOP/ICP, **MH trigger**
  - **Contraindications:** burns/SCI/denervation/immobilization ≥24–48 h, neuromuscular disease (e.g., Duchenne), hyperkalemia, pseudocholinesterase deficiency
- **Non-depolarizing (NDMRs)**
  - **Rocuronium: 0.6–1.0 mg/kg** (RSI **1.2 mg/kg**); 30–60 min; biliary/renal; **sugammadex** reversible
  - **Cisatracurium: 0.1–0.2 mg/kg**; **Hofmann/ester** (organ-independent) → good in renal/hepatic failure
- **Indications**
  - Tracheal intubation, abdominal/thoracic/laparoscopic surgery, motionless field for microsurgery



NMBAs (Part 2: Monitoring, Targets, Reversal, Pitfalls)

- **Monitoring**
  - **Quantitative TOF** (ulnar/adductor pollicis): when relaxation needed, aim **TOF 1–2/4 twitches**
  - **Extubation only if TOF ratio ≥0.9 (ideally ≥1.0)**
- **Reversal**
  - **Sugammadex** (for rocuronium/vecuronium):
    - 2 mg/kg (TOF 2/4), 4 mg/kg (deep block PTC 1–2), 16 mg/kg (immediate reversal/RSI)
  - **Neostigmine 0.04–0.07 mg/kg + glycopyrrolate** (when TOF ≥2/4) for others
- **Interactions & pitfalls**
  - Potentiation: **Mg^{2+}**, aminoglycosides, CCBs, hypothermia, acidosis, myasthenia
  - **Residual paralysis** → airway risk; **anaphylaxis** (rare; more reports with rocuronium)
- **Strategy**
  - Choose agent by **speed**, **organ function**, **need for rapid reversal**
  - Dose by **objective TOF**, not clock time; pair paralysis with adequate **hypnosis/analgesia** to prevent awareness



Monitoring

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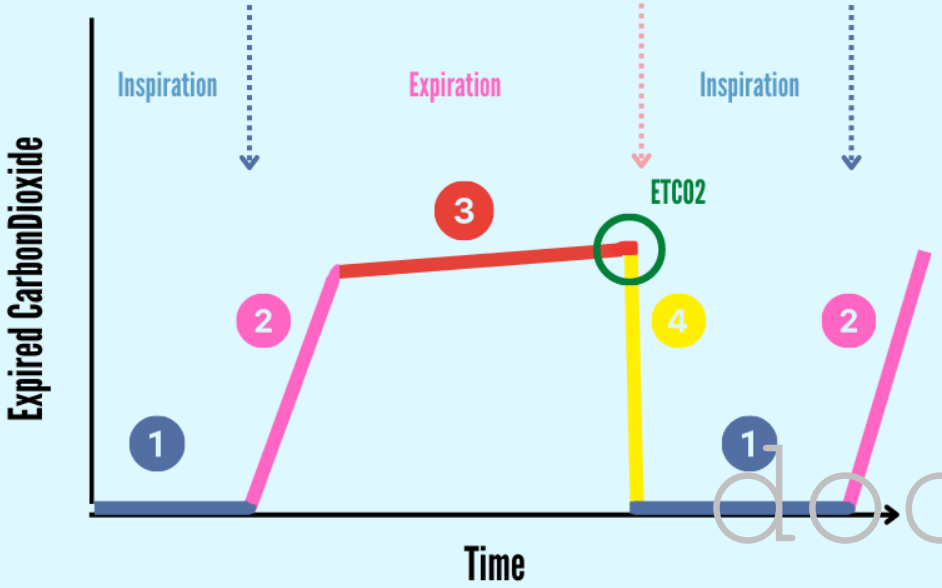
Monitoring Standards (ASA/International)

- **Basic**: ECG, NIBP, SpO_2, $EtCO_2$, temperature
- **Ventilation**: capnography mandatory with airway devices
- **Depth**: clinical signs ± processed EEG (BIS/PSI)
- **Neuromuscular**: TOF for NMBAs
- **Advanced**: A-line, central access, cardiac output, ultrasound

"You can't manage what you don't monitor."

Basic Monitoring (ASA/International Standards)

- **Core aims:** continuous evaluation of **oxygenation, ventilation, circulation, temperature** during anesthesia.
  What you put on every patient under GA (and most under RA/sedation):
- **ECG** (lead II for rhythm; add **V5** for ischemia).
  - Watch for ST-trends, QRS widening (electrolytes), arrhythmias during induction/emergence.
- **NIBP** (q 3–5 min) or invasive BP if indicated.
  - Trends > single numbers; check cuff size/position (too small → falsely high).
- **SpO_2 (pulse oximetry)**
  - Reads oxygenation, not ventilation. Pleth waveform helps detect hypoperfusion/vasoconstriction.
  - Artifacts: motion, dyes (methylene blue), poor perfusion, ambient light.
- **$EtCO_2$ (capnography)** — see next slide for depth; mandatory with advanced airways.
- **Temperature** (core when GA/long cases): esophageal, nasopharyngeal, bladder, rectal, or tympanic-membrane probes.
  - Aim **normothermia**; active warming (forced-air, warmed fluids). Hypothermia → coagulopathy, delayed recovery, shivering.



Don't Forget The Bubbles

2022

Owen Hibberd

Ventilation Monitoring: Capnography (Mandatory with Airway Devices)

What it measures: Exhaled CO_2 concentration vs time → confirms **ventilation** and **airway** integrity.
Normal values: $EtCO_2$ ~ **35–45 mmHg**; typically **2–5 mmHg lower** than $PaCO_2$ (V/Q effects).

- **Waveform anatomy (use it diagnostically):**
- **Phase I (baseline)**: inspired $CO_2 \approx 0$.
- **Phase II (upstroke)**: mixing of dead space + alveolar gas.
- **Phase III (plateau)**: alveolar emptying (slope ↑ with V/Q mismatch).
- **Phase 0 (downstroke)**: inspiration starts.

Key patterns & causes:

- **Sudden loss to zero** → circuit disconnect, apnea, esophageal intubation, cardiac arrest.
- **Progressive rise** → hypoventilation, CO_2 absorption (laparoscopy), malignant hypermetabolism.
- **Low $EtCO_2$** → hyperventilation, pulmonary embolism, low cardiac output.
- **Elevated inspiratory CO_2 / "shark fin"** → **rebreathing** (faulty valve, exhausted soda lime) / **bronchospasm**.
- **Curare cleft** on plateau → spontaneous breaths/insufficient paralysis.

Depth of Anesthesia: Clinical Signs ± Processed EEG

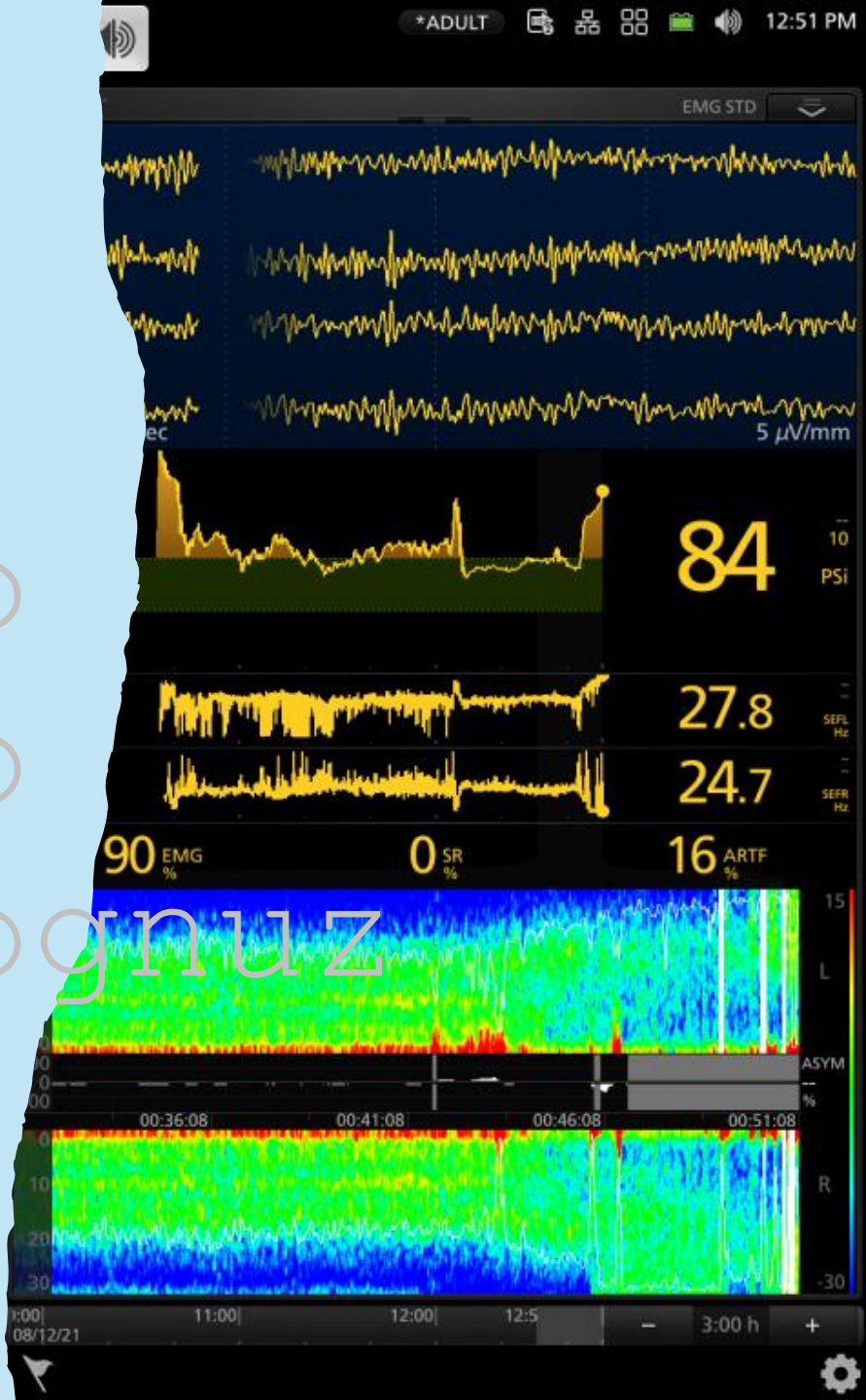
Why monitor depth? Avoid **awareness** and **overdose-related hypotension**; tailor to surgical stimulus & patient risk.

Clinical & gas proxies:

- **Volatiles:** monitor **MAC** (age-adjusted); typical maintenance **0.8–1.2 MAC**.
- **Signs:** movement, tearing, tachycardia/HTN (also reflect pain/autonomics). Drugs (beta-blockers) can blunt signs.

Processed EEG (BIS/PSI):

- **Target range in GA: ~40–60** (device-specific).
- **Benefits:** titration in TIVA/low-gas states; reduces drug use/recovery time in some settings.
- **Limitations/confounders:** EMG activity (tight facial muscles), **ketamine**, N_2O, electrocautery, hypothermia, poor sensor contact.
- **Plain EEG (pattern awareness):**
- Light anesthesia: high-frequency/low-amplitude;
- Adequate: delta/spindle dominance;
- Too deep: burst suppression/isoelectric (avoid unless neuro strategy).



Neuromuscular Monitoring: Quantitative TOF

Goal: ensure adequate paralysis when needed and **full reversal** before extubation (patient safety).

How to do it:

- **Site: ulnar nerve** at wrist; record at **adductor pollicis** (acceleromyography/EMG preferred).
- **Setup:** baseline calibration (**TOF ratio ≈ 1.0**), **supramaximal current**, good electrode contact, **normothermia**.
- **Protocol:** deliver **Train-of-Four** (4 stimuli at 2 Hz) q **12–20 s**. Use **post-tetanic count (PTC)** if TOF=0/4 to gauge deep block.

Targets & decisions:

- **Intubation:** TOF **0/4** (or PTC 1–2 if needed).
- **Intraop relaxation: TOF 1–2/4 twitches** when paralysis is required.
- **Extubation: TOF ratio ≥0.9 (ideally ≥1.0) plus** clinical readiness (ventilation, airway reflexes).
- **Common pitfalls:** residual blockade (airway risk), hypothermia, magnesium/aminoglycosides potentiation, facial nerve for onset vs ulnar for recovery.
- **Reversal: Sugammadex** for rocuronium/vecuronium (dose by depth/TOF/PTC); **Neostigmine + glycopyrrolate** when TOF ≥2/4 for other agents.

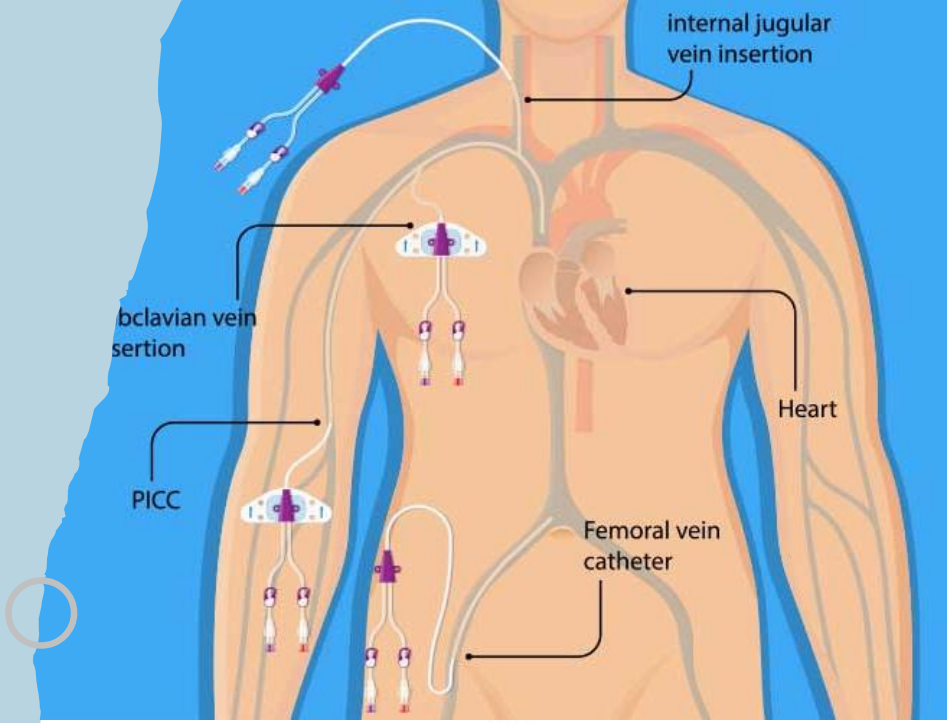
Arterial Line & Central Venous Access

Arterial line (A-line)

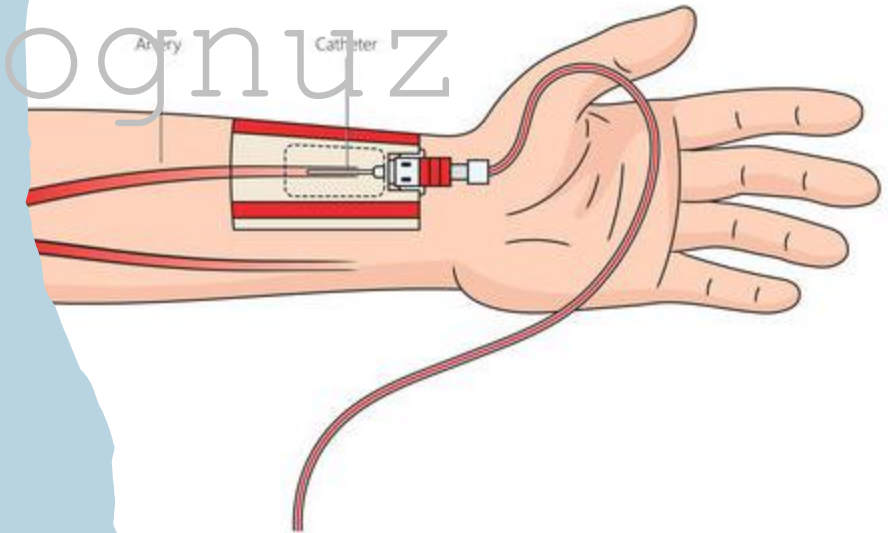
- **Indications:** beat-to-beat BP (major surgery/shock), frequent ABGs, vasoactive drugs.
- **Site & setup:** radial (Allen/Barbeau if needed) → transducer **zeroed/leveled** at **phlebostatic axis** (4th ICS, mid-axillary).
- **Quality check: Fast-flush/square-wave** test → avoids **over/under-damping** (misleading SBP/PP).
- **Waveform pearls:** dicrotic notch = aortic valve closure; low amplitude = hypotension/over-damping; PP ↑ with vasodilation.
- **Complications (minimize with ultrasound & asepsis):** thrombosis/ischemia, hematoma, infection, nerve injury.
- **Troubleshooting:** check tubing for bubbles/kinks, transducer height, clot in catheter; correlate with NIBP.

Central venous access (CVC)

- **Indications:** vasoactive infusions, limited peripheral access, hemodialysis, frequent blood sampling.
- **Approach: Ultrasound-guided** IJ/subclavian/femoral; full sterile bundle (cap, mask, gown, drape, chlorhexidine).
- **Tip confirmation:** waveform + CXR or **POCUS (saline "swirl")**; ECG-guided methods where available.
- **Complications:** arterial puncture, pneumothorax (subclavian), air embolism, malposition, infection, thrombosis.
- **Prevention:** smallest lumens needed, securement, CHG dressing, daily necessity review, remove early.



Arterial line



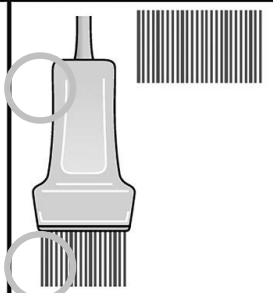
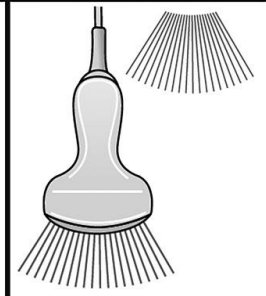
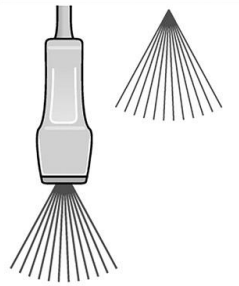
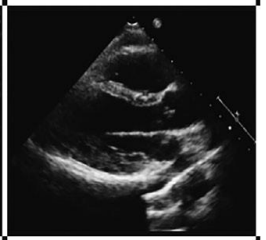
Cardiac Output, Dynamic Indices & Perioperative Ultrasound

Cardiac output (CO) monitoring

- **Techniques:** pulse-contour analysis (FloTrac/PiCCO/LiDCO), **esophageal Doppler**, **PAC** (thermodilution), TEE/TTE estimates.
- **Use:** trend CO/SV, guide fluids/pressors/inotropes; validate trends against clinical picture & labs.
- **Dynamic preload indices (predict fluid responsiveness)**
- **PPV/SVV** valid only if: **controlled ventilation**, **regular rhythm**, **TV ≥ ~8 mL/kg**, **closed chest**, no large inspiratory efforts.
- **Typical cutoffs:** PPV **>12–13%** or SVV **>10–12%** → likely fluid responsive (context-dependent).
- **When unreliable:** AF/ectopy, spontaneous breathing, low TV, high PEEP, open chest, severe RV failure.

Perioperative ultrasound (POCUS/TEE/TTE)

- Cardiac: LV/RV size & function, pericardial effusion, LVOT VTI for SV/CO, dynamic LVOT obstruction, tamponade signs.
- Lung: B-lines (edema), consolidation, pleural effusion, pneumothorax (absent sliding/Barcode sign).
- Vascular: IVC size/collapsibility (supportive, not definitive), DVT screening, real-time vascular access.
- Airway & gastric: confirm ETT depth, gastric content/volume to assess aspiration risk.
- Integration: combine CO trends + dynamic indices + POCUS to choose fluids vs vasopressor vs inotrope; reassess after each intervention.

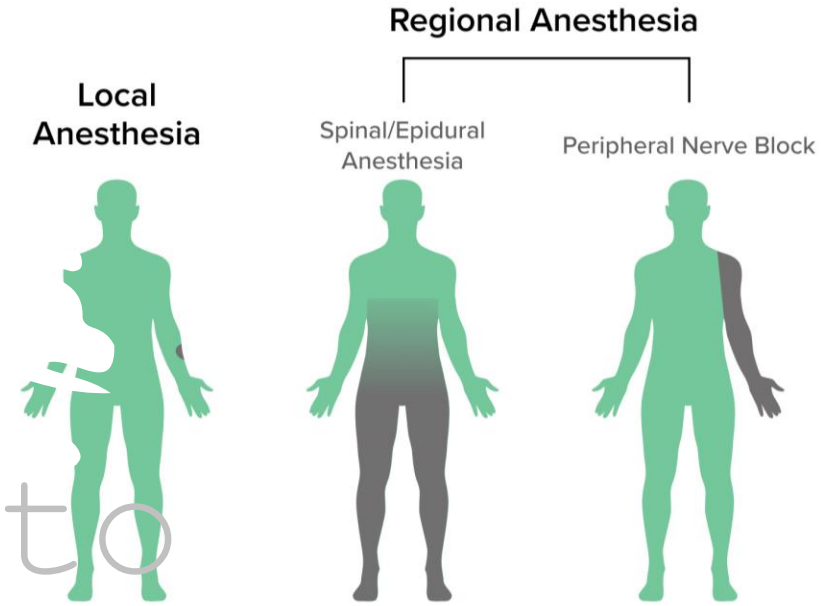
Transducer type	Linear	Curvilinear	Phased array
			
Frequency range	5–10 MHz	2–5 MHz	1–5 MHz
Imaging depth	9 cm	30 cm	35 cm
Footprint			
Image			
Applications	Arteries/veins Procedures Pleura Skin/soft tissues Musculoskeletal Testicles/hernia Eyes Breast	Gallbladder Liver Kidney Bladder Abdominal aorta Abdominal free fluid Uterus/ovaries	Heart Inferior vena cava Lungs Pleura Abdomen

Classification of Anesthesia

- **General anesthesia (GA)**
- **Regional anesthesia (RA)**: neuraxial & peripheral nerve blocks
- **Local anesthesia** (infiltration/topical)
- **Sedation** (minimal → moderate → deep; continuum)

Notes: Same patient may receive combinations (e.g., GA + block).

General Anesthesia: Definition, Safety Checks & Pre-oxygenation



Definition & goals

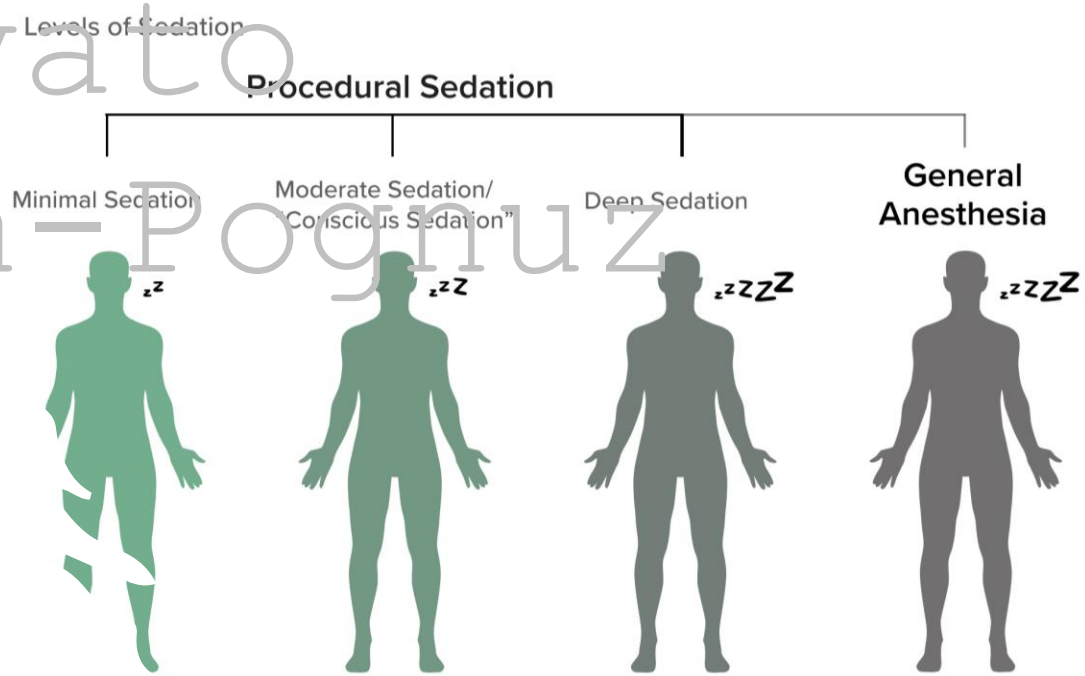
- **Controlled, reversible unconsciousness** with **amnesia**, **immobility**, **analgesia**, and **autonomic control**.
- Delivered as **Balanced GA** (volatile/IV + opioid ± NMBA ± regional) or **TIVA** (propofol + short-acting opioid).

