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Medical Laser Applications

Third Stage

Lec 7

Using Laser to Treat Cancer

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Introduction

Using Lasers to Treat Cancer.

This cutting-edge technology combines principles of optics, quantum mechanics, and biological systems to address one of humanity's greatest health challenges. By the end of this lecture, you will understand how lasers work, the mechanisms by which they interact with biological tissues, and their applications in cancer treatment.

1: Fundamentals of Laser Technology

A. What is a Laser?

- **Laser** stands for *Light Amplification by Stimulated Emission of Radiation*.
- Characteristics of laser light:
 - **Monochromatic:** Single wavelength or color.
 - **Coherent:** All photons are in phase.
 - **Directional:** A highly focused beam.

B. Components of a Laser System

- **Active Medium:** Material that amplifies light (e.g., gas, solid, or liquid).
- **Energy Source:** Provides energy to excite the medium (e.g., electrical current).
- **Optical Cavity:** Mirrors that reflect light to amplify it further.

C. Types of Lasers

- **Gas Lasers:** CO₂ lasers, He-Ne lasers.
- **Solid-State Lasers:** Nd:YAG
- **Semiconductor Lasers:** Laser diodes.
- **Dye Lasers:** Tunable across a range of wavelