Electrotherapy Puzzles on Therapeutic Currents and Physiological Effects: Case Study Style

Inspired by case-based learning approaches (similar to advanced rehabilitation and physiotherapy programs), these 20 puzzles are presented as clinical case studies emphasizing therapeutic currents in electrotherapy, with a focus on both the currents themselves and their physiological effects on tissues, nerves, muscles, and healing processes. They cover low-frequency (e.g., TENS, galvanic, NMES) and high-frequency currents (e.g., interferential, diathermy, radiofrequency). Each requires identifying the current, its parameters, or primary physiological impact. Answers follow each puzzle.

Puzzle 1

A patient with postoperative pain receives pulsed asymmetric biphasic currents at 100 Hz, reporting immediate paresthesia masking sharp pain. What low-frequency current is used, and what physiological effect on spinal cord neurons explains the rapid analgesia?

Answer: Conventional TENS. It activates large A-beta afferents, stimulating inhibitory interneurons in the substantia gelatinosa to block nociceptive transmission via gate control theory.

Puzzle 2

In treating chronic tendonitis, constant direct current is applied with a positively charged electrode over the injury to reduce inflammation. What low-frequency current facilitates this, and what physiological effect repels negatively charged inflammatory mediators?

Answer: Galvanic current (direct current). Anodal polarity creates hyperemia and disperses acidic byproducts, while repelling negatively charged proteins to decrease edema.

Puzzle 3

A denervated muscle in a peripheral nerve injury patient is stimulated with long-duration rectangular pulses (10-100 ms) to elicit visible twitches. What low-frequency current is appropriate, and what physiological effect prevents rapid fatigue compared to faradic?

Answer: Interrupted galvanic or triangular pulsed current. Prolonged pulse duration directly depolarizes muscle membranes (denervation accommodation), sustaining contractions without relying on nerve conduction.

Puzzle 4

For deep abdominal pain, four electrodes deliver medium-frequency currents at 4000-5000 Hz with a 80-120 Hz beat, penetrating without skin irritation. What current is this, and what physiological effect enhances endorphin release for prolonged relief?

Answer: Interferential current therapy (IFT). The low-frequency envelope stimulates A-delta fibers and opioid pathways, providing deeper analgesia with reduced cutaneous resistance.

Puzzle 5

A patient with low back strain undergoes therapy at 27.12 MHz continuous mode, feeling deep warmth and improved mobility. What high-frequency current induces this, and what physiological effect increases collagen extensibility via molecular oscillation?

Answer: Continuous shortwave diathermy (CSWD). Dielectric heating causes vigorous rotation of dipoles, elevating tissue temperature 4-6°C for vasodilation and enhanced metabolic activity.

Puzzle 6

To promote wound healing in a venous ulcer, monophasic twin-peaked pulses at 105 Hz and high voltage (>150 V) are applied. What low-frequency current accelerates epithelial migration, and what physiological effect involves galvanotaxis?

Answer: High-voltage pulsed current (HVPC). Cathodal stimulation attracts keratinocytes and macrophages via direct current fields, mimicking endogenous bioelectric injury currents.

Puzzle 7

Superficial facial muscles are treated with 2450 MHz electromagnetic waves via a director applicator, heating selectively in fat and muscle. What high-frequency current is used, and what physiological effect limits depth due to reflection at interfaces?

Answer: Microwave diathermy (MWD). Selective absorption in water-rich tissues causes rapid heating to 3-5 cm depth; bone-muscle interfaces reflect waves, sparing deeper structures.

Puzzle 8

An athlete with quadriceps inhibition post-injury receives burst-modulated 2500 Hz currents at 50 bursts/sec for strong contractions. What current type is this, and what physiological effect minimizes fatigue during strengthening?

Answer: Russian current (medium-frequency burst). High carrier reduces skin impedance; bursts allow rest intervals, recruiting more motor units via central summation.

Puzzle 9

In non-thermal mode at 27 MHz with 200 µs pulses, a patient with acute ankle sprain experiences reduced swelling without heat sensation. What high-frequency current variant is applied, and what physiological effect modulates membrane permeability?

Answer: Pulsed shortwave diathermy (PSWD). Athermal effects increase calcium influx, enhancing cellular repair, phagocytosis, and anti-inflammatory cytokine release.