Pre-induction safety bundle (2–3 min)

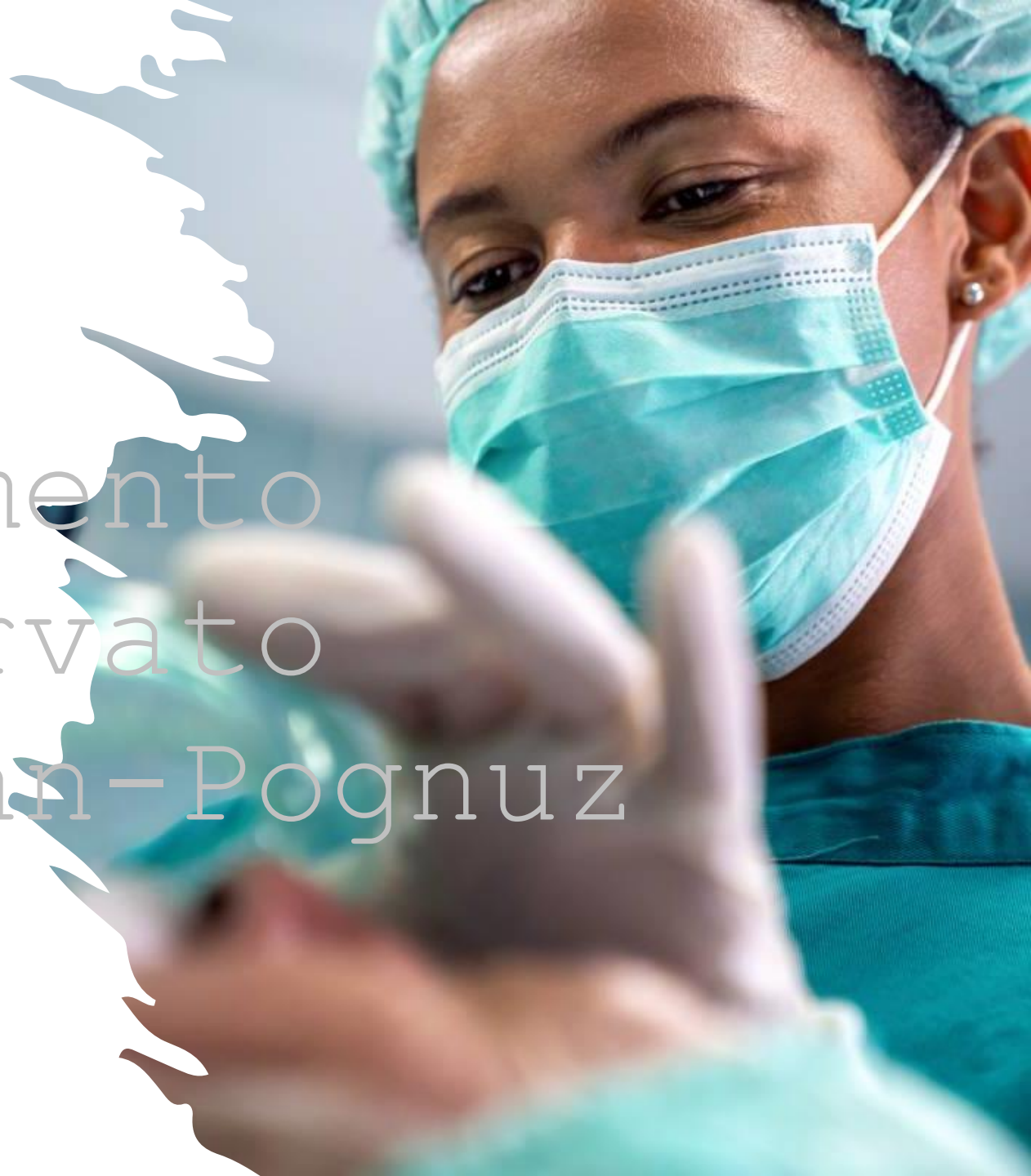
- Verify **fasting**, **consent**, **allergies**, **OSA/MH history**, last **anticoagulant/antiplatelet** dose.
- Place monitors: **ECG**, **NIBP q3–5 min**, **SpO_2**, capnography **ready**, **temperature** for GA/long cases.
- **Airway plan A–B–C**: mask → SGA → ETT; **video laryngoscope** available; **cric kit** visible.
- Prep & **label drugs**: induction agent, opioid, **NMBA**, **vasopressor** (phenylephrine/norepinephrine), ephedrine, atropine, bronchodilator.
- Equipment: suction, oxygen source, circuit check, **ambu-bag**, working capnograph; **IV access x1–2**; patient **positioning/ramping** as needed.
- **PONV prophylaxis strategy** considered (risk-based).

Pre-oxygenation (denitrogenation)

- Tight mask, **100% O_2**: 3–5 min tidal breathing **or** 8 vital-capacity breaths.
- Aim **EtO_2 ≥ 0.8**; consider **apneic oxygenation** via nasal cannula 10–15 L/min in expected difficult/RSI cases.
- Rationale: **prolongs safe apnea time**, reduces desaturation during airway manipulation.



Induction, RSI, Airway Securement & Initial Ventilation

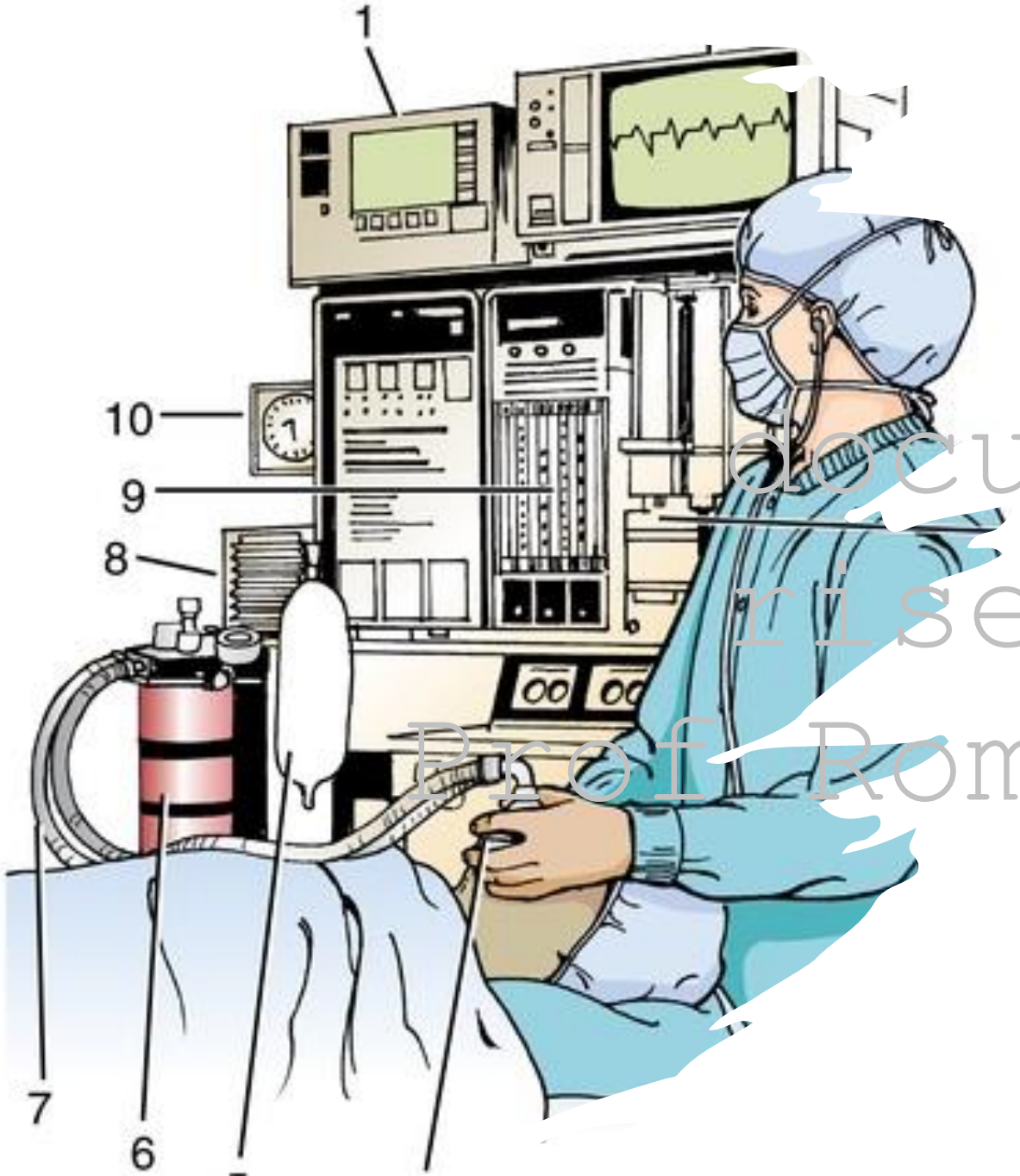


IV induction (typical adult—titrate to effect)

- **Propofol 1.5–2.5 mg/kg** (↓SVR); **Etomidate 0.2–0.3 mg/kg** (CV stability); **Ketamine 1–2 mg/kg** (↑BP/HR, bronchodilation).
- Analgesic blunting: **Fentanyl 1–2 µg/kg** (or start remifentanil).
- Paralysis (if ETT planned): **Rocuronium 0.6–1.0 mg/kg** (RSI **1.2 mg/kg**) **or Succinylcholine 1–1.5 mg/kg**(observe contraindications).
- **Rapid Sequence Induction (aspiration risk)**
- No mask ventilation (or **gentle ≤10–12 cmH_2O** if desaturation).
- Induction agent → **immediate NMBA** → laryngoscopy at optimal timing; **cricoid** per local policy.
- **Confirm tracheal intubation by $ETCO_2$** (sustained waveform), bilateral chest rise, auscultation.

Airway securement & verification

- ETT depth ~**21–23 cm** at teeth in adults; cuff pressure **20–30 cmH_2O**.
- If difficulty: switch to **video laryngoscopy**, use **bougie/SGA**; **oxygenation first**; escalate per difficult-airway algorithm.
- **Initial ventilation & hemodynamics**
- Vt **6–8 mL/kg PBW**, **PEEP 5 cmH_2O**, adjust RR to **$EtCO_2$ 35–45 mmHg**; FiO_2 0.5–1.0 then titrate to **SpO_2 ≥94–96%**.
- **Induction hypotension**: treat quickly (phenylephrine **50–100 µg** or norepinephrine **5–10 µg** IV bolus) ± **250–500 mL** balanced crystalloid.
- Begin **active warming** early.



Maintenance: Strategy, Depth, Analgesia & Neuromuscular Block

Maintenance strategies

- **Balanced GA:** sevo/des/iso at **~0.8–1.2 MAC** + opioid ± NMBA ± regional.
- **TIVA: Propofol 50–200 µg/kg/min** + **Remifentanil 0.05–0.2 µg/kg/min** (or TCI). Choose by patient factors (e.g., PONV risk, neuro cases, MH risk).
- **Depth of anesthesia**
- Track **clinical signs** + **processed EEG (BIS/PSI ~40–60)**; understand confounders (EMG, ketamine, N_2O, cautery).
- Avoid awareness and **over-deep** anesthesia (hypotension, burst suppression).

Analgesia (multimodal, intraop)

- **Acetaminophen** 1 g IV/PO; **NSAID/COX-2** if appropriate.
- **Ketamine** low-dose: 0.1–0.3 mg/kg bolus → 0.1–0.2 mg/kg/h infusion.
- **Lidocaine** infusion 1–1.5 mg/kg/h (avoid in significant conduction disease).
- **Dexmedetomidine** 0.2–0.7 µg/kg/h (bradycardia risk).
- **Regional/neuraxial** when feasible to blunt afferent input and reduce opioids.
- **Neuromuscular block (when required)**
- **Quantitative TOF** (ulnar/adductor pollicis): target **1–2/4 twitches** for surgical relaxation.
- Re-dose by **TOF**, not clock; plan **reversal** strategy early (sugammadex vs neostigmine).

Autonomic Management, Ventilation, Emergence & PACU Handover

Autonomics & physiology

- **MAP goal ≥65 mmHg** (individualize for CAD/CKD/elderly).
- **Hypotension**: treat cause (depth/analgesia/bleeding) → fluids if responsive → **phenylephrine** (vasodilation), **norepinephrine** (vasodilatory hypotension); **ephedrine** if low HR + low BP.
- **Hypertension/tachycardia**: increase analgesia/depth; consider **esmolol/nitroglycerin**.
- Ventilation: maintain **$EtCO_2$ 35–45**, treat **bronchospasm** (deepen anesthesia, inhaled β_2-agonist; severe → epinephrine).
- **Temperature**: forced-air warming, warmed fluids; target **36–37 °C**.
- Fluids: aim **euvolemia**; use **goal-directed** indices when valid. Check labs (glucose, Hb, ABG/electrolytes) as indicated.

Emergence & extubation

- Wean volatile/propofol; stop remifentanil; ensure **residual analgesia** (opioid/NSAID/acetaminophen/regional).
- **Reverse NMB**: **Sugammadex** (2–4–16 mg/kg per depth) or **Neostigmine 0.04–0.07 mg/kg + Glycopyrrolate** when TOF ≥2/4.
- Extubate only when: **TOF ratio ≥0.9–1.0**, follows commands, adequate ventilation (Vt >5 mL/kg, acceptable **$EtCO_2$**), stable oxygenation/hemodynamics, **normothermia**.
- High-risk airway (ENT, prone, OSA, edema): consider **awake** or delayed extubation (PACU/ICU).
- **PACU handover (SBAR) & early priorities**
- **S**urgery & key intraop events; **B**aseline risks/comorbidities; **A**nesthetics/analgesics/NMBA doses & reversal, **fluids/EBL/vasoactives/blocks**; **R**ecommendations (pain plan, **PONV** meds, O_2, monitoring, labs).
- PACU focus: airway patency, pain control, PONV treatment, temperature, bleeding, urinary retention, early complications.

IV Induction (Propofol / Etomidate / Ketamine)

Goal: rapid, controllable loss of consciousness with airway/hemodynamic safety.
Agents & typical adult doses (titrate to effect):

- **Propofol 1.5–2.5 mg/kg** → very fast onset; ↓SVR/contractility → **hypotension**, apnea; antiemetic.
- **Etomidate 0.2–0.3 mg/kg** → **hemodynamic stability**; myoclonus; transient adrenal suppression (avoid prolonged use).
- **Ketamine 1–2 mg/kg** → **sympathomimetic** (↑BP/HR), bronchodilation; preserves respiratory drive/reflexes; salivation, emergence phenomena (mitigate with midazolam).
  When IV is preferred: full stomach/**RSI**, aspiration risk, predicted difficult airway (video scope ready), **hemodynamic lability** (etomidate/ketamine), bronchospasm (ketamine).

- Technique essentials: preoxygenate (EtO_2 ≥0.8), blunten response (fentanyl 1–2 µg/kg or remifentanil), give **NMBA** if intubating (rocuronium 0.6–1.0 mg/kg; RSI 1.2 mg/kg or succinylcholine 1–1.5 mg/kg if no contraindications), confirm ETT by **capnography**.

- Pitfalls & fixes: hypotension (phenylephrine 50–100 µg / norepinephrine 5–10 µg + fluids), apnea (bag–mask/SGA), jaw stiffness (succinylcholine-related), awareness risk if under-dosed (watch signs/EEG).

Inhalational Induction

Who/why: Pediatrics (needle-free, cooperative), needle-averse adults **without** aspiration risk; reactive airways (bronchodilation).
Why sevo? Non-pungent, rapid alveolar wash-in, favorable bronchodilatory profile.

How to do it: Fresh gas flow **6–8 L/min** (O_2/air), **sevo 8%** "vital-capacity" or step-up technique; maintain **spontaneous breathing**; obtain IV after loss of consciousness, then secure airway (mask/SGA/ETT).

Adjuncts: N_2O may speed onset/MAC-sparing; avoid in **closed-space** pathology (pneumothorax, bowel obstruction).

Cautions/limits: not for **full stomach/RSI**; slower control in adults; early **hypotension** possible; risk of airway obstruction—use jaw thrust, CPAP, oral/nasal airway.

Troubleshooting waveform: rising $EtCO_2$ with poor chest excursion → obstruction; "shark-fin" → bronchospasm (deepen anesthesia, β_2-agonist).

Volatile Maintenance (Sevo / Des / Iso)

- **Dose target:** age-adjusted **~0.8–1.2 MAC**; consider **low-flow** once stable.
  Pros: simple titration via vaporizer; **sevo** bronchodilation; minimal equipment dependence.

- Cons: **↑PONV**, dose-dependent **hypotension** (↓SVR), respiratory depression; **MH trigger**; OR pollution.
  Agent nuances:
- **Sevoflurane:** smooth, non-pungent; great with masks/bronchospasm; follow local guidance for very low flows.
- **Desflurane:** fastest titration; airway irritant at high % (tachycardia/cough).
- **Isoflurane:** cost-effective; slower kinetics; good for long cases if hemodynamics tolerate.
  Physiology & management: anticipate ↓BP—optimize depth/analgesia first, then vasopressor; maintain $EtCO_2$ 35–45; active warming to 36–37 °C.

- When volatiles shine: reactive airways, straightforward logistics, limited infusion pump availability, cost constraints.
- Risk notes: avoid in **MH-susceptible** patients; plan PONV prophylaxis (Apfel-based).

TIVA Maintenance (Propofol + Remifentanil ± Adjuncts)

- **Typical dosing: Propofol 50–200 µg/kg/min** + **Remifentanil 0.05–0.2 µg/kg/min** (or TCI). Consider adjuncts: low-dose **ketamine**, **lidocaine**, **dexmedetomidine**.
- Pros: **low PONV**, excellent neuro profile (↓ICP/clean EEG), **no MH trigger**, no OR gas pollution, ideal for **shared airway** surgery and when rapid, smooth wake-up desired.
- Cons: **hypotension** (propofol), needs reliable IV access & pumps/TCI expertise; line dislodgement risk; **remifentanil**leaves **no residual analgesia**—plan PACU pain control.
- Monitoring: favor **processed EEG** (BIS/PSI ≈ 40–60) to reduce awareness risk; secure lines; clearly **label infusions**.
- When TIVA shines: **high PONV risk**, **MH susceptibility**, **neurosurgery** (ICP/evoked potentials), ENT/shared airway, situations needing minimal movement and fast wake-up.
- Choice algorithm (quick):
- **PONV↑ / Neuro goals / MH risk / Shared airway → TIVA.**
- **Bronchodilation need / Simpler logistics / Cost concerns → Volatile.**

Always integrate **regional blocks** to reduce opioids and improve autonomic stability.

AIRWAY MANAGEMENT

documento
riservato
Prof Roman-Pognuz

Airway Management in GA

- Preop assessment: **Mallampati**, mouth opening, TMD, neck mobility
- Devices:
  mask, **supraglottic** (LMA), **ETT** (oral/nasal)
- Strategies: standard vs **RSI** (aspiration risk)
- Rescue: adjuncts, **video laryngoscopy**, bougie, **surgical airway** (rare)
- **Notes:** Always have a plan B (and C).

Pre-op Airway Assessment & Setup (Plan A–B–C)

- **History & risks:** prior difficult airway, OSA (STOP-BANG), reflux/full stomach, facial/neck radiation, tumors, pregnancy, trauma.

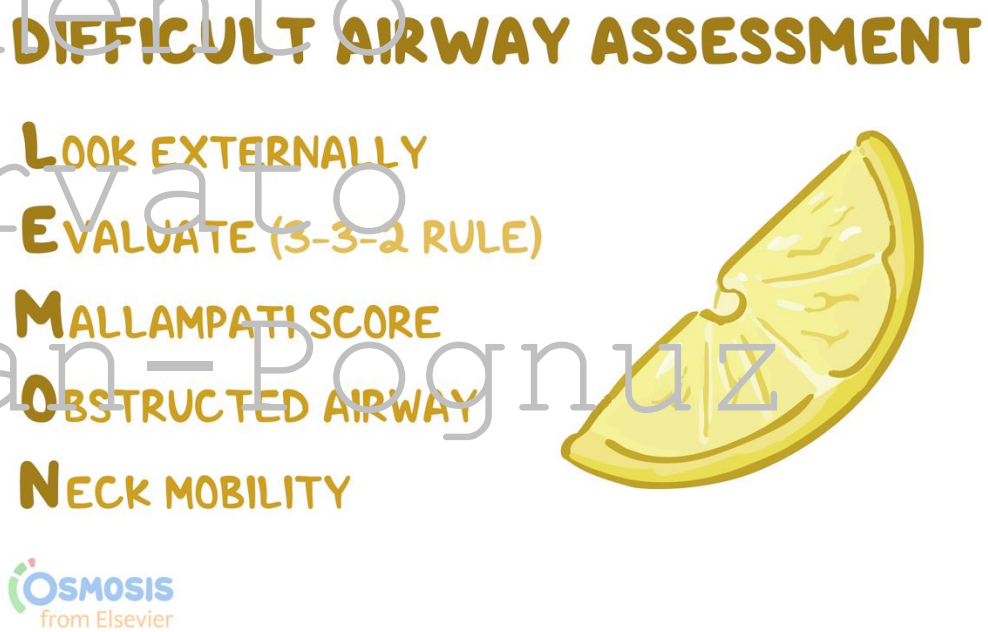
Look & measure (predictors):

- **Mallampati I–IV** (tongue vs pillars)
- **Mouth opening (inter-incisor) ≥ 3 cm** (≈ 2–3 fingerbreadths)
- **Thyromental distance (TMD) ≥ 6.5–7 cm**; **Sterno-mental ≥ 12–13 cm**
- **Upper-lip bite test** (mandibular protrusion)
- **Neck**: flexion/extension limitation; circumference > **40 cm** (obesity)

Pre-op Airway Assessment & Setup (Plan A–B–C)

Dentition: loose/capped teeth; beard, micro/retrognathia

- Difficult mask ventilation (DMV) clues: Obesity, Beard, Edentulous, OSA, Age>55, Snoring, Limited jaw protrusion.
- Scales: LEMON (Look-Evaluate-Mallampati-Obstruction-Neck), MACOCHA (ICU).
- Optimization: head-elevated/ramped position (tragus ↔ sternal notch horizontal), suction ready, two IVs if high-risk, bite block, eye protection.
- Preoxygenation: 100% O_2 (3–5 min tidal or 8 VC breaths), aim EtO_2 ≥0.8; consider apneic oxygenation (nasal 10–15 L/min).
- Kit out (labelled): mask/OPAs/NPAs, SGA (2nd-gen), ETTs (female 7.0–7.5, male 7.5–8.5), bougie, video laryngoscope, suction, eFONA set; vasopressor, bronchodilator.
- Declare plans: Plan A (primary), Plan B (SGA or alt device), Plan C (wake/awake FOI), Plan D (eFONA).



Pre-op Airway Assessment & Risk Stratification 1

History red flags

- Prior difficult mask/intubation, OSA (STOP-BANG ≥3), reflux/full stomach, pregnancy, trauma/burns/airway tumors, cervical spine disease, neck radiation.
- Look & measure (predictors of difficulty)
- Mallampati I–IV: tongue vs faucial pillars/uvula (III–IV ↑ difficulty).
- Mouth opening (inter-incisor): ≥3 cm (2–3 fingerbreadths) desirable.
- Thyromental distance (TMD): ≥6.5–7 cm; Sterno-mental ≥12–13 cm.
- Upper-lip bite test (mandibular protrusion): Class I easiest → III hardest.
- Neck mobility: flex–extend; limited extension ↑ difficulty.
- Dentition & facial features: loose teeth, micro/retrognathia, beard, large neck circumference (>40 cm).
- Predictors of difficult mask ventilation (DMV)
- Obesity, Beard, Edentulous, Age>55, Snoring/OSA, poor jaw protrusion.

Pre-op Airway Assessment & Risk Stratification 2

Risk tools

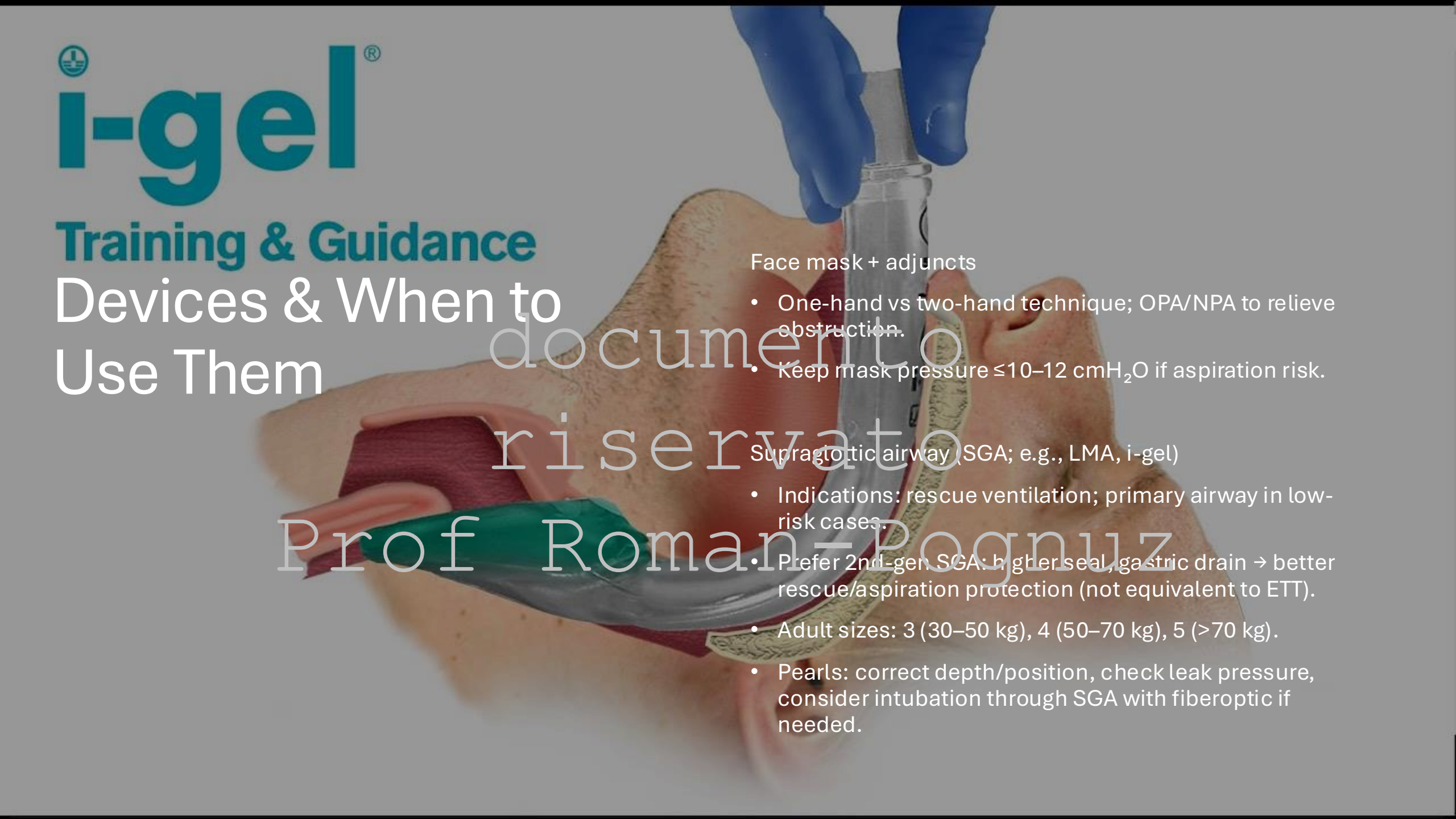
- LEMON (Look–Evaluate–Mallampati–Obstruction–Neck).
- MACOCHA (ICU): Mallampati III/IV, Apnea (OSA), Cervical limitation, Opening mouth <3 cm, Coma, Hypoxia, Non-anesthesiologist.

Preparation & positioning

- Plan A–B–C–D declared (primary, backup, wake/awake FOI, eFONA).
- Ramped/head-elevated (external auditory meatus aligned with sternal notch).
- Two IVs if high-risk; suction; video laryngoscope available; cric kit visible.
- Preoxygenation (denitrogenation)
- 100% O_2 via tight mask 3–5 min (or 8 vital-capacity breaths); aim EtO_2 ≥0.8.
- Consider apneic oxygenation (nasal O_2 10–15 L/min) for RSI/difficult airway.

DEVICES FOR VENTILATION

Prof Roman-Pognuz



Devices & When to Use Them

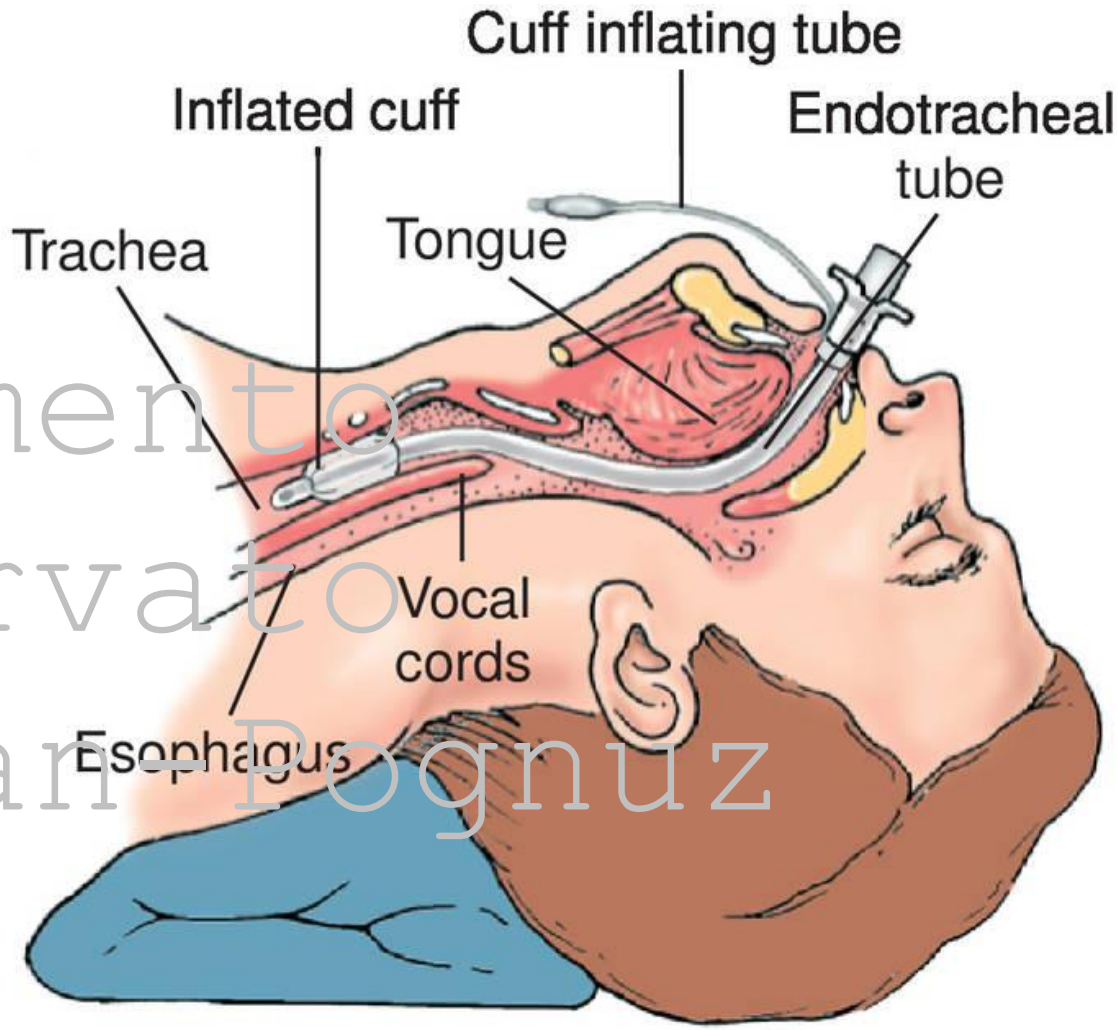
Face mask + adjuncts

- One-hand vs two-hand technique; OPA/NPA to relieve obstruction.
- Keep mask pressure ≤10–12 cmH_2O if aspiration risk.

Supraglottic airway (SGA; e.g., LMA, i-gel)

- Indications: rescue ventilation; primary airway in low-risk cases.
- Prefer 2nd-gen SGA: higher seal, gastric drain → better rescue/aspiration protection (not equivalent to ETT).
- Adult sizes: 3 (30–50 kg), 4 (50–70 kg), 5 (>70 kg).
- Pearls: correct depth/position, check leak pressure, consider intubation through SGA with fiberoptic if needed.

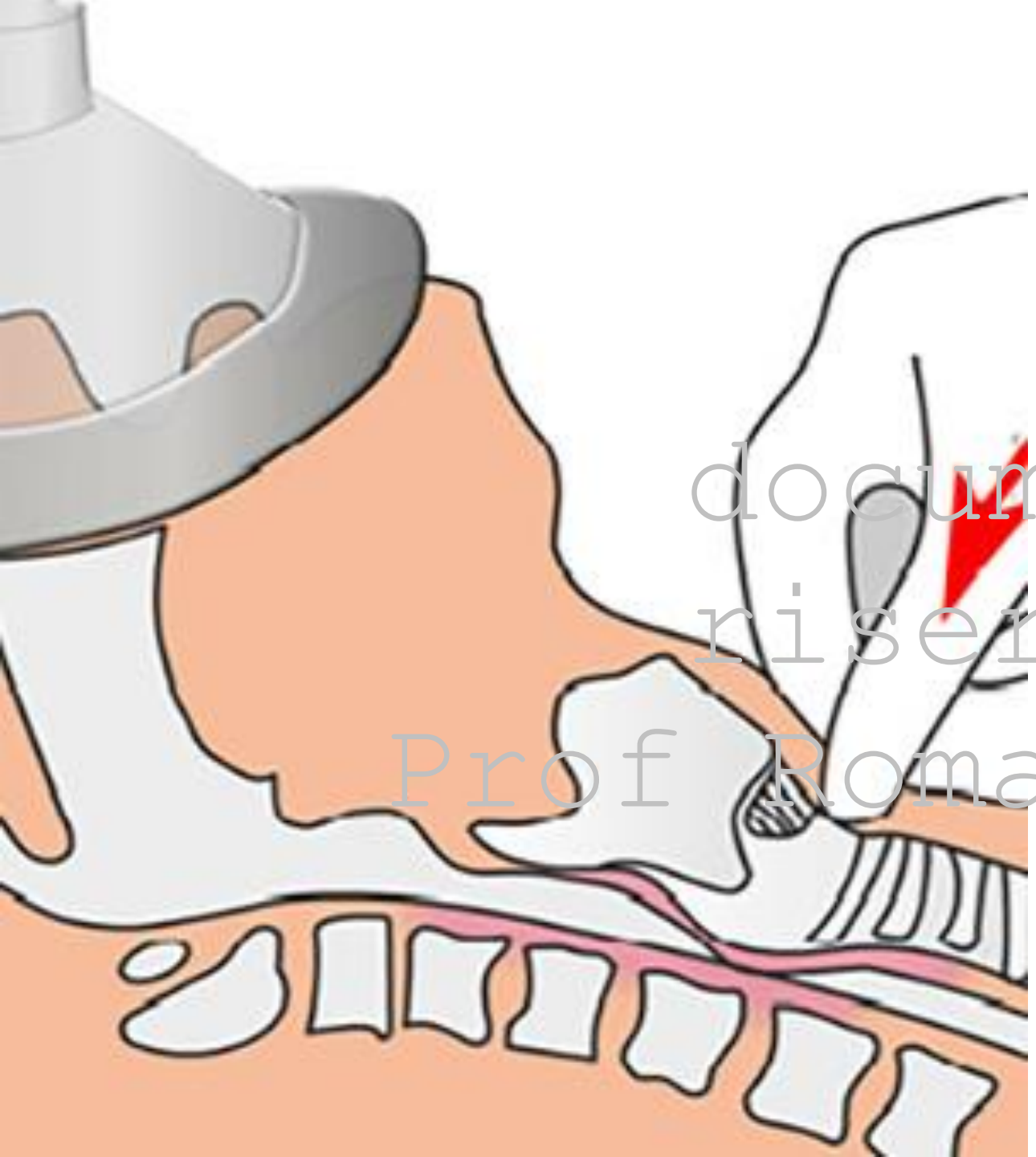
Endotracheal tube (ETT)



- Oral (standard) or nasal (smaller ID by 0.5–1.0 mm; lube + vasoconstrictor; beware epistaxis).
- Sizing (typical adults): women 7.0–7.5, men 7.5–8.5.
- Depth: ~21–23 cm at teeth (confirm with auscultation/POCUS + continuous capnography).
- Cuff pressure: 20–30 cmH_2O.

Visualization & aids

- Video laryngoscopy (often first-line): better glottic view, especially in predicted difficulty.
- Bougie/stylet: “bougie-first” for grade 2–3 views; feel tracheal clicks/hold-up.
- Flexible bronchoscope: awake or asleep; ideal through SGA or for distorted airways.



Strategies: Standard Sequence vs Rapid Sequence Induction (RSI)

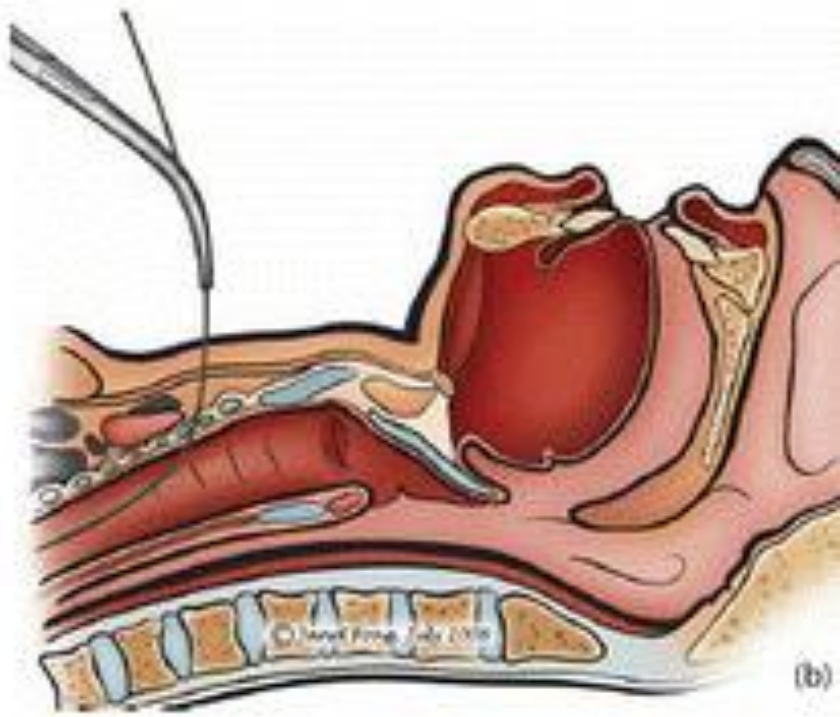
Standard sequence (low aspiration risk)

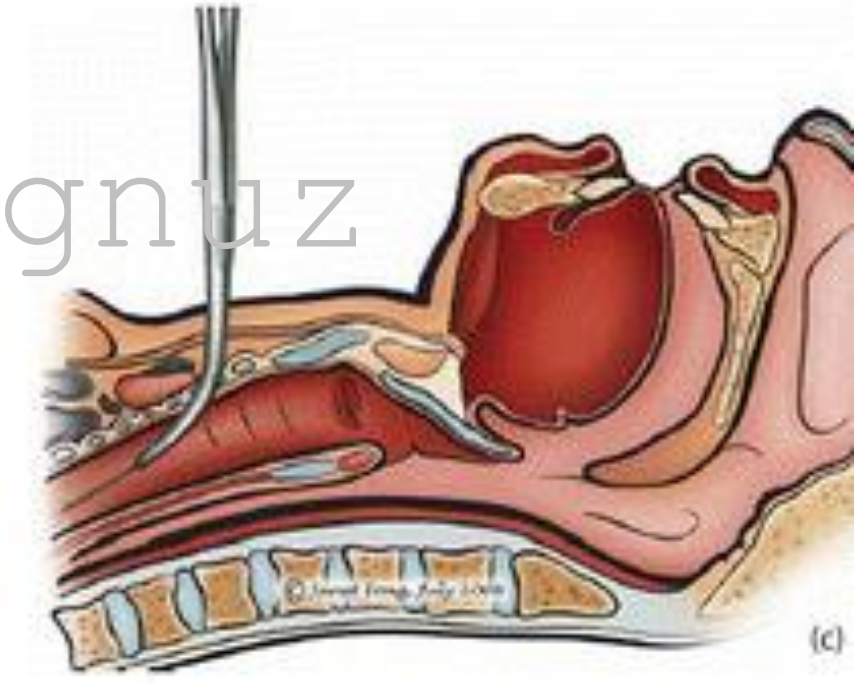
- Preoxygenate (EtO_2 ≥0.8).
- IV analgesic + hypnotic (e.g., fentanyl + propofol/etomidate/ketamine).
- Ensure mask ventilation is possible.
- Give NMBA (e.g., rocuronium 0.6–1.0 mg/kg).
- Laryngoscopy (video preferred), ETT/SGA, capnography confirmation.

- RSI (aspiration risk: full stomach, ileus, pregnancy >20 w, severe GERD, GI bleed, trauma)
- Preoxygenate thoroughly; consider nasal apneic O_2.
- Rapid hypnotic + full-dose NMBA (rocuronium 1.2 mg/kg or succinylcholine 1–1.5 mg/kg if no contraindications).
- No mask ventilation (or very gentle ≤10–12 cmH_2O if desaturating).
- Intubate at optimal relaxation; confirm with sustained $ETCO_2$ waveform.
- Cricoid pressure only if your institution mandates it and trained staff apply it correctly (may worsen view—be ready to release).

Tracheostomy

- Awake options (when losing the airway is dangerous)
- Awake video/fiberoptic intubation with topicalization (2–4% lidocaine), possible superior laryngeal + transtracheal blocks; light sedation (dexmedetomidine/remifentanil).
- Consider awake tracheostomy in extreme distortion/obstruction
- https://www.youtube.com/watch?v=YBZFIcIDhQw
- https://www.youtube.com/watch?v=njE3Qlkh044





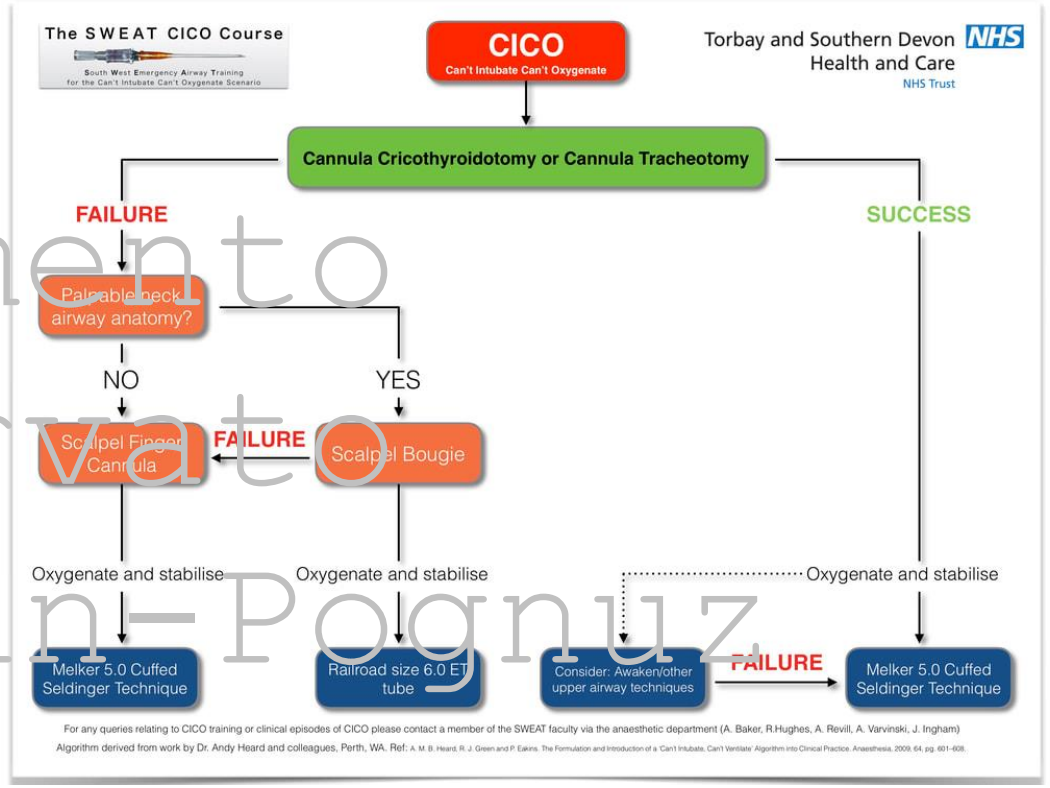
Rescue & “Can’t Intubate / Can’t Oxygenate” (CICO) Algorithm

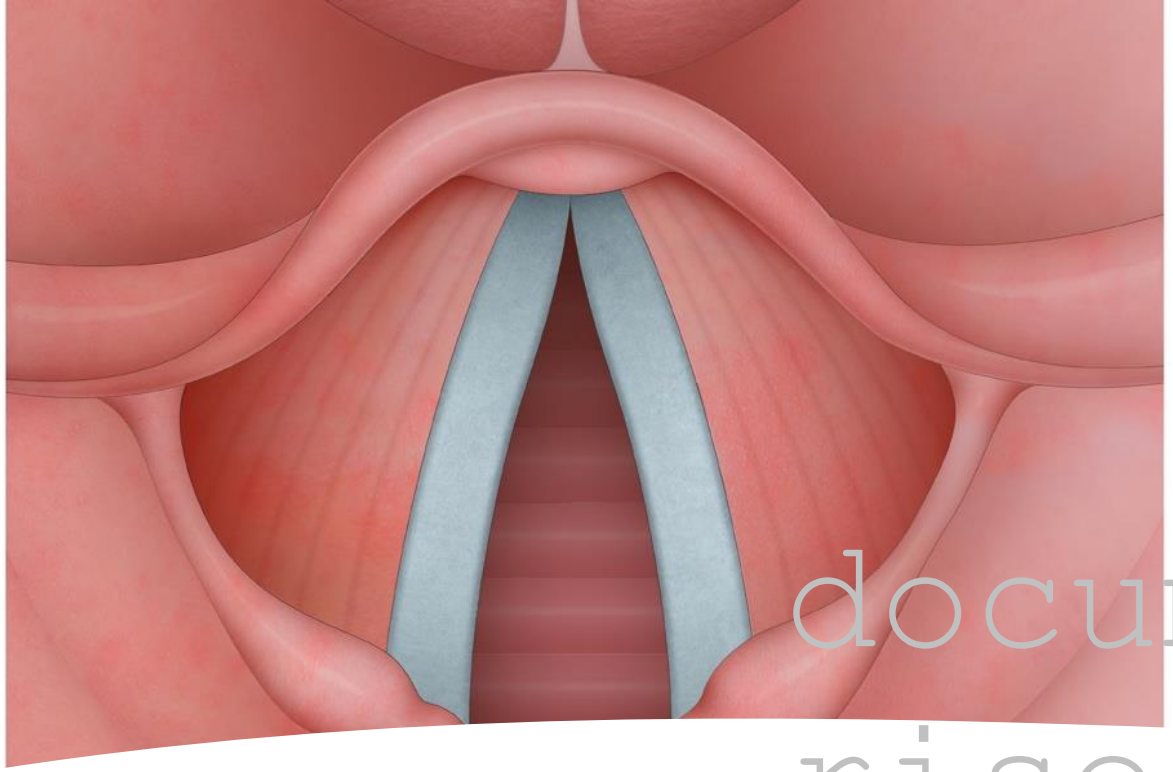
If laryngoscopy view poor (can ventilate)

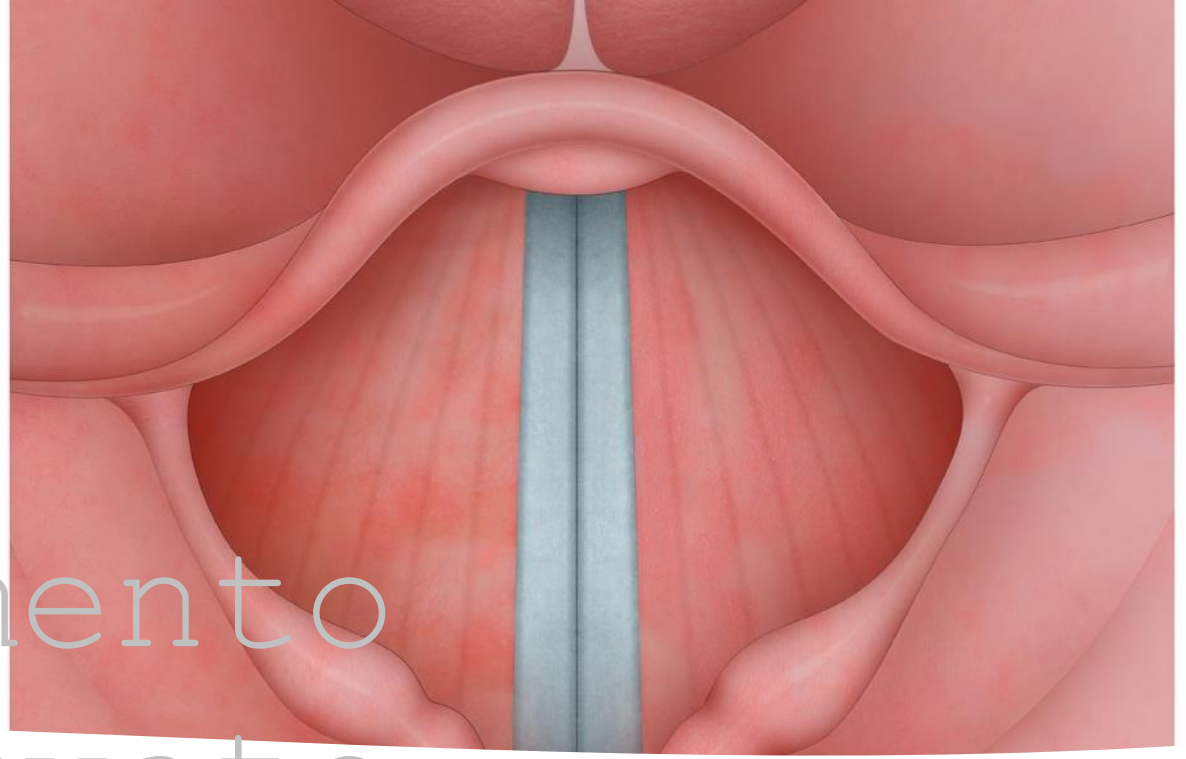
- Optimize position; external laryngeal manipulation; switch to video; smaller tube; bougie-first; alternate blade; call help early.
- If cannot intubate but can ventilate
- Insert 2nd-gen SGA for oxygenation/ventilation; consider fiberoptic-guided intubation through SGA.