Puzzle 10

Chronic pelvic pain is managed with low-frequency bursts (2-4 Hz) of high-rate pulses, providing relief lasting hours post-treatment. What TENS variant is this, and what physiological effect involves diffuse noxious inhibitory control (DNIC)?

Answer: Low-frequency or acupuncture-like TENS (AL-TENS). Activation of small A-delta and C-fibers triggers descending serotonergic and noradrenergic inhibition from the brainstem.

Puzzle 11

Large joint arthritis is treated with 13.56 MHz inductive coils, heating deep tissues uniformly. What high-frequency method avoids capacitive burns, and what physiological effect arises from eddy currents in conductive tissues?

Answer: Inductive shortwave diathermy. Magnetic fields induce circulating currents, preferentially heating muscle and vascular tissues for sustained therapeutic hyperemia.

Puzzle 12

A hemiplegic patient uses gait-synchronized pulses at 30 Hz to activate tibialis anterior during swing phase. What low-frequency current supports orthotic substitution, and what physiological effect promotes cortical reorganization?

Answer: Functional Electrical Stimulation (FES). Timed contractions enhance proprioceptive feedback, facilitating motor relearning via Hebbian plasticity.

Puzzle 13

For skin tightening, monopolar currents at 0.5-1 MHz pass through tissue between electrodes, remodeling dermis. What high-frequency current is this, and what physiological effect denatures collagen triple helices?

Answer: Monopolar radiofrequency (RF) therapy. Resistive heating to 40-60°C causes immediate collagen contraction and long-term fibroblast stimulation for neocollagenesis.

Puzzle 14

Carpal tunnel syndrome is treated with premodulated medium-frequency currents via two electrodes for convenience. What current simplifies IFT setup, and what physiological effect remains comparable to true interferential?

Answer: Premodulated interferential current. Single-channel amplitude modulation produces similar low-frequency envelope in superficial tissues, though with less depth.

Puzzle 15

Muscle re-education after immobilization uses surged sinusoidal AC at 50 Hz with gradual rise. What low-frequency current mimics voluntary effort, and what physiological effect recruits slow-twitch fibers first?

Answer: Faradic-type surged current. Ramp modulation allows selective activation of fatigue-resistant motor units, preventing discomfort and accommodating sensory nerves.

Puzzle 16

In lymphedema management, sequential low-frequency pulses (1-10 Hz) mimic manual drainage. What current enhances lymph flow, and what physiological effect involves rhythmic vascular compression?

Answer: Intermittent pneumatic compression-like electrical stimulation (e.g., NMES for pumping). Muscle contractions increase interstitial pressure gradients, propelling lymph proximally.

Puzzle 17

Bipolar radiofrequency at 448 kHz is applied for subacute injuries to boost metabolism without excessive heat. What current balances thermal and athermal effects, and what physiological effect upregulates HSP70 expression?

Answer: Capacitive-resistive electric transfer (CRET) or TECAR therapy. Controlled heating enhances ATP synthesis and cellular proliferation via heat shock protein pathways.

Puzzle 18

Spasticity in multiple sclerosis is reduced with prolonged high-frequency stimulation (100 Hz) over antagonist muscles. What low-frequency current induces reciprocal inhibition, and what physiological effect fatigues hyperactive Ia afferents?

Answer: High-rate TENS or NMES. Prolonged stimulation causes presynaptic inhibition and post-activation depression of H-reflex pathways.

Puzzle 19

Fracture healing is accelerated with very low-intensity pulsed currents (20 μA) mimicking bone piezoelectric signals. What specialized low-frequency current is this, and what physiological effect stimulates osteoblast activity?

Answer: Bone growth stimulator (pulsed electromagnetic fields or direct current). It upregulates growth factors (BMP, TGF-β) and calcium uptake, enhancing callus formation.

Puzzle 20

In acute inflammation, cathodal galvanic current for 30 minutes causes vessel dilation. What polarity shift is needed next for vasoconstriction, and what physiological effect reduces persistent edema?

Answer: Switch to anodal polarity. Initial cathodal hyperemia disperses metabolites; subsequent anodal vasoconstriction and protein coagulation decrease fluid exudation.