If cannot intubate, cannot oxygenate (CICO) → EMERGENCY

- Call for help; 100% O_2; move to eFONA (Front-of-Neck Access):
- Scalpel–bougie–tube: vertical skin incision → horizontal cricothyroid membrane stab → bougie → 6.0 ETT over bougie → confirm with capnography.







Common intra-op airway events & fixes

Laryngospasm: jaw thrust + 100% O_2 + CPAP → deepen anesthesia (propofol) → succinylcholine 0.1–0.5 mg/kg IV (or 4 mg/kg IM) if persistent.

- Bronchospasm: deepen anesthetic (sevo/propofol/ketamine), inhaled β_2-agonist, consider epinephrine if severe.

Mainstem intubation: withdraw ETT 1–2 cm; re-auscultate/POCUS.

- Aspiration suspected: suction oropharynx, head-down/right side, oxygenate, apply PEEP as appropriate; manage hypoxemia; bronchoscopy if obstruction.
- Cuff leak/high cuff pressure: adjust to 20–30 cmH_2O; replace tube if persistent leak threatens ventilation.

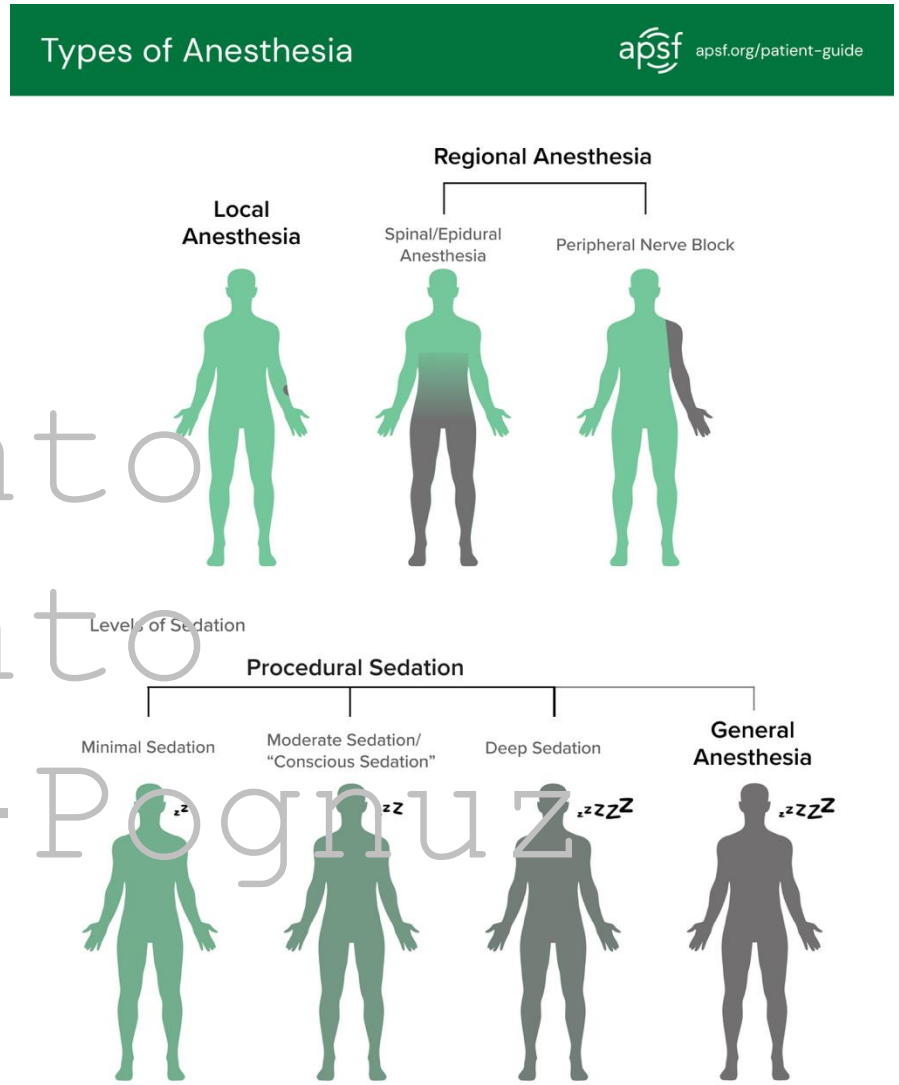
REGIONAL ANESTHESIA

What Regional Anesthesia Is (and where it fits)

Definition: Targeted, reversible interruption of nerve conduction using local anesthetics (LAs) at neuraxial (spinal/epidural/CSE) or peripheral (plexus/single nerve/fascial plane) sites.

- Goals: Analgesia ± surgical anesthesia; reduce stress response; enable ERAS pathways.
- Taxonomy (with examples):
- Neuraxial: spinal (subarachnoid), epidural, combined spinal-epidural.
- Upper limb: interscalene, supraclavicular, infraclavicular, axillary.
- Lower limb: femoral/adductor canal, sciatic (popliteal), IPACK.
- Truncal/Chest: paravertebral, PECS I/II, serratus plane, ESP, TAP.

When to choose RA: Ortho, thoracic, abdominal, breast, rib fractures; high opioid-risk pts (OSA/frail), when early mobilization is desired.



Why Regional? (Benefits you can explain to patients & surgeons)

- Superior analgesia vs systemic opioids → lower pain scores, improved patient satisfaction.
- Opioid sparing → ↓ PONV, pruritus, ileus, respiratory depression—especially valuable in OSA/elderly.
- Improved physiology: less catecholamine surge, better pulmonary mechanics (rib fractures / thoracotomy), ↓ ileus (abdomen).
- Faster milestones: earlier mobilization, participation in PT, potential ↓ LOS and complications in ERAS.
- Procedural advantages: smoother emergence, lower anesthetic requirements, better hemodynamic stability in selected cases.
- Caveat: Benefit is technique- and execution-dependent; use the right block, dose, and catheter plan.

How to Do It (setup, imaging, injection safety)

- Asepsis & monitoring: full skin prep (chlorhexidine), sterile probe cover/gel, mask/cap/gloves; standard monitors; IV access; resuscitation drugs + lipid emulsion in room.
- Patient communication: explain benefits/risks; maintain light sedation so the patient can report paresthesias/pain.

Ultrasound (first-line):

- Probe choice: linear (10–15 MHz) for superficial; curvilinear (2–5 MHz) for deep.
- Technique: in-plane (see shaft + tip) or out-of-plane (track the tip carefully); hydrodissection to open fascial planes; seek circumferential spread.
- Needle: echogenic (80–100 mm for deep blocks).
- Nerve stimulation (adjunct): 0.3–0.5 mA motor response is acceptable; <0.2 mA raises intraneural concern—withdraw.
- Injection pressure monitoring: keep opening injection pressure < 15 psi (if high → stop, reposition).
- Fractionated injection: aspirate every 3–5 mL, inject incrementally, reassess spread and patient symptoms continuously.
- Test dose (neuraxial/epidural): low-dose lidocaine + epinephrine to detect intrathecal/intravascular placement (per institutional policy).

Local Anesthetics: choices, doses, adjuvants (the practical table in prose) 1

Common LAs & profiles

- Lidocaine 1–2%: fast onset, short–intermediate duration (infiltration/IVRA/short blocks).
- Bupivacaine 0.25–0.5%: slower onset, long duration (dense sensory; caution cardiotoxicity).
- Ropivacaine 0.2–0.5%: long duration, motor-sparing at lower % (good for analgesic infusions).
- Mepivacaine 1–1.5%: fast onset, intermediate duration (diagnostic/short procedures).
- Typical single-shot concentrations (examples; tailor to block & patient):
- Interscalene: 0.5% ropi 10–15 mL (or 0.25% 15–20 mL analgesic-biased).
- Adductor canal: 0.2–0.375% ropi 15–20 mL (motor-sparing).

Local Anesthetics: choices, doses, adjuvants (the practical table in prose) 2

TAP/ESP: 0.25–0.375% ropi or bupi 20–30 mL per side/level.

Maximum dose guides (approx., adults):

Lidocaine: 4.5 mg/kg (max ~300 mg); with epi up to 7 mg/kg (max ~500 mg).

Bupivacaine: 2.5 mg/kg (max ~175 mg); with epi ~3 mg/kg (max ~225 mg).

Ropivacaine: ~3 mg/kg (commonly max 200–250 mg). (Always correct for frailty, pregnancy, blocks with high vascular uptake, and cumulative mixtures.)

Adjuvants:

Epinephrine (1:200k–1:400k) ↓ systemic uptake, marker for intravascular injection.

Dexmedetomidine (perineural 25–50 µg) or clonidine (30–150 µg) may prolong block (watch for bradycardia/hypotension).

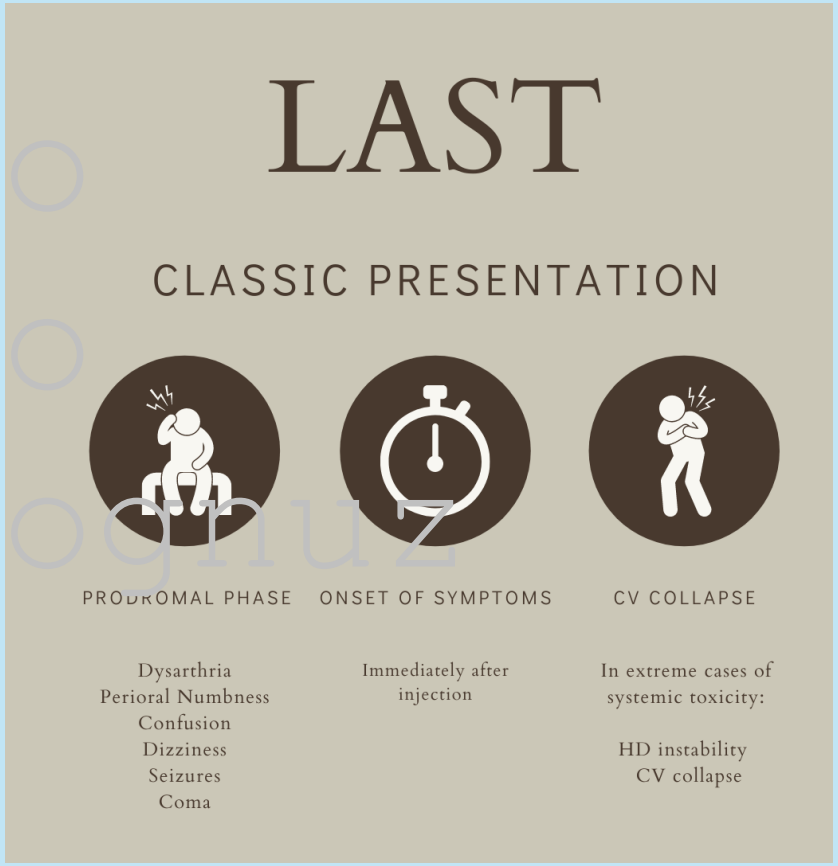
Dexamethasone 4–8 mg IV (or 2–4 mg perineural, off-label) extends duration; consider glycemic impact.

Continuous catheters: securement + sterile dressing; ropivacaine 0.1–0.2% at 5–8 mL/h (bolus 3–5 mL PRN); daily site checks.

Safety: complications you must name (and how to handle them)

Local Anesthetic Systemic Toxicity (LAST)

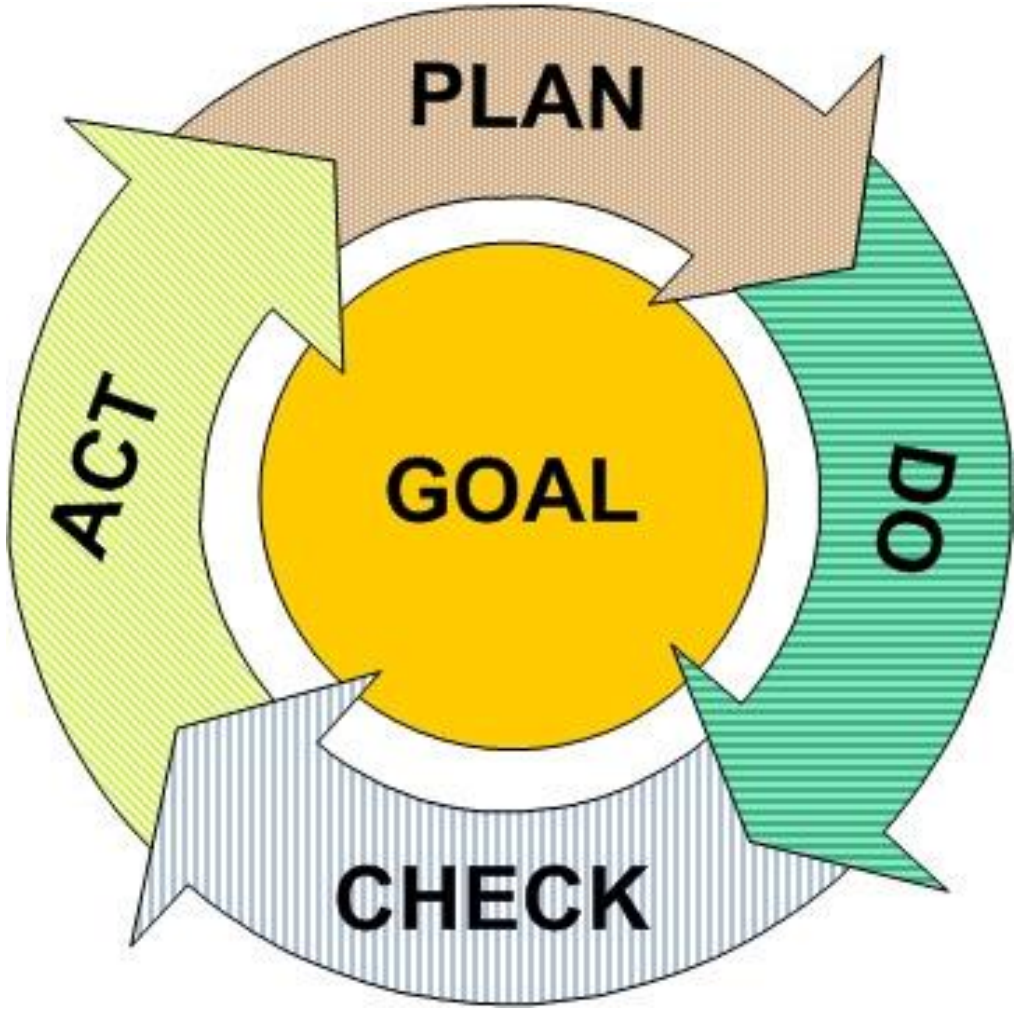
- Early signs: circumoral numbness, tinnitus, metallic taste, agitation; then seizures, ↓LOC; CV: arrhythmias, hypotension, cardiac arrest.
- Immediate actions: STOP injection, call help, airway/oxygen/ventilation, treat seizures (benzodiazepine), avoid large propofol doses if unstable.
- Lipid rescue (20%): Bolus 1.5 mL/kg, then 0.25 mL/kg/min infusion; repeat bolus x2 for persistent instability; increase infusion to 0.5 mL/kg/min if needed; continue ~10 min after stability; max ≈ 10–12 mL/kg.



- Nerve injury: avoid intraneural injection (monitor pressure, US tip visualization, paresthesia/pain on injection); document baseline neuro exam; most deficits are transient—arrange follow up.
- Hematoma/bleeding: compressible sites safer; avoid deep blocks in coagulopathy.
- Infection: strict asepsis; higher risk with catheters → daily inspection, remove if erythema/fever/pus.
- Neuraxial specific: hypotension/bradycardia (treat with vasopressor/fluids), high/total spinal (support airway/ventilation, vasopressors), PDPH after dural puncture (epidural blood patch if symptomatic).
- Phrenic nerve paresis (interscalene): counsel dyspneic/resp-limited patients; consider suprascapular + axillary or low-volume/more distal approaches.

Contraindications, Anticoagulation & Must-do Checks

- Absolute contraindications (most RA): patient refusal, active infection at site, true LA allergy.
- Neuraxial specific absolute: raised ICP with mass lesion, uncorrected hypovolemia/shock, untreated coagulopathy.
- Relative contraindications: bacteremia/sepsis (individual risk), severe aortic/mitral stenosis (sympathetic block risk), pre-existing neuro deficits (document), distorted anatomy.
- Anticoagulation/antiplatelets (principles; follow latest ASRA/ESAIC + local policy):
- Aspirin/NSAIDs: usually not a contraindication to single-shot peripheral blocks or neuraxial alone, but combine therapies raise risk.
- Clopidogrel/Prasugrel/Ticagrelor: hold 5–7 days before neuraxial; avoid catheters until drug off; peripheral deep blocks often treated as neuraxial-equivalent risk in many centers.
- LMWH: prophylactic → wait ≥12 h (therapeutic ≥24 h) before neuraxial; after catheter removal, delay next dose (usually ≥4 h).
- DOACs (apixaban, rivaroxaban, dabigatran): hold 2–4+ days depending on dose & renal function before neuraxial/deep block; resume ≥24 h after needle/catheter removal.
  (Times vary—check current guideline tables and institutional rules.)
- Non-negotiables: Informed consent (benefits/risks/alternatives), anticoagulation review, baseline neuro exam, timeout and side marking, full resus kit + lipid 20% available.



SPINAL

Core Concept, Indications & Block Height Targets Spinal Anesthesia (Subarachnoid)

What it is: Injection of local anesthetic (LA) into CSF at L2–L3/L3–L4/L4–L5 → rapid, dense sensory ± motor block with a finite duration.

Primary goals: Surgical anesthesia (below umbilicus) and/or superior postoperative analgesia (with intrathecal opioids).

- Common indications (with typical target dermatome)
- Cesarean section → T4 (nipples)
- Lower abdominal (e.g., hernia, pelvic) → T6–T8
- Urology (TURP/TURBT) → T10
- Hip/knee/foot & ankle → T10–L1 (hip often higher than knee/foot)
- Perineal/hemorrhoids → S2–S4

Absolute advantages

- Fast onset, dense block, minimal drug quantities, less PONV/opioids, excellent operating conditions.
- Key dermatomes to remember
- T4 nipples, T6 xiphoid, T10 umbilicus, L1 inguinal, S2–S5 perineum.

https://www.youtube.com/shorts/PowhNibzN9I

Anatomy, Equipment & Step-by-Step Technique

Anatomy checkpoints

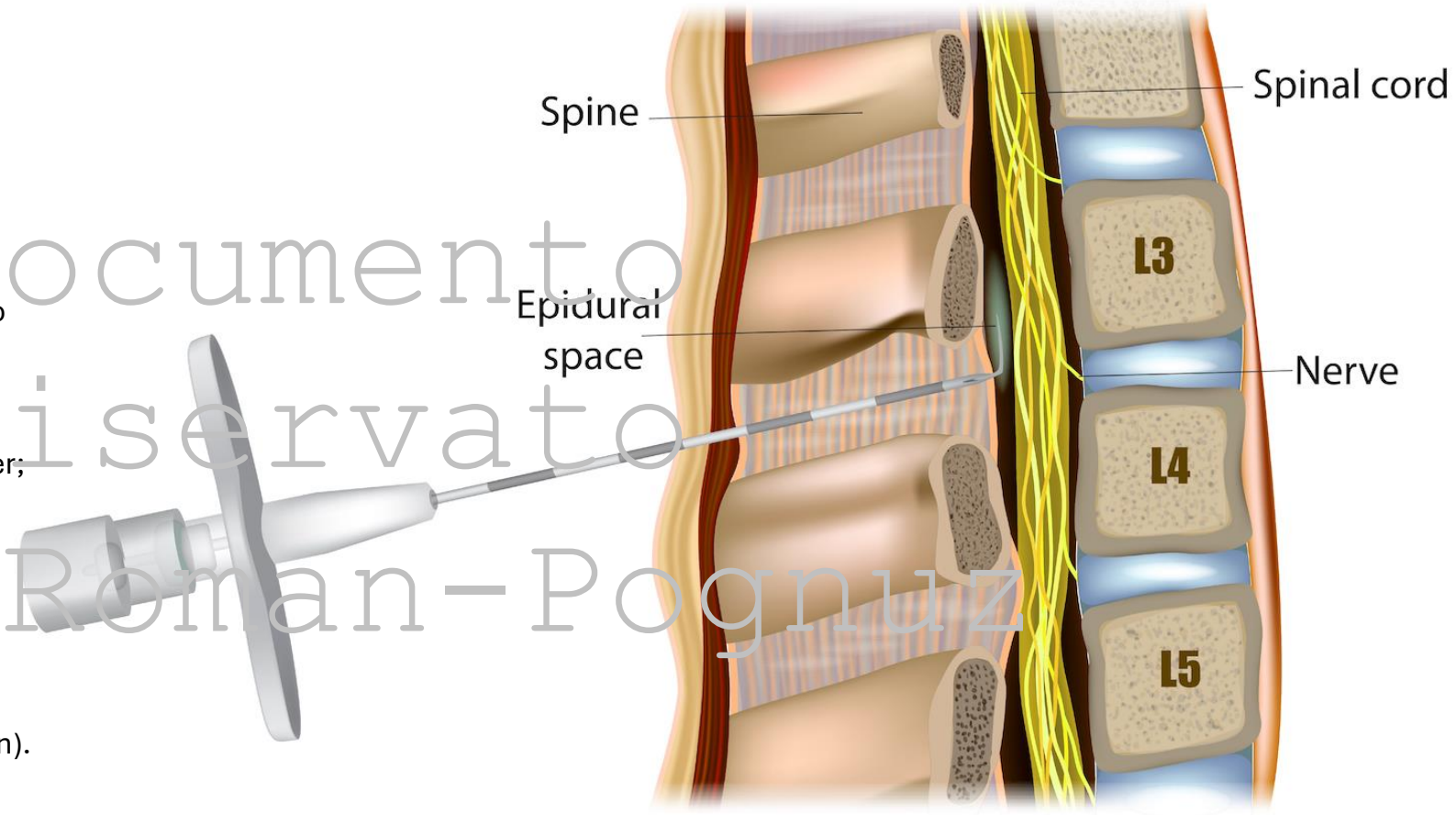
- Adult cord ends at ~L1 → aim below L2 (L3–4 or L4–5; Tuffier's line ≈ L4).
- Layers (midline): skin → subcut → supraspinous → interspinous → ligamentum flavum → epidural space → dura/arachnoid → CSF.

Equipment

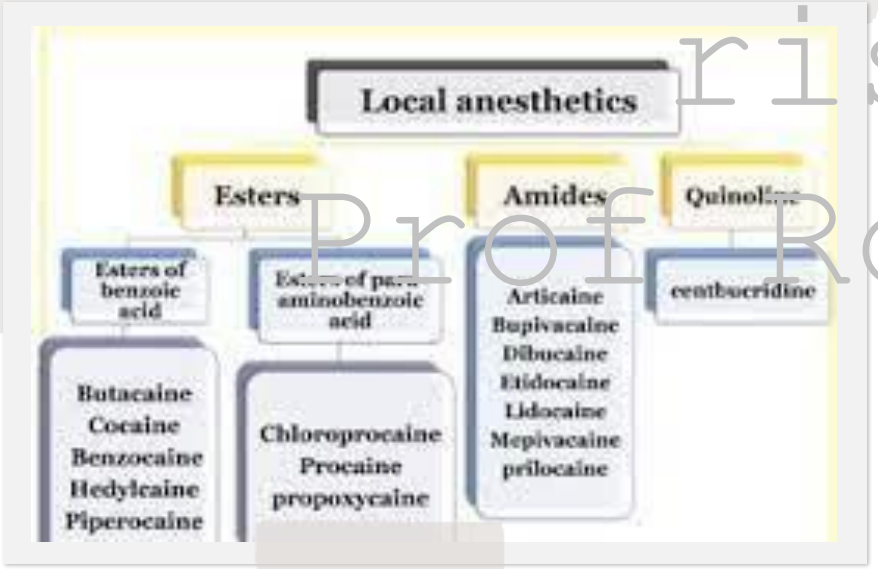
- Sterile prep (chlorhexidine), drape, mask/cap/gloves.
- Pencil-point needle (Whitacre/Sprotte) 25–27G + introducer (↓PDPH vs Quincke).
- LA syringes; optional intrathecal adjuvants (opioids).
- Standard monitors; IV access; resuscitation drugs + 20% lipid in the room.

Technique (midline; sitting or lateral)

- Position sitting (flexed, “angry cat”) or lateral (knees to chest).
- Identify interspace; local infiltration.
- Advance introducer → spinal needle through introducer; feel “pops” (ligamentum flavum, dura).
- CSF flow confirmation → aspirate gently (clear, free-flowing) → inject slowly (no pain/paresthesia).
- Remove needle, lay patient immediately; position to direct spread (see Slide 4).
- Start hemodynamic vigilance (q1–2 min for first 10 min).
- Paramedian approach helpful in elderly/calcified ligaments: 1–2 cm lateral, aim medially/cephalad.



Drugs, Doses, Baricity & Adjuvants (Intrathecal)



Local anesthetics (common)

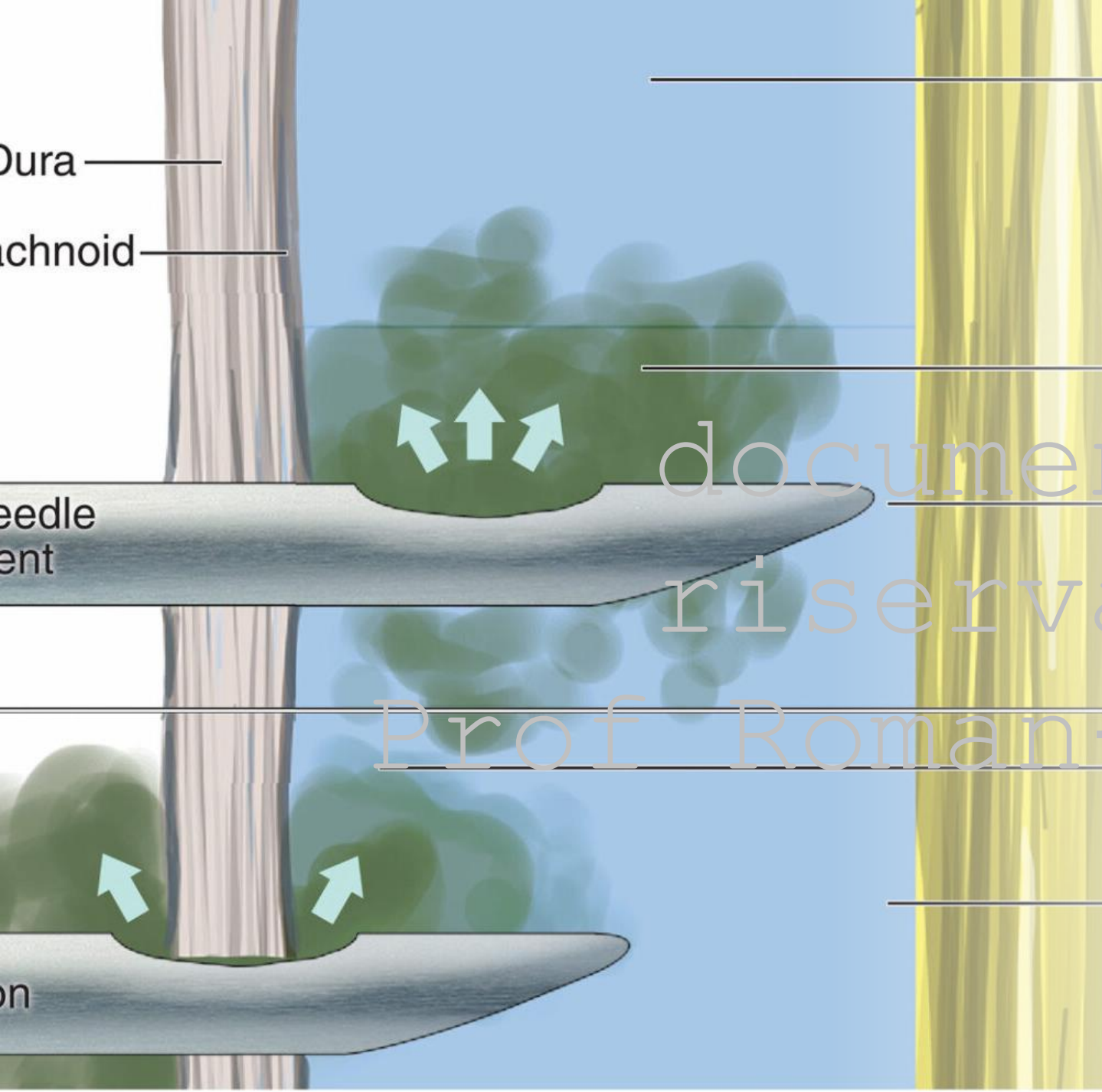
- Bupivacaine 0.5% hyperbaric (“heavy,” in dextrose) or isobaric (“plain”)
- Dose ranges (adults, single-shot):
- Cesarean: 10–12.5 mg (often with opioids)
- Lower abd/T6–T8: 12–15 mg
- T10 targets (TURP/LL ortho): 7.5–12 mg (elderly often need lower dose)
- Duration: ~90–150 min surgical anesthesia (longer sensory than motor).
- Chloroprocaine (preservative-free) 2–3%: 30–60 mg for short cases (30–60 min).
- Tetracaine 0.5% (heavy): 5–15 mg for very long cases (less common now).
- Lidocaine (intrathecal): historical (TNS risk with 5% heavy); modern practice largely avoids.

Baricity (drives spread with gravity)

- **Hyperbaric** (heavier than CSF; in dextrose): settles **dependent**; you can "steer" with tilt.
- **Isobaric** (≈ CSF): more position-independent spread; slower cephalad spread.
- **Hypobaric** (lighter): rare elective use (e.g., perianal in jackknife).

Intrathecal adjuvants

- **Fentanyl 10–25 µg** → faster onset, better intra-op comfort.
- **Morphine 100–200 µg** → **12–24 h** analgesia (watch **delayed respiratory depression**—monitor for ≥12 h per local policy).
- **Clonidine 15–45 µg (off-label)** → prolongs block; risks **hypotension/sedation**.
  (Avoid preservatives; use spinal-approved ampoules only.)



Factors Affecting Block Height & Practical Positioning

Determinants of spread

- Dose (mg), baricity, volume, injection speed, CSF volume.
- Patient factors: pregnancy (↓ CSF volume → higher spread → use lower dose), elderly (↓CSF), obesity (compression), height (minor effect).

Positioning:

- Hyperbaric: cephalad with Trendelenburg, caudad with reverse Trendelenburg.
- Isobaric: less position-sensitive; slower cephalad spread.
- Unilateral block: lateral position with operative side down during/after injection of hyperbaric solution.

Hemodynamic Physiology, Prophylaxis & Treatment

- **Why hypotension/bradycardia happen**
- Sympathetic block (T1–L2) → **venodilation & ↓SVR**; high thoracic spread may block **cardioaccelerator (T1–T4)** and trigger **Bezold–Jarisch reflex** (bradycardia + hypotension + nausea).
- **Prevention (modern approach)**
- **Co-load** crystalloids (e.g., 500–1000 mL) at time of spinal; **pre-load alone is insufficient**.
- **Vasopressor-first** mindset in high-risk/OB:
  - **Phenylephrine** infusion **25–50 µg/min** (or bolus **50–100 µg**) titrated to **MAP ≥65 mmHg** (or SBP within 10% of baseline).
  - **Norepinephrine 2–5 µg** boluses or **0.02–0.05 µg/kg/min** infusion if bradycardic/vasodilatory hypotension.
- Left uterine displacement in **pregnancy**.

1

Assess level (is it rising?) + airway/oxygen; place A-line if unstable/prolonged.

2

MAP low, HR normal/high → Phenylephrine 50–100 µg IV (repeat/titrate).

3

MAP low, HR low → Ephedrine 5–10 mg IV or norepinephrine 5–10 µg IV; consider atropine 0.5 mg if vagal.

4

Fluids: small balanced boluses (250 mL) if hypovolemia suspected; avoid overload.

5

Reassess every 1–2 min initially; adjust table tilt (reduce Trendelenburg if block is creeping too high).

Treatment algorithm

Complications, Contraindications & High/Total Spinal Rescue

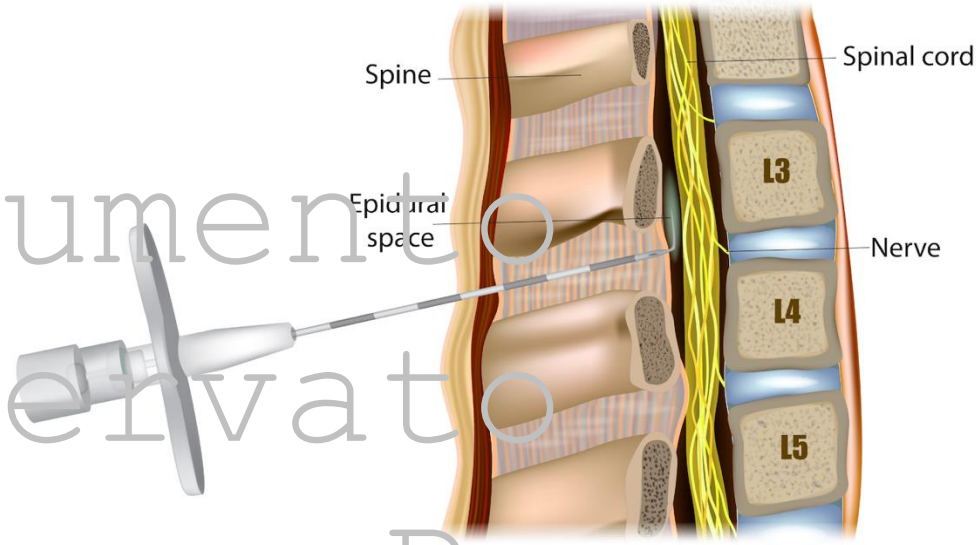
Common/important complications

- PDPH (post-dural puncture headache): orthostatic, occipital/neck; ↑ with young women, large cutting needles; ↓ with 25–27G pencil-point.
- Tx: hydration, caffeine/acetaminophen/NSAIDs, sphenopalatine ganglion block (optional), epidural blood patch (15–20 mL) if persistent/severe.
- High/total spinal (rare): rapidly rising numbness/weak arms → dyspnea → apnea, profound hypotension/bradycardia.
- Rescue: Call help; 100% O_2; bag-mask/ventilate → intubate if needed; vasopressors (phenylephrine/norepinephrine), ephedrine if bradycardic; maintain until block regresses.
- Nausea/vomiting: often hypotension-mediated → treat BP; give antiemetics.
- Urinary retention: monitor; catheter if necessary.
- Rare: infection (meningitis), hematoma (neurologic emergency), nerve injury, TNS (historically with intrathecal lidocaine).

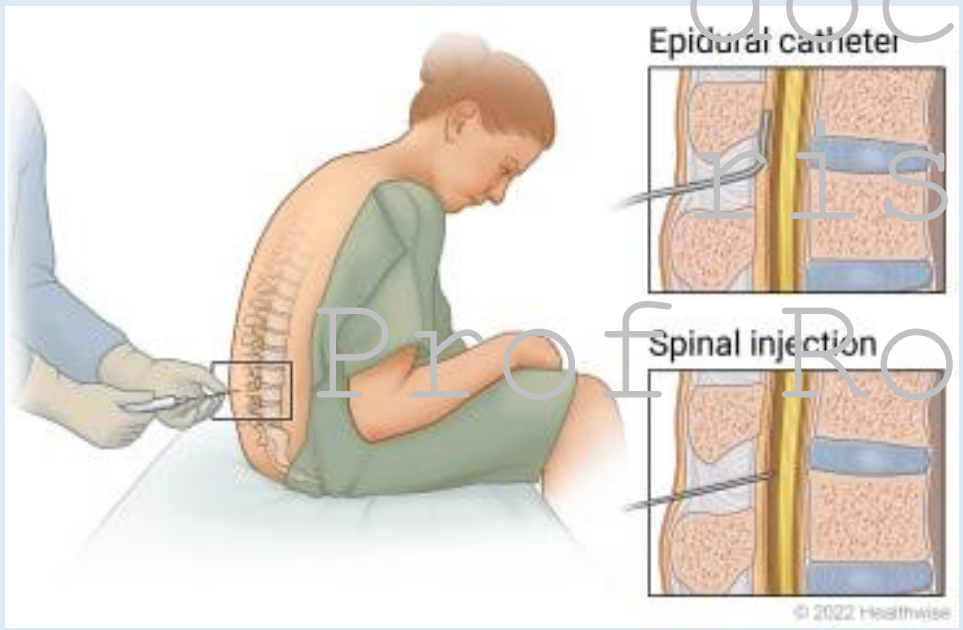
Contraindications (checklist)

- Absolute: patient refusal, infection at puncture site, true LA allergy, uncorrected hypovolemia/shock, increased ICP from mass lesion, major coagulopathy/therapeutic anticoagulation (follow current ASRA/ESAIC & institutional timing tables).
- Relative: bacteremia/sepsis, severe aortic/mitral stenosis (sympathectomy risk), pre-existing neuro deficits (document), spinal deformity/previous surgery.
- Obstetric specifics
- Dose reduction (↓CSF volume/pregnancy), routine vasopressor prophylaxis, left tilt for aortocaval compression; intrathecal morphine 100–200 µg → monitor 12–24 h for late respiratory depression.
- Documentation (non-negotiable)
- Consent (risks/benefits/alternatives), anticoagulation review, approach/space/needle size, drug names/doses/baricity, achieved level, hemodynamics/vasopressors, complications and management.

EPIDURAL



What an Epidural Is & When to Use It



Definition

- Injection of local anesthetic (± adjuvants) into the epidural space, usually via catheter, enabling continuous titration of segmental sensory ± motor block.
- Where it helps (examples)
- Thoracic: thoracotomy, sternotomy, rib fractures (improves ventilation & cough).
- Abdominal: open/laparoscopic major bowel, AAA, upper abdominal cancer surgery (attenuates ileus & stress).
- Obstetrics: labor analgesia, cesarean (as surgical anesthesia with adequate dosing).
- Major orthopedics: bilateral TKAs/hip revisions (analgesia; note: many centers now prefer peripheral catheters for motor-sparing).

Why choose an epidural

- Adjustable level & duration, excellent analgesia, opioid sparing (↓PONV, ileus, resp depression), ERAS-friendly.
- Enables hemodynamic modulation (thoracic epidural blunts sympathetic response).
- https://www.youtube.com/watch?v=_mE-rTnb3qE

Anatomy, Equipment & Technique (Step-by-Step)

Key anatomy

- Space runs from foramen magnum to sacral hiatus; bordered by ligamentum flavum posteriorly & dura anteriorly.
- Thoracic epidural is narrower; paramedian approach often easier than midline.
- Equipment & prep
- Full monitors, IV access, resuscitation drugs + lipid 20% present.
- Sterile prep: chlorhexidine (allow to dry), mask/cap/sterile gloves, drape.
- Tuohy needle 17–18G, epidural catheter (multi-orifice preferred), sterile saline for loss-of-resistance (LOR) (saline > air).

Technique (lumbar/thoracic)

- Position: sitting (flexed) or lateral decubitus; identify interspace (US pre-scan helpful).
- Advance Tuohy until LOR to saline (often 4–6 cm lumbar; shallower thoracic).
- Thread catheter 3–6 cm into space (thoracic often 3–4 cm; lumbar 4–6 cm).
- Negative aspiration; test dose (see Slide 5).
- Incremental dosing with frequent aspiration & communication.

Drugs, Doses & Adjuvants (Initial & Top-Up)

Local anesthetics (typical choices)

- Bupivacaine 0.0625–0.25% (denser motor at higher %).
- Ropivacaine 0.1–0.5% (slightly less motor block → good for analgesia/ambulation).
- Lidocaine 1–2% (rapid onset; shorter duration; surgical top-ups).
- Chloroprocaine 2–3% (short surgical cases; rapid offset).

Rule of thumb (segmental spread)

- ~1–2 mL per dermatome targeted; thoracic injections spread more cephalad-caudal per mL than lumbar.

Drugs

- Example initial doses (titrate to effect, in 3–5 mL increments)
- Thoracic analgesia (rib/upper abd): ropi 0.1–0.2% 5–10 mL → then assess; add opioid (e.g., fentanyl 2–5 µg/mL).
- Lumbar analgesia (hip/knee): ropi 0.1–0.2% 5–10 mL.
- Surgical anesthesia through epidural: bupi 0.5% 10–20 mL slowly (or ropi 0.5% similar) — check BP closely.
- OB labor loading: ropi 0.1–0.2% 8–10 mL + fentanyl 2 µg/mL (or sufentanil 0.5–1 µg/mL).
- Adjuvants (per infusion)
- Opioids: fentanyl 1–5 µg/mL, sufentanil 0.5–1 µg/mL → improve analgesia, ↓LA dose
- Epinephrine: 1:200,000 (5 µg/mL) ↓ systemic uptake (use case-by-case).
- Clonidine low-dose can prolong block (sedation/hypotension risk).

Maintenance Strategies: CEI, PIEB & PCEA

Continuous epidural infusion (CEI)

- Typical rates: 6–10 mL/h (analgesia concentrations).
- Pros: simple; Cons: risk of ropivacaine/bupivacaine creep → motor block.
- Programmed Intermittent Epidural Bolus (PIEB)
- e.g., 3–6 mL every 20–40 min (smart pump), often + PCEA.
- Pros: better spread, lower LA use & less motor block vs CEI in labor; often superior patient satisfaction.

Patient-Controlled Epidural Analgesia (PCEA)

- Bolus 3–5 mL, lockout 10–20 min, background CEI 0–6 mL/h or PIEB.
- Titrate to sensory goal (dermatomes) with motor sparing (especially in ERAS/OB).
- Typical OB maintenance recipe (examples)
- Ropi 0.1–0.125% + fentanyl 2 µg/mL; PIEB 4 mL q30 min + PCEA 5 mL, lockout 15 min.
- Aim: pain ≤3/10, Bromage 0–1 (can straight-leg raise).
- Post-op thoracic epidural
- Ropi 0.1–0.2% + fentanyl 2–5 µg/mL at 6–10 mL/h; wean day 2–3 as ileus/pain improve.

Test Dose, Safety Checks & Troubleshooting Patchy Blocks

Test dose (after negative aspiration)

- Common: 3 mL lidocaine 1.5% + epinephrine 1:200,000 (≈ 45 mg lido + 15 µg epi).
- Intravascular → HR rise ≥20 bpm within 30–60 s (caution in labor/preeclampsia/beta-blockers).
- Intrathecal → rapid motor block of legs within a few minutes.
- OB variant: some avoid epinephrine; use fractionated dosing + careful observation.
- Patchy or unilateral block — fixes
- Catheter manipulation: withdraw 1 cm (or advance 1 cm), then re-bolus 5 mL.
- Positioning: place patient on the non-blocked side down for 10–15 min; use PIEB.
- Volume & level: switch to larger volume, lower concentration for better spread; use multi-orifice catheter.
- If persistent failure: replace catheter at a different level.

Subdural block (important mimic)

- Clues: delayed onset, extensive sensory spread with minimal motor & relative hemodynamic stability; respiratory compromise if very high.
- Action: stop dosing; support airway; convert plan if surgery imminent; document.

Hemodynamics, Complications & Red Flags

Hemodynamics

- Sympathetic block → ↓SVR & venous pooling (more with higher thoracic volumes).
- Prevention: preload/co-load judiciously, vasopressor ready (phenylephrine bolus 50–100 µg or infusion; norepinephrine bolus 5–10 µg if bradycardic/vasodilated).
- Treatment: identify cause (depth/bleeding/level), adjust table, small fluid bolus (250 mL) if needed, vasopressor first mindset in high-risk.

Complications

- Intravascular injection / LAST: tinnitus, perioral numbness, seizures → lipid 20% (1.5 mL/kg bolus, then 0.25 mL/kg/min; repeat bolus ×2 as needed; max ≈ 10–12 mL/kg).
- Inadvertent dural puncture ("wet tap") → PDPH risk; consider intrathecal catheter management per policy vs remove & epidural blood patch later if symptomatic.
- High neuraxial block (if large dose intrathecal): dyspnea → apnea, hypotension/bradycardia → oxygenate/ventilate, vasopressors, support until regression.
- Epidural hematoma/abscess (rare, but critical)

Red flags: new or progressive motor block, new severe back pain, fever, radicular pain, bowel/bladder dysfunction.

- **Action: STOP infusion, urgent MRI and neurosurgery consult; decompression ideally <8–12 h from neuro deficit onset.**

Contraindications, Anticoagulation Timing & OB Notes

Absolute contraindications

- Refusal, infection at site, true LA allergy, uncorrected hypovolemia/shock, severe coagulopathy/anticoagulation not appropriately held.

Relative

- Bacteremia/sepsis, severe aortic/mitral stenosis (sympathectomy risk), raised ICP from mass lesion (for epidural bolus caution), pre-existing neuro disease (document baseline), anatomic distortion/spinal surgery.
- Anticoagulation/antiplatelets (principles — follow current ASRA/ESAIC + local policy)
- LMWH prophylactic: wait ≥12 h before insert/remove; next dose ≥4 h after removal.
- LMWH therapeutic: wait ≥24 h before insert/remove.
- DOACs (apixaban/rivaroxaban/dabigatran): hold 2–4+ days (depend on renal function/dose).
- Clopidogrel/prasugrel/ticagrelor: hold 5–7 days before neuraxial; avoid catheter with active therapy.
- Warfarin: INR ≤1.4 for placement; verify daily if catheter in situ.
- UFH IV: stop 4–6 h, verify normal aPTT. (Prophylactic SQ heparin: coordinate timing with insertion/removal.)

BLOCKS

PNBs: Concepts, Benefits & Safety Guardrails

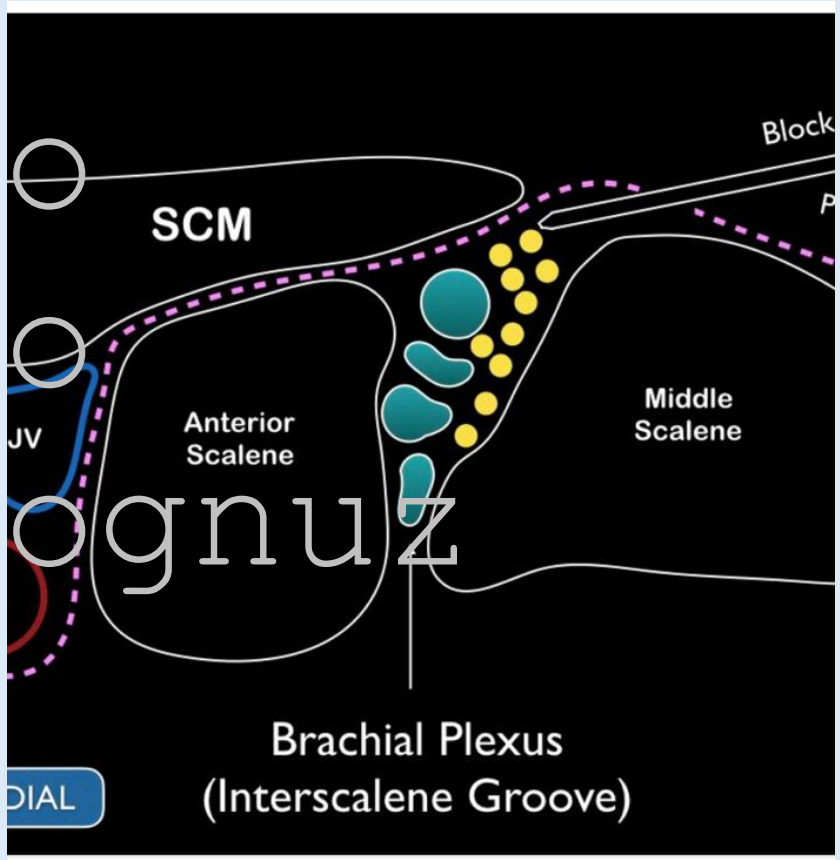
- What: Targeted, reversible blockade of peripheral nerves/plexuses with local anesthetic (LA); single-shot or continuous catheter.
- Why: Superior analgesia, opioid-sparing (↓PONV/resp depression), better rehab/early mobilization, smoother emergence.

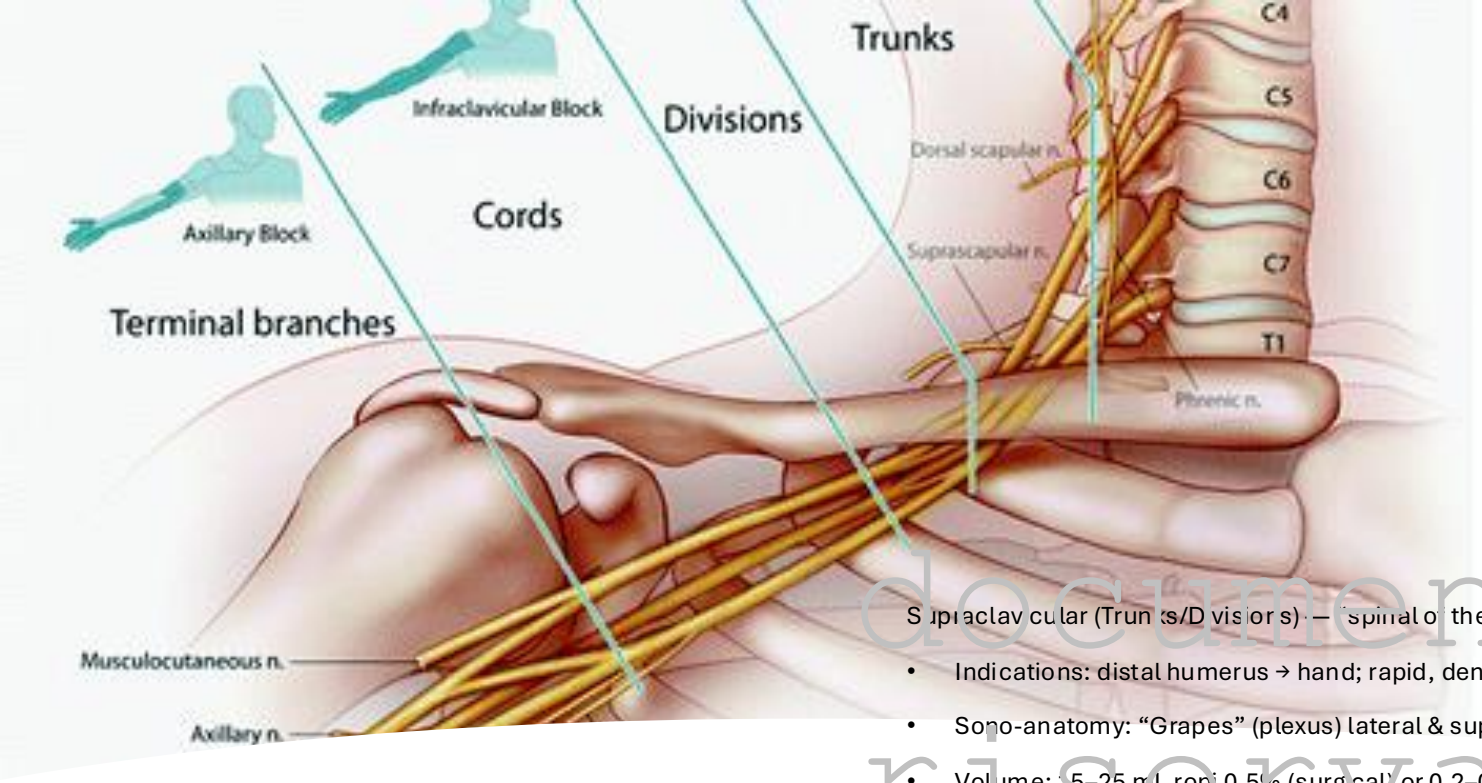
Core safety bundle:

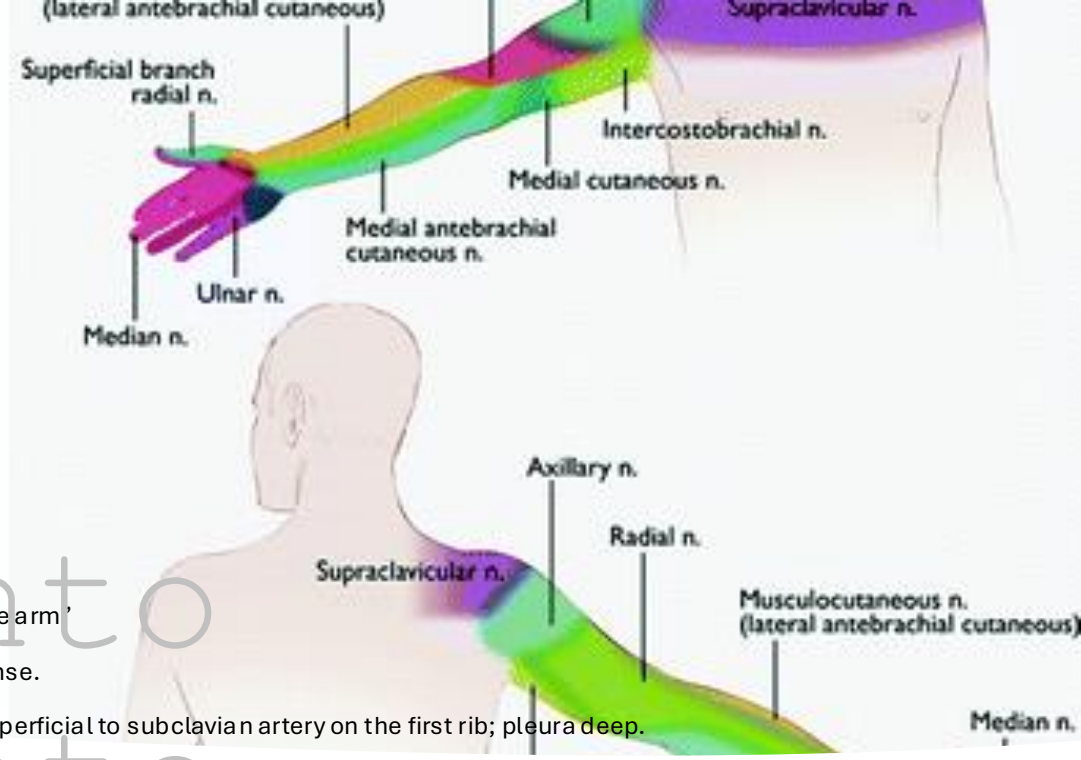
- Standard monitors, IV access, resus drugs + 20% lipid in room.
- Ultrasound guidance first-line; nerve stim as adjunct.
- Incremental injections (3–5 mL), frequent aspiration, low injection pressure (<15 psi), stop if pain/paresthesia/high resistance.
- Dose calculations (mg/kg) — consider cumulative LA dose across blocks/planes.
- Anticoagulation: deep, non-compressible sites (e.g., paravertebral, infraclavicular) → stricter timing (treat like neuraxial-equivalent per local policy).
- Adjuvants (off-label per local policy): perineural dexamethasone 2–4 mg (↑duration), dexmedetomidine 25–50 µg (↑duration, bradycardia risk).
- Catheters: securement + sterile dressing; ropivacaine 0.1–0.2% at 5–8 mL/h, patient-bolus 3–5 mL, lockout 30–60 min.

Upper Limb: Interscalene (Roots C5–7)

- Surgery/analgesia: shoulder/upper humerus; best analgesia but phrenic nerve paresis common.
- Sono-anatomy: C5–7 root “stop-light” between anterior & middle scalene at cricoid (C6).
- Technique: patient supine/semi-sitting, head turned contralateral; in-plane lateral→medial; target spread around C5–C6 roots
- Volume/concentration (adult): 10–15 mL ropi 0.5% (surgical) or 0.2-0.375% (analgesic); low-volume (5–7 mL) can reduce but not eliminate phrenic paresis.
- Pearls: keep needle superficial to prevertebral fascia; avoid medial/pleural trajectory.
- Complications: hemidiaphragm paresis (~virtually all at standard volumes), Hörner’s syndrome, RLN hoarseness, intravascular (vertebral), neuraxial injection (rare).
- Avoid in: severe pulmonary disease/one-lung dependence—consider suprascapular + axillary nerve combo instead.







Upper Limb: Supraclavicular, Infraclavicular, Axillary

Supraclavicular (Trunks/Divisions) — "spinal of the arm"

- Indications: distal humerus → hand; rapid, dense.
- Sono-anatomy: "Grapes" (plexus) lateral & superficial to subclavian artery on the first rib; pleura deep.
- Volume: 15–25 mL ropi 0.5% (surgical) or 0.2–0.375% (analgesic).
- Risk: pneumothorax (↓ with US); keep needle on rib, avoid medial passes.

Infraclavicular (Cords) — long-acting, catheter-friendly

- Indications: elbow to hand; when catheter desired.
- Sono-anatomy: axillary artery with cords around it (often posterior → deep to artery).
- Volume: 20–30 mL; deeper target → consider longer needle & pressure monitoring.
- Risks: vascular puncture/hematoma; pectoral discomfort during needle passage.

Axillary (Terminal branches) — motor-sparing options

- Indications: forearm/hand; good when pneumothorax risk must be nil.
- Sono-anatomy: radial/median/ulnar around axillary artery; musculocutaneous in coracobrachialis (must inject separately).
- Volume: 20–30 mL total, split 3–5 mL per nerve for completeness.
- Pearl: abduct arm; compressible field = safer in anticoagulated pts (local policy dependent).

Lower Limb: Femoral / Adductor Canal (Saphenous) / Fascia Iliaca

Femoral nerve (inguinal crease)

- Analgesia: anterior knee, femur fractures; quadriceps weakness (fall risk).
- Sono-anatomy: nerve lateral to femoral artery, under fascia iliaca.
- Volume: 10–20 mL ropi 0.2–0.375% (analgesia).
- Pearl: ensure sub-fascia iliaca spread (watch hydrodissection).

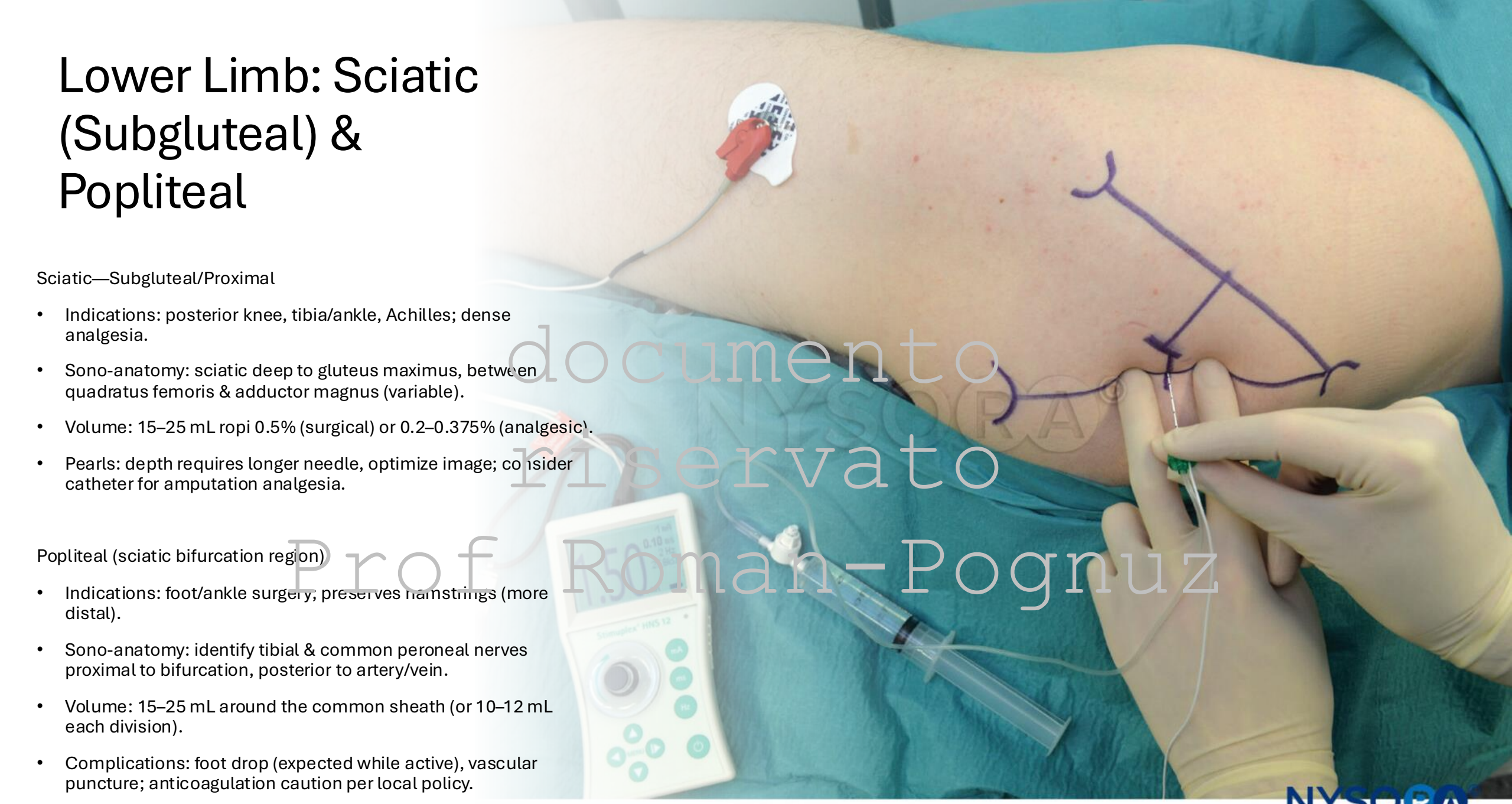
Adductor canal (saphenous nerve + vastus medialis branch)

- Analgesia: knee with motor-sparing (quadriceps preserved vs femoral).
- Sono-anatomy: femoral artery under sartorius mid-thigh; nerve anterolateral to artery.
- Volume: 10–15 mL ropi 0.2–0.375%. Catheter feasible.

Fascia iliaca compartment (FICB)

- Analgesia: hip fracture, lateral thigh; easier, broad spread to femoral/LFCN/±obturator.
- Sono-anatomy: lateral to artery; inject under fascia iliaca (large volume).
- Volume: 30–40 mL dilute ropi 0.1–0.2%.

Lower Limb: Sciatic (Subgluteal) & Popliteal



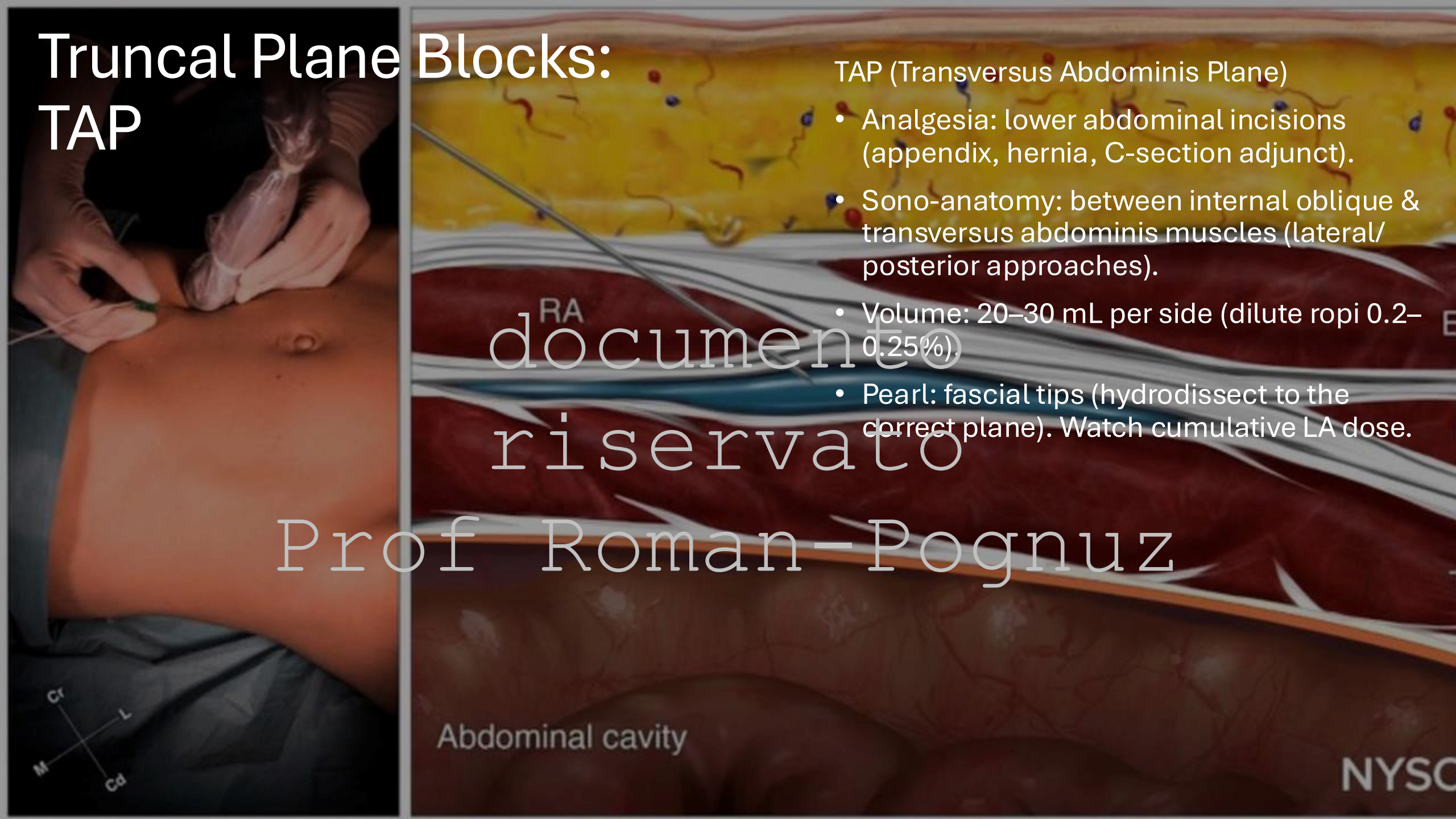
Sciatic—Subgluteal/Proximal

- Indications: posterior knee, tibia/ankle, Achilles; dense analgesia.
- Sono-anatomy: sciatic deep to gluteus maximus, between quadratus femoris & adductor magnus (variable).
- Volume: 15–25 mL ropi 0.5% (surgical) or 0.2–0.375% (analgesic).
- Pearls: depth requires longer needle, optimize image; consider catheter for amputation analgesia.

Popliteal (sciatic bifurcation region)

- Indications: foot/ankle surgery; preserves hamstrings (more distal).
- Sono-anatomy: identify tibial & common peroneal nerves proximal to bifurcation, posterior to artery/vein.
- Volume: 15–25 mL around the common sheath (or 10–12 mL each division).
- Complications: foot drop (expected while active), vascular puncture; anticoagulation caution per local policy.

Truncal Plane Blocks: TAP



TAP (Transversus Abdominis Plane)

- Analgesia: lower abdominal incisions (appendix, hernia, C-section adjunct).
- Sono-anatomy: between internal oblique & transversus abdominis muscles (lateral/ posterior approaches).
- Volume: 20–30 mL per side (dilute ropi 0.2–0.25%).
- Pearl: fascial tips (hydrodissect to the correct plane). Watch cumulative LA dose.

PECS I–II / Serratus / ESP

PECS I (between Pec Major/Minor) & PECS II (between Pec Minor/Serratus)

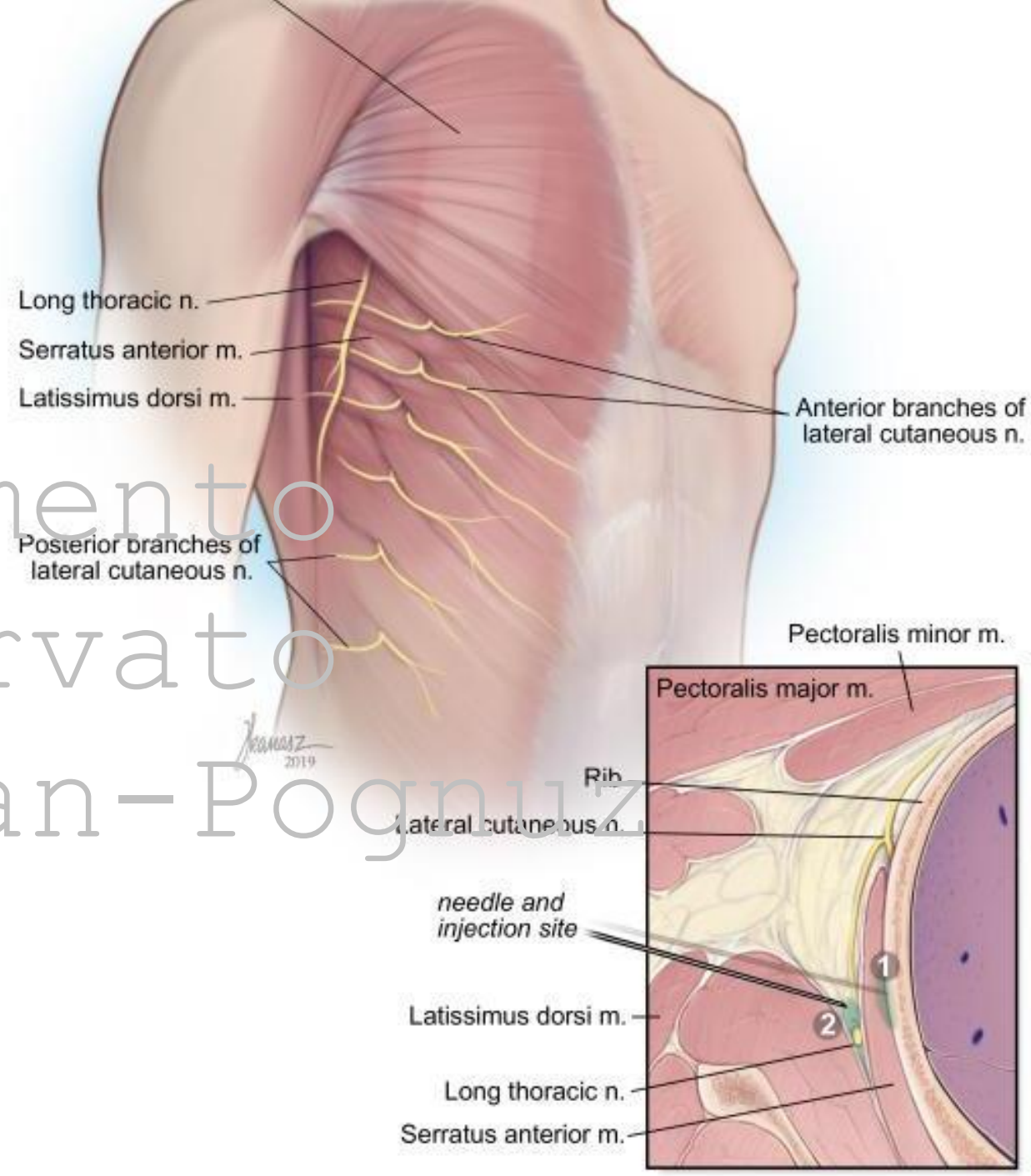
- Analgesia: breast/axillary surgery, pacemaker pockets.
- Volumes: PECS I ~10 mL, PECS II ~15–20 mL (dilute ropi 0.2–0.3%).
- Pearl: deposit both planes for axillary coverage.

Serratus Anterior Plane (SAP)

- Analgesia: lateral thoracotomy, chest drains, rib fractures (mid-axillary line).
- Volume: 20–30 mL superficial or deep to serratus.

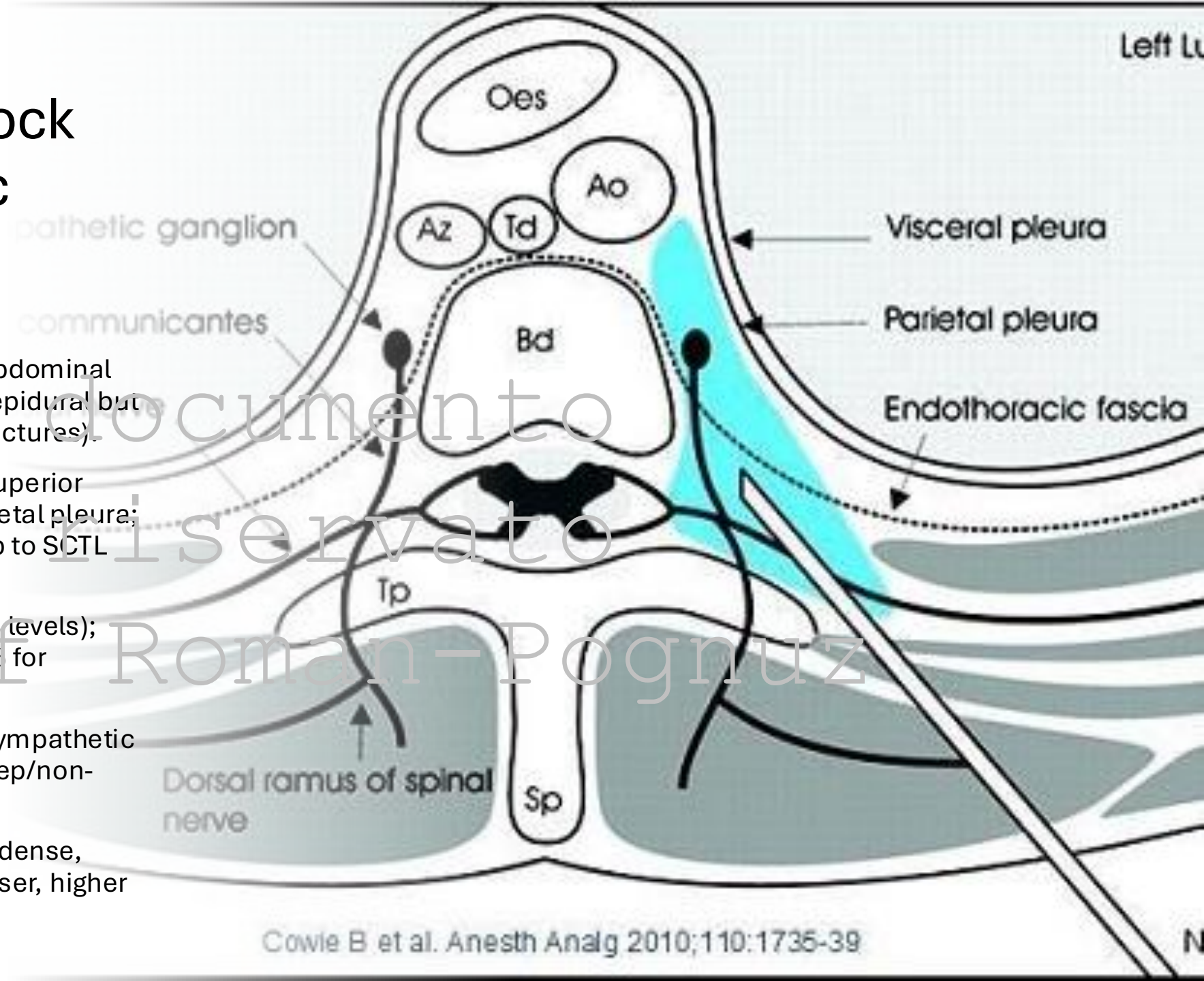
ESP (Erector Spinae Plane)

- Analgesia: thoracic/abdominal/hip fractures; wide spread via dorsal rami ± paravertebral connections.
- Sono-anatomy: transverse process; inject deep to erector spinae.
- Volume: 20–30 mL; catheter friendly.
- Pearl: easier, safer alternative to paravertebral in anticoagulated pts only if local policy allows (still consider depth/compressibility).



Paravertebral Block (PVB) & Thoracic Wall Analgesia

- Why PVB: Unilateral thoracic/upper abdominal anesthesia/analgesia approximating epidural but unilateral (breast, thoracotomy, rib fractures).
- Sono-anatomy: transverse process, superior costotransverse ligament (SCTL), parietal pleura; inject in paravertebral space just deep to SCTL without pleural puncture.
- Volume: 10–20 mL per level (often 2–3 levels); ropi 0.375–0.5% for surgical, 0.2–0.3% for analgesia.
- Risks: pneumothorax, hypotension (sympathetic block), vascular puncture; treat as deep/non-compressible for anticoagulation.
- ESP vs PVB: ESP easier/safer but less dense, more variable visceral block; PVB denser, higher risk profile



Practical Dosing, Duration & Troubleshooting

Typical single-shot durations (adult, ropivacaine):

- **0.5%**: ~8–14 h sensory (site-dependent). **0.2–0.375%**: ~6–10 h analgesia with less motor block.

“Surgical vs analgesic” recipe:

- Surgical: higher **%** (0.5) & moderate **mL** → dense but more motor block.
- Analgesic: lower **%** (0.2-0.3) & adequate **mL** → better spread, motor-sparing.

Common misses & fixes:

- **Axillary**: forgot **musculocutaneous** → add 5 mL in **coracobrachialis**.
- **Supraclavicular**: inadequate **corner-pocket** (inferolateral plexus) → redirect and complete U-shaped spread.
- **Adductor canal**: inject **anterolateral to artery** under sartorius; avoid too proximal (becomes femoral).
- **TAP**: wrong plane (between EO/IO) → reposition; confirm **IO–TA** plane with hydrodissection.

Practical Dosing, Duration & Troubleshooting

Complications overview:

- **LAST** → follow lipid protocol (bolus **1.5 mL/kg**, infusion **0.25 mL/kg/min**, repeat bolus up to total **10–12 mL/kg**).
- **Nerve injury** (rare): avoid intraneural (no high opening pressure, no severe pain on injection).
- **Hematoma/infection:** asepsis; compressible sites safer if anticoagulated.
- **Documentation:** block type/side, LA **drug/conc/volume/total mg**, adjuvants, US images (if policy), dermatomal/motor checks, complications, discharge instructions (falls risk after femoral; foot drop after sciatic until resolution).

PACU

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PACU Priorities & Discharge Scoring

Immediate priorities (ABCTs):

- **Airway** patency (look/listen/feel; OPA/NPA/positioning).
- **Breathing:** RR, work of breathing, **SpO_2**, **$EtCO_2$** if on supplemental O_2 or high risk.
- **Circulation:** HR, **NIBP**, rhythm, cap refill, drain outputs.
- **Temperature:** prevent/treat hypothermia (forced-air warmer; warmed IV fluids).
- **Monitoring frequency:** q5–15 min initially, then titrate by stability; continuous SpO_2; add capnography for high OIRD risk (OSA, high opioids).
- **Discharge scoring (to Phase II/ward):**
  - **Aldrete/Modified Aldrete** (activity, respiration, circulation, consciousness, SpO_2) → **≥9/10** (or baseline) **and** clinician judgment.
- **Ambulatory add-ons:** PADS (pain, N/V controlled, oral intake, ambulation, void if indicated, escort arranged).

Pain: Assessment & Multimodal Plan

Assessment tools:

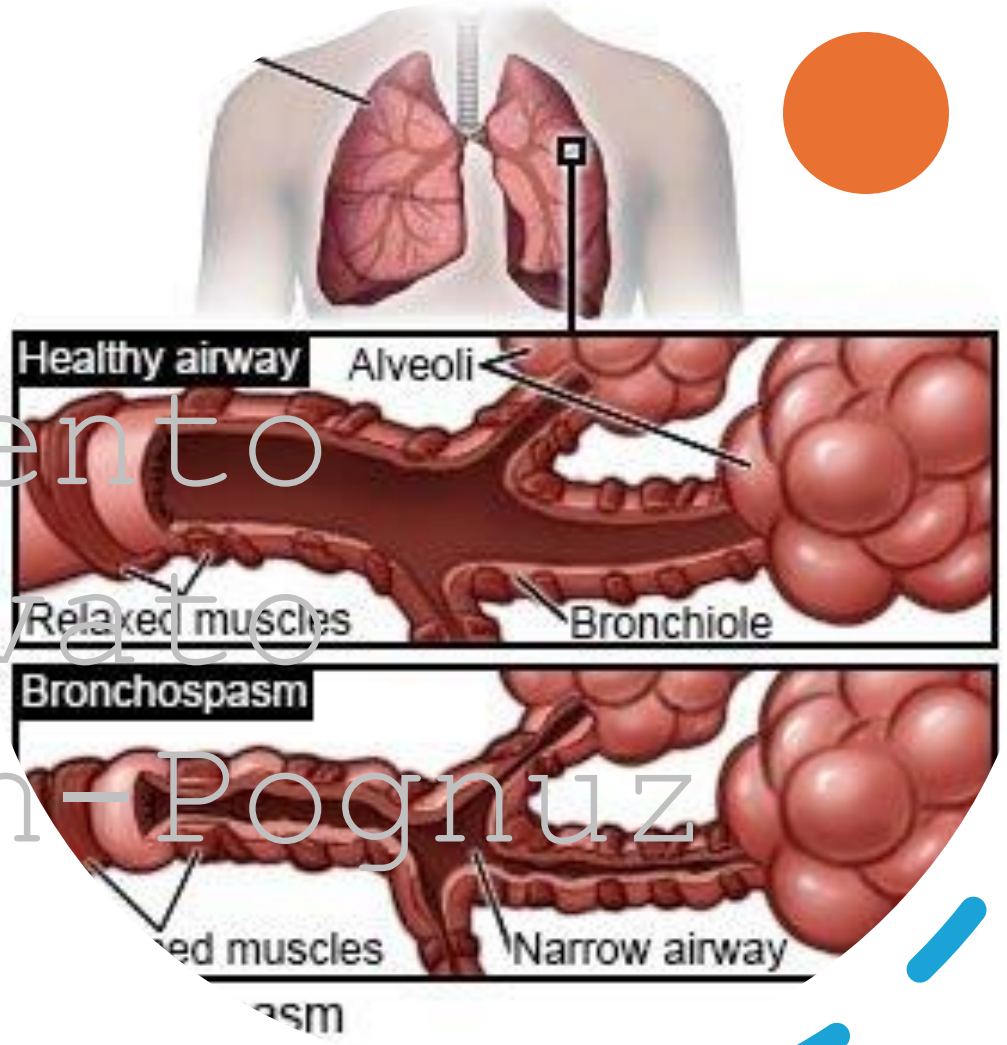
- **NRS 0–10** or VAS; **POSS/RASS** for sedation; **CPOT/BPS** for non-verbal.
- Set a goal (e.g., **NRS ≤3 at rest, ≤5 with movement**). Reassess 15–30 min after interventions.
- **Multimodal foundation (unless contraindicated):**
- **Acetaminophen** 1 g PO/IV q6h (max **3–4 g/day**; reduce with liver disease/low weight).
- **NSAID/COX-2** (e.g., **ketorolac 15–30 mg IV q6h**, max 60–120 mg/day): avoid if AKI risk, GI bleed, bleeding risk, third-trimester pregnancy.
- **Regional/neuraxial:** confirm block function/catheter site; document **dermatomal level** & motor exam (Bromage).
- **Opioid rescue (titrate slowly, monitor sedation/O_2):**
- **Fentanyl 25–50 µg IV** q5–10 min PRN (short-acting).
- **Hydromorphone 0.2–0.4 mg IV** q10–15 min PRN (longer tail).
- **Morphine 1–2 mg IV** q10–15 min PRN.
- Avoid basal infusions in **opioid-naïve** and **OSA**.
- **PCA (if needed, typical starts):**
- Morphine **1 mg demand**, lockout **6–10 min**, **no basal** (OSA/naïve).
- Hydromorphone **0.2 mg demand**, lockout **6–10 min**.
- **Opioid adverse effects:** pruritus, **respiratory depression**, ileus, urinary retention—treat/prevent (see Slide 5).

PONV: Risk, Prophylaxis & Rescue

- **Risk stratification (Apfel):** female, non-smoker, PONV history/motion sickness, postop opioids (0–4 points).
- **Prophylaxis (choose ≥2 classes if moderate/high risk):**
- **Dexamethasone 4–8 mg IV** at induction.
- **Ondansetron 4 mg IV** near end of case.
- Consider **droperidol 0.625–1.25 mg IV** (QT caution), **haloperidol 0.5–1 mg IV**, **scopolamine patch**, **aprepitant 40 mg PO** preop for very high risk.
- **Rescue (use a different class than prophylaxis):**
- **Ondansetron 4 mg IV** (if not already used) or **granisetron 1 mg IV**.
- **Droperidol 0.625–1.25 mg IV** or **haloperidol 0.5–1 mg IV**.
- **Metoclopramide 10 mg IV** as adjunct.
- Rehydrate; treat pain/anxiety; **avoid emetogenic opioids** when possible.
- **Disposition:** sustained vomiting, intractable symptoms → observe longer, consider alternative analgesia (regional, ketamine low-dose, acetaminophen/NSAID).

Early Complication Detection & Management

- **Airway/Respiratory**
- **Obstruction/hypoventilation:** jaw thrust, OPA/NPA, head-elevated; consider residual NMB (TOF **≥0.9–1.0** before extubation).
- **Laryngospasm:** 100% O_2 + CPAP, deepen anesthesia (propofol), **succinylcholine 0.1–0.5 mg/kg IV** if persistent.
- **Bronchospasm:** β_2-agonist neb, deepen anesthesia (sevo/propofol/ketamine), epinephrine if severe.
- **Hypoxemia:** verify airway, atelectasis (incentive spirometry), aspiration, pneumothorax (post block/line) → POCUS/CXR.



Early Complication Detection & Management

Hemodynamics

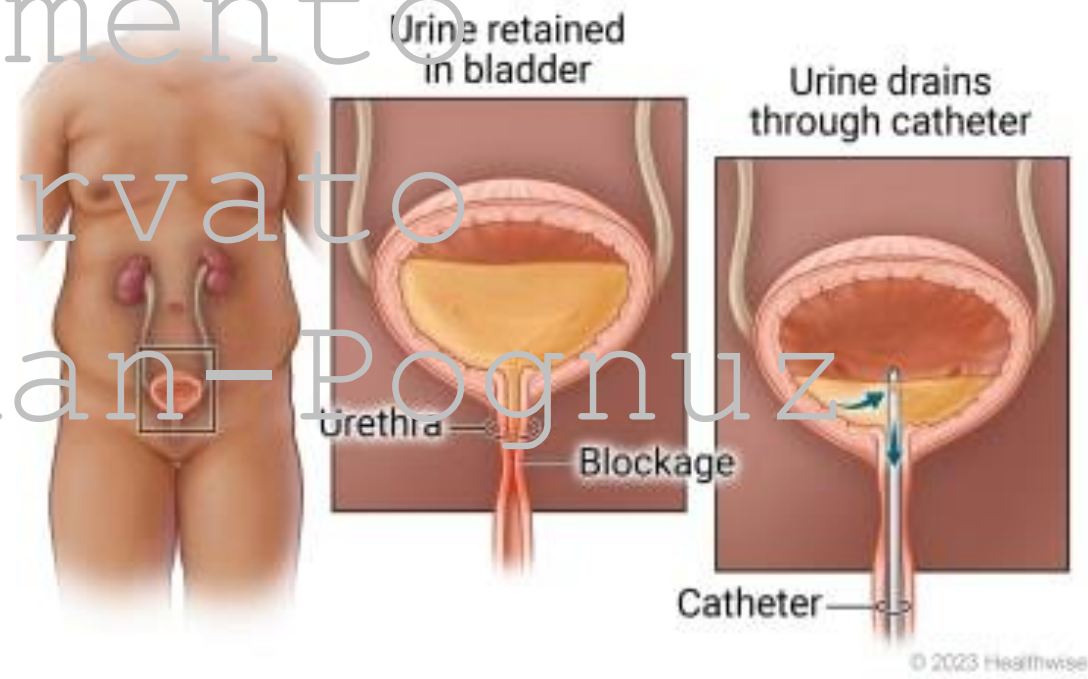
- **Hypotension:** r/o bleeding (surgical site/drains), residual anesthetic effect, sepsis; small balanced fluid bolus (250 mL) **if** responsive; **phenylephrine 50--100 µg IV** or **norepinephrine 5–10 µg IV** for vasodilation; **ephedrine 5–10 mg IV** if low HR + low BP.
- **Hypertension/tachycardia:** pain, bladder distension, hypoxia, withdrawal, thyroid issues; treat cause ± **esmolol/nitro**.

Temperature/Shivering

- **Active warming** to **36–37 °C**; **meperidine 12.5 -25 mg IV** for shivering (or clonidine/ondansetron adjuncts).
- **Bleeding**
- Check wound/hematoma; drain outputs; serial vitals; labs (Hb, coagulation) if concern; notify surgeon early.

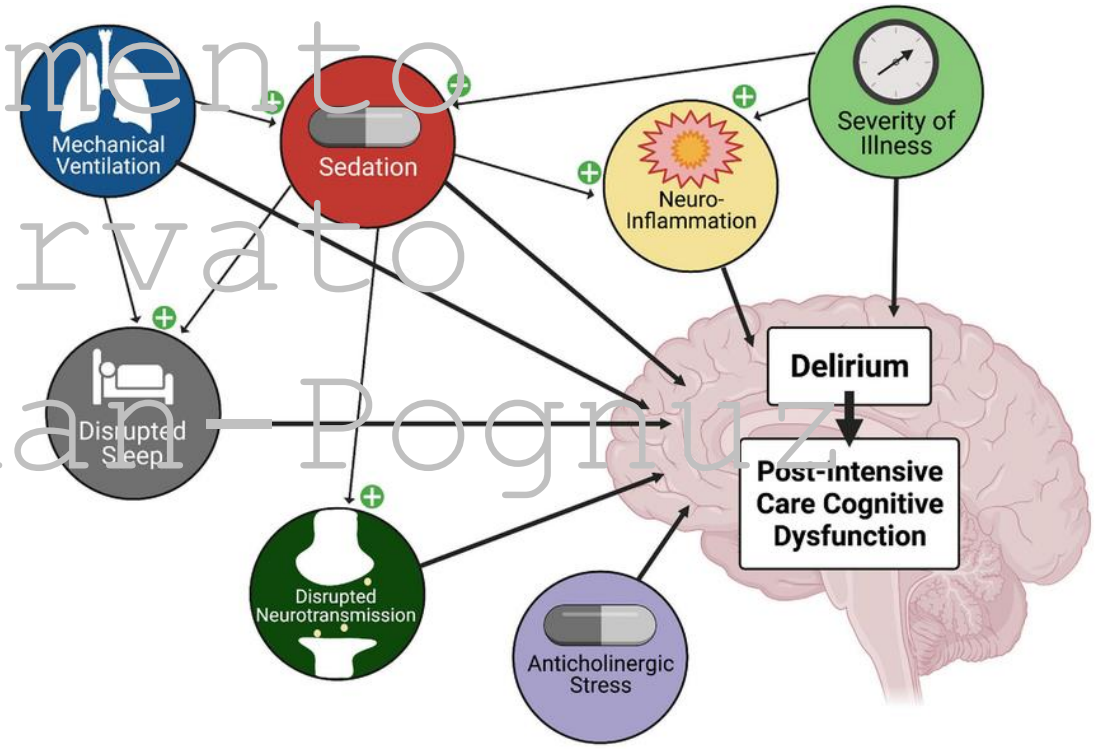
OIRD, Urinary Retention

- **Opioid-Induced Respiratory Depression (OIRD)**
- **High-risk:** OSA, elderly, renal/hepatic impairment, high cumulative opioids, concurrent sedatives.
- **Prevention:** smallest effective opioid dose, avoid basal PCA, continuous **pulse oximetry ± capnography**.
- **Treatment:** stimulate, O_2, support ventilation; **naloxone 20–40 µg IV** q2–3 min to effect; consider **infusion 0.04–0.4 mg/h** if long-acting opioids used (avoid abrupt withdrawal).
- **Urinary retention**
- Risk: neuraxial opioids, pelvic/hernia surgery, anticholinergics, high opioid load.
- **Bladder scan** if no void and discomfort; typical threshold **>400–600 mL** → intermittent catheterization.
- Optimize analgesia, mobilize; review meds.



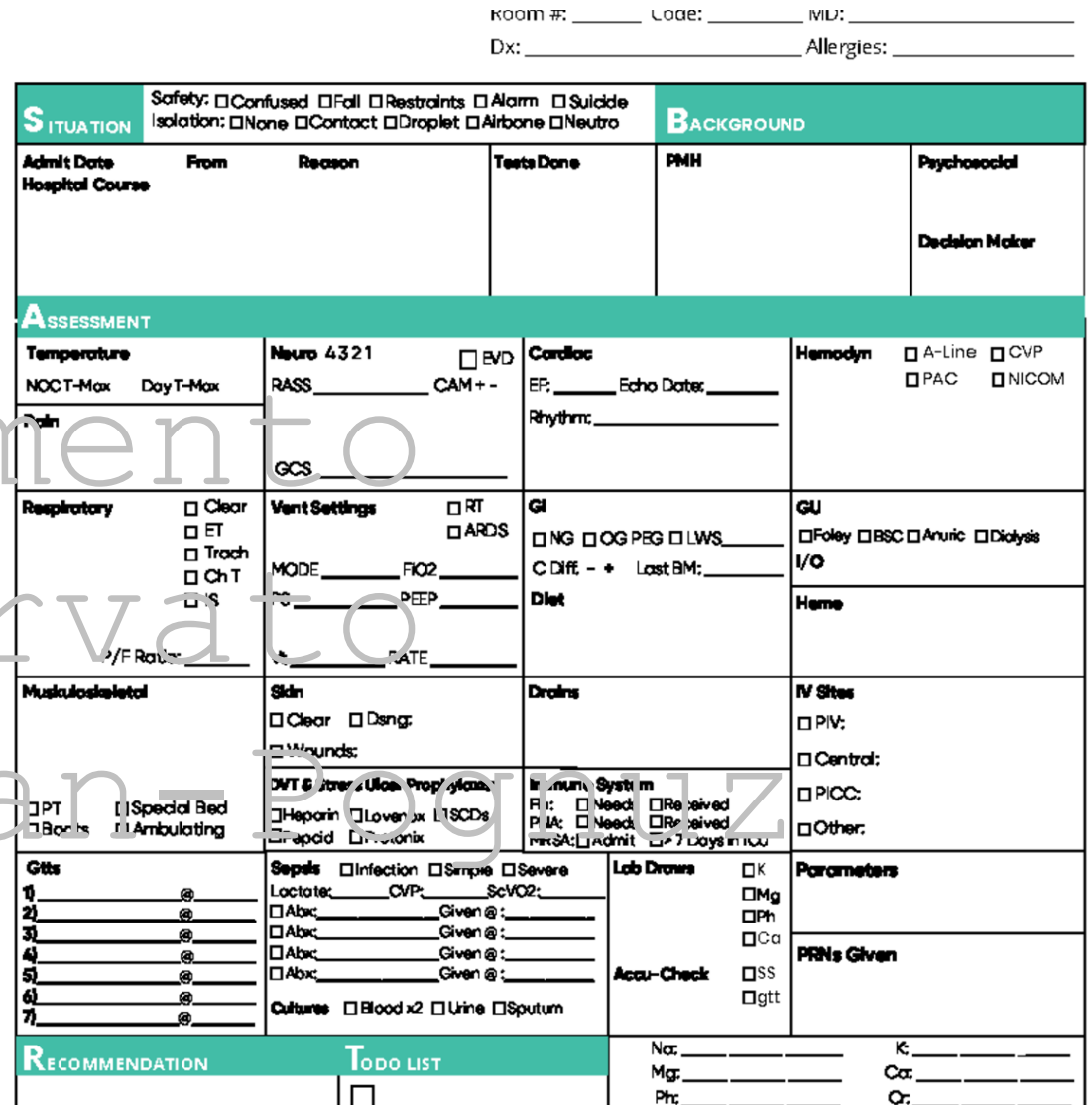
OIRD, Delirium & Glycemia

- **Delirium/Emergence agitation**
- Screen (CAM-ICU), correct pain, hypoxia, urinary retention; minimize deliriogenic meds; **dexmedetomidine** low-dose or low-dose antipsychotic if needed (QT/age caution).
- **Glycemic control**
- Target **140–180 mg/dL** (7.8–10 mmol/L); treat hypo-/hyperglycemia per protocol; resume home insulin strategy when eating.



Handover, Ward Transfer & Orders

- **Structured handoff (SBAR)**
- **S**urgery & key intraop events.
- **B**aseline comorbidities/risk (OSA, CAD, anticoagulation).
- **A**nesthetics/analgesics (last opioid time/dose; **regional catheters** details & checks; antiemetics; fluids/EBL; vasoactives; antibiotics).
- **R**ecommendations: pain plan, PONV PRNs, oxygen strategy, monitoring level (e.g., continuous oximetry for OSA/high-risk), labs/targets.


Room #: _____ Code: _____ MD: _____
Dx: _____ Allergies: _____

SITUATION Safety: ☐Confused ☐Fall ☐Restraints ☐Alarm ☐Suicide
Isolation: ☐None ☐Contact ☐Droplet ☐Airborne ☐Neutro

BACKGROUND

Admit Date / From / Reason / Hospital Course | Tests Done | PMH | Psychosocial / Decision Maker

ASSESSMENT

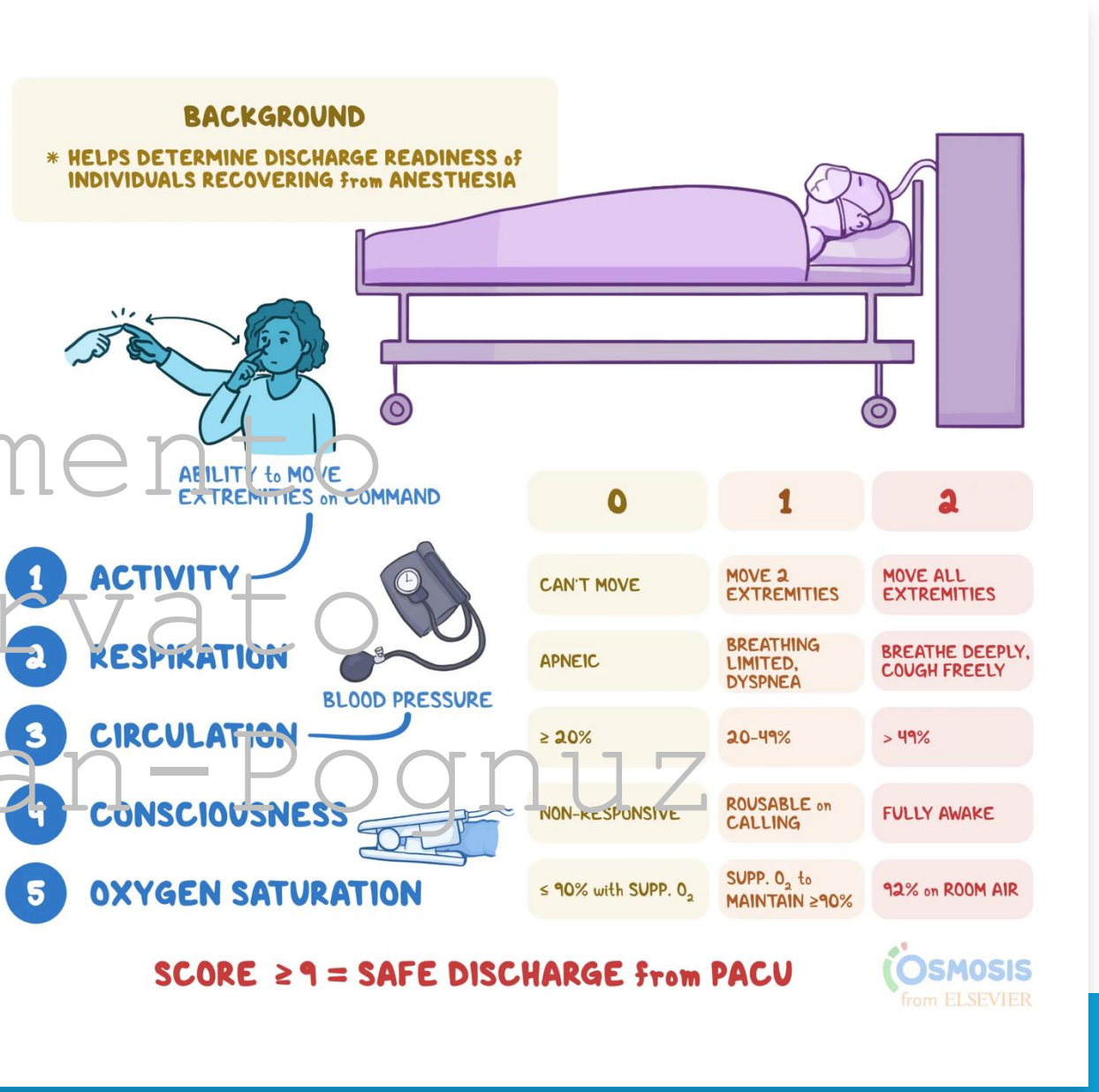
Temperature — NOC T-Max / Day T-Max
Pain
Neuro 4321 ☐EVD — RASS _____ CAM + -
GCS _____
Cardiac — EF: _____ Echo Date: _____ Rhythm: _____
Hemodyn ☐A-Line ☐CVP ☐PAC ☐NICOM
Respiratory ☐Clear ☐ET ☐Trach ☐Ch T ☐NS — P/F Ratio: _____
Vent Settings ☐RT ☐ARDS — MODE _____ FiO2 _____ PEEP _____ RATE _____
GI ☐NG ☐OG PEG ☐LWS _____ C Diff: - + Last BM: _____ Diet
GU ☐Foley ☐BSC ☐Anuric ☐Dialysis I/O
Heme
Musculoskeletal
Skin ☐Clear ☐Dsng: ☐Wounds:
Drains
IV Sites ☐PIV: ☐Central: ☐PICC: ☐Other:
☐PT ☐Special Bed ☐Boots ☐Ambulating
DVT & Stress Ulcer Prophylaxis ☐Heparin ☐Lovenox ☐SCDs ☐Rapid ☐Protonix
Immune System R: ☐Needs ☐Received PIA: ☐Needs ☐Received MRSA: ☐Admit ☐>7 Days in ICU
Gtts
1) _____ @ _____
2) _____ @ _____
3) _____ @ _____
4) _____ @ _____
5) _____ @ _____
6) _____ @ _____
7) _____ @ _____
Sepsis ☐Infection ☐Simple ☐Severe
Lactate: _____ CVP: _____ ScVO2: _____
☐Abx: _____ Given @: _____
☐Abx: _____ Given @: _____
☐Abx: _____ Given @: _____
☐Abx: _____ Given @: _____
Cultures ☐Blood x2 ☐Urine ☐Sputum
Lab Draws ☐K ☐Mg ☐Ph ☐Ca
Accu-Check ☐SS ☐gtt
Parameters
PRNs Given

RECOMMENDATION **TODO LIST** ☐

Na: _____ K: _____
Mg: _____ Ca: _____
Ph: _____ Cr: _____

Handover, Ward Transfer & Orders

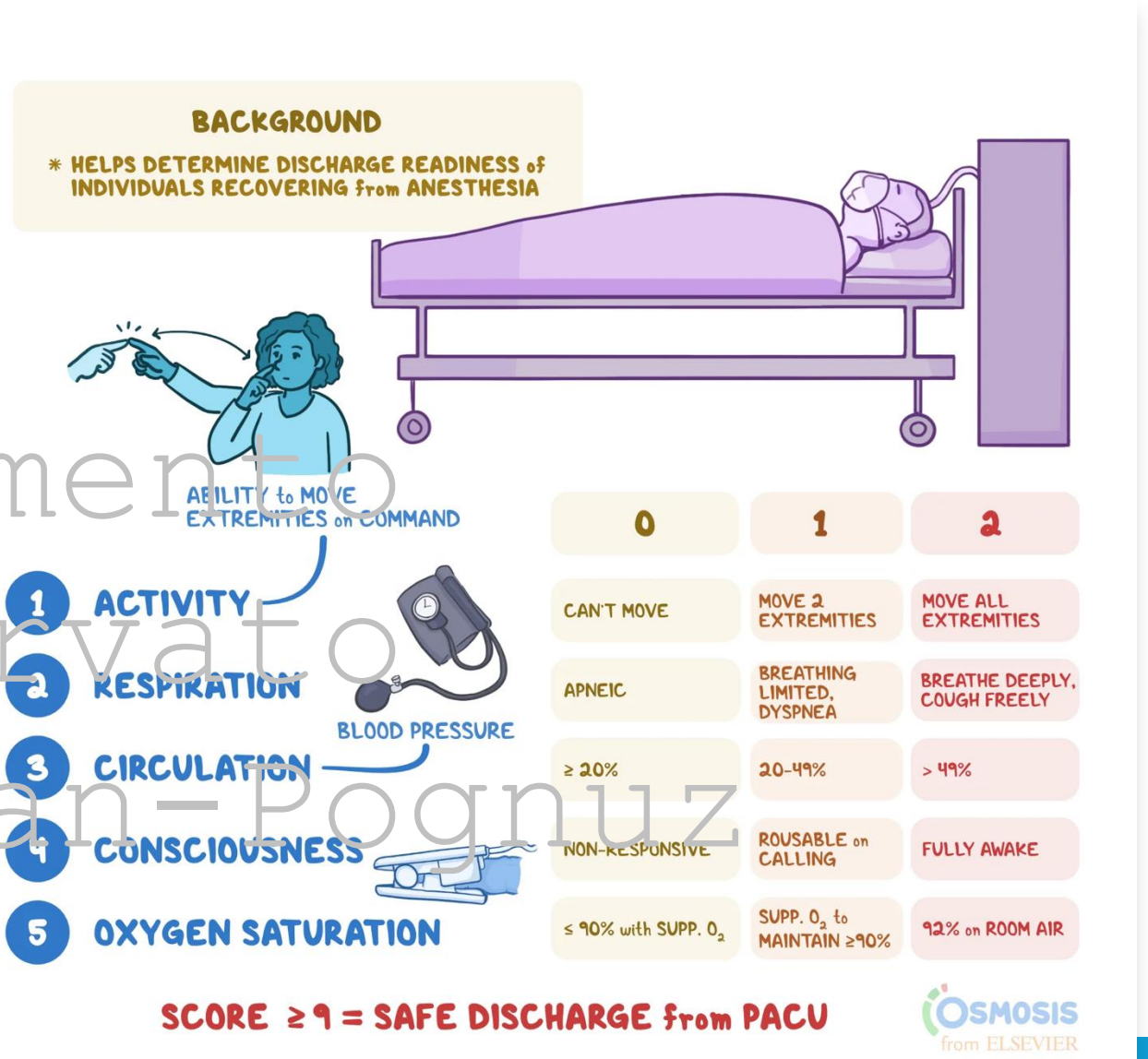
- **Before transfer — must confirm**
- **Aldrete ≥9**, hemodynamically stable, **SpO_2 at or near baseline** on planned O_2, **pain controlled** on oral/IV transition plan, **N/V controlled**, temp ≥36 °C, no active bleeding, mental status acceptable for destination.
- **Regional**: document dermatomes, motor exam, catheter depth/rate; provide **LAST** instructions & lipid availability on the ward if catheter infusing.
- **Respiratory risk/OSA**: encourage **CPAP** (use patient's device); **no basal PCA**; continuous oximetry.

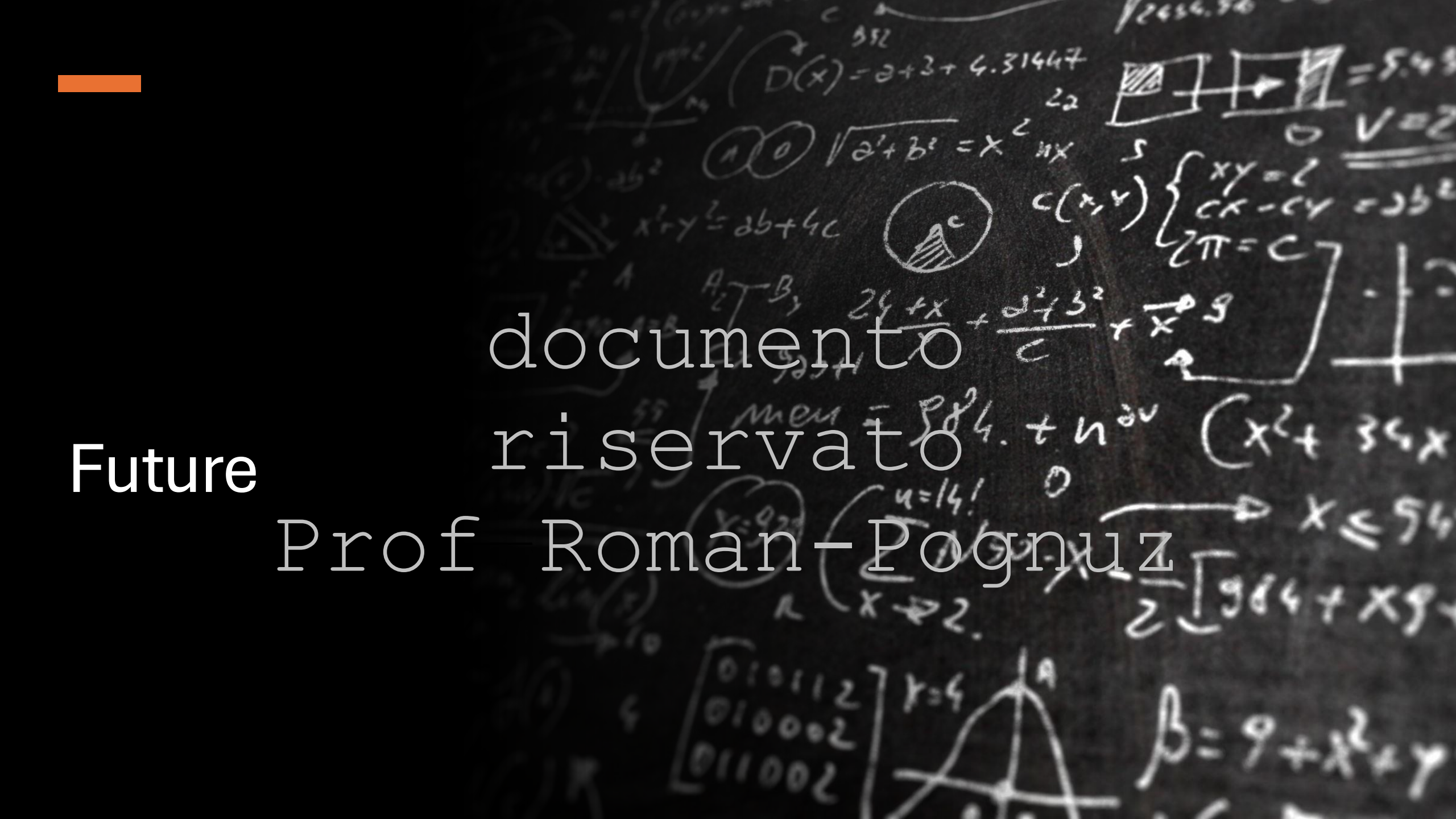


Handover, Ward Transfer & Orders

Postop orders & counseling

- **Analgesia**: scheduled acetaminophen ± NSAID/COX-2; opioid PRNs with **clear hold parameters** (sedation score, RR); bowel regimen.
- **PONV PRNs** from a different class than prophylaxis.
- **Early mobilization**, DVT prophylaxis per protocol, incentive spirometry, diet advancement plan.
- **Red flags education** (to nurses/patient): escalating pain/swelling at wound, fever/chills, **increasing somnolence with shallow breathing**, inability to void, intractable N/V, chest pain/shortness of breath.





Future

documento riservato

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Precision Anesthesia & Individualized Dosing

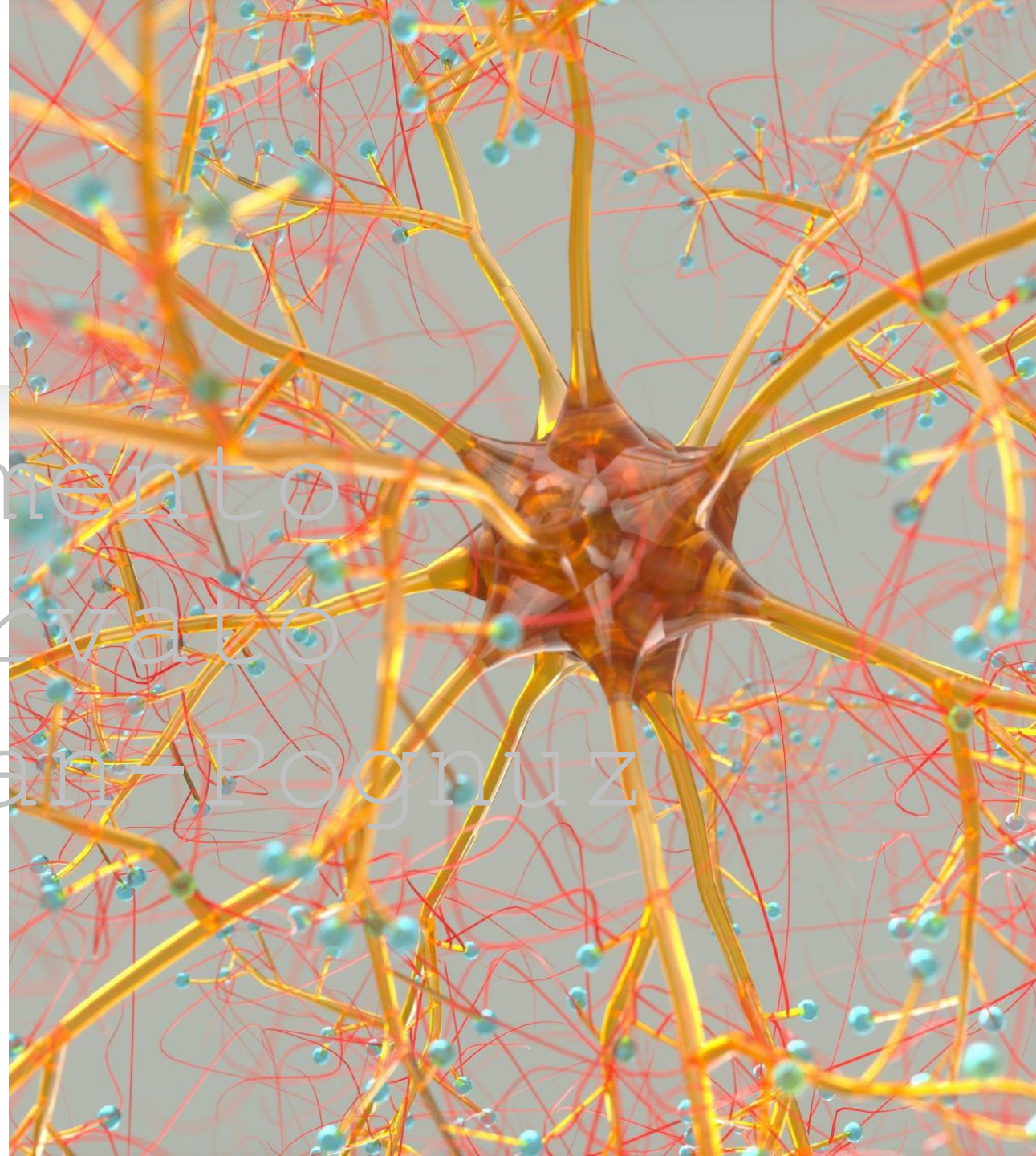
- **What it means:** tailoring hypnotic/analgesic/NMBA plans to a patient's **genotype, phenotype, and physiology** (age, frailty, comorbidities, EHR data).
- **Pharmacogenomics (examples you can teach):**
  - **BCHE variants** → prolonged **succinylcholine**/mivacurium effect (plan: avoid or dose-test; consider rocuronium + sugammadex).
  - **CYP2B6/UGT1A9** variability → differences in **propofol** clearance (watch hypotension/slow wake in slow metabolizers).
  - **CYP2D6 ultra/poor metabolizers** → altered response to **tramadol/codeine** (prefer direct-acting opioids or non-opioids).
  - **OPRM1 A118G** → reduced opioid sensitivity in some patients (anticipate higher opioid requirement or use multimodal/regional).
  - **MC1R (red hair)** associations → ↑ inhalational anesthetic requirement, ↑ pain sensitivity (anticipate dosing & analgesia adjustments).

Individualized Dosing

- **Phenotype-driven titration:**
  - Frailty index, sarcopenia, OSA risk, hepatic/renal function, **hemodynamic reactivity** during induction.
  - Use **processed EEG** to titrate hypnosis; **quantitative TOF** to titrate NMBAs instead of fixed schedules.
- **Decision support now/near-term:** EHR-based risk scores (PONV, hypotension), smart pump libraries, “suggested dose ranges” that adjust to age/BMI/comorbidity.

Ultrasound-First: Regional & Vascular Access (with Emerging Tech)

- **Standard of care trend: US guidance** for peripheral nerve blocks and central/peripheral vascular access (↑ success, ↓ complications).
- **Block quality mechanics:**
  - **In-plane** needle visualization; deliberate **hydrodissection**; aim for **circumferential LA spread** around nerves/fascial planes.
  - **Low injection pressure** (<15 psi) + **incremental 3–5 mL** injections with frequent aspiration to reduce intraneural/intravascular risk.
- **Vascular access:** dynamic US for IJ/subclavian/axillary; **long-axis cannulation**, confirm with **saline swirl/POCUS**; use microintroducers.



What’s next:

- **Needle-tip tracking** (magnetic/reflective), **AI nerve segmentation**, auto-measurements (depth, distance).
- **3D/Matrix probes** for paravertebral/ESP/paraspinal mapping; **handheld** battery probes at bedside and in ambulatory centers.
- **AR overlays** and **haptic feedback** systems to guide trainees.
- **Long-acting local analgesia evolution:** perineural catheters with **ropivacaine 0.1–0.2%** smart-bolus algorithms; newer depot formulations (liposomal/combination) for infiltration—know institutional policies on **mixing/compatibility**.

AI-Assisted Monitoring & Closed-Loop Delivery

- **AI for prediction & detection:**
  - Arterial-waveform–based models that **predict hypotension minutes ahead** → pre-emptive vasopressor/fluids.
  - Automated **alarm filtration** and **artifact rejection**; early detection of bronchospasm, apnea, circuit disconnects.
- **Closed-loop control (human-in-the-loop):**
  - **Hypnosis loop:** propofol TCI adjusted to **EEG index** target (e.g., BIS/PSI 40–60).
  - **Analgesia loop:** remifentanil adjusted to **nociception surrogates** (HR/BP/NOL/SPI) while minimizing opioid exposure.
  - **Vasoactive loop:** phenylephrine/norepinephrine titrated to **MAP setpoint**; fluid-responsiveness logic (PPV/SVV validity checks).
  - **NMB loop:** rocuronium guided by **quantitative TOF** to maintain 1–2 twitches intraop and **TOF ratio ≥0.9–1.0** for reversal.

Opioid-Sparing Pathways & New/Next-Gen Analgesics

- **Pathway design (ERAS mindset):**
  - Preop education + **acetaminophen/NSAID/COX-2** baseline; **regional/neuraxial** prioritized; intraop **ketamine low-dose**, **lidocaine infusion**, **dexmedetomidine** where appropriate; postop **scheduled non-opioids** with rescue opioid only.
- **Newer/adjunctive drugs & devices:**
  - **Oliceridine** (biased μ-agonist) — potential less respiratory depression (still opioid stewardship needed).
  - **Liposomal bupivacaine/bupivacaine+meloxicam** infiltration products — extended local effect (efficacy varies by procedure; follow your institution's guidance).
  - **S-ketamine** low-dose infusions for hyperalgesia/OIH reduction; **IV lidocaine** for visceral/neuropathic components.
  - **NaV1.7/1.8-selective blockers** and other non-opioid pipelines (under study).

New/Next-Gen Analgesics

- **Non-pharmacologic adjuncts with evidence signals:**
  - **VR distraction**, **music therapy**, **acupuncture**, **TENS**, **guided hypnosis** → lower pain/anxiety and opioid use.
  - **Prehab/sleep optimization** and **CBT-I** approaches decrease perioperative pain catastrophizing.
- **Stewardship & safety:**
  - Standardized **discharge opioid quantities**, PDMP checks, **naloxone** co-prescribing for high-risk patients, and **buprenorphine-informed** perioperative plans.

Beyond the OR: Perioperative “Command Center,” Wearables

Continuous periop loop:

- Preop risk stratification → intraop precision → **remote PACU/ward monitoring** (wireless pulse ox, intermittent capnography, mobility trackers).
- Early warning scores integrated with EHR to catch **sepsis, bleeding, OIRD** sooner.

Wearables/At-home monitoring:

- Post-discharge **SpO_2/HR/steps**, pain e-diaries, photo wound checks; automated flags to acute pain service.

& Green Anesthesia

Green anesthesia (sustainability as a clinical quality metric):

- **Retire desflurane**/minimize **N_2O**; **low-flow** volatile techniques with scavenging; expand **TIVA** where appropriate.
- Device re-use pathways (where safe), anesthetic gas capture, and OR energy optimization.

Education & equity:

- Simulation for crisis/airway/regional; **tele-mentoring** for low-resource settings; bias checks in algorithms to avoid exacerbating disparities.

How Students Can Plug Into Innovation (Actionable “Next Steps”)

- **Read & follow:** anesthesia journals’ **technology/QA** sections; join **quality improvement** and **ERAS** committees as a student observer.
- **Skills to learn early:**
  - **Point-of-care ultrasound** basics (lung, IVC, gastric, vascular).
  - **Basic EEG patterns** and MAC/age-adjustment; **quantitative TOF** use and documentation.
  - **Data literacy:** interpreting ROC curves, calibration, and bias/variance in clinical AI papers.

Projects you can start:

- Build a **PONV/analgesia order set** that defaults to multimodal and tracks outcomes.
- Audit **hypotension minutes < MAP 65** vs complications; propose a **vasopressor bundle**.
- Pilot a **VR/music** protocol in PACU with pain/PONV outcomes.

- **Mindset:** stay curious; ask "**Will this change management?**" for every monitor, algorithm, or drug. If yes, design **fail-safes** and **measure outcomes**, not just adoption.
- **Bottom line:** the future is **patient-specific dosing**, **ultrasound-first procedures**, **AI-supported & closed-loop physiology control**, and **opioid-sparing, multimodal care**—all delivered sustainably and safely with clinicians firmly **in the loop**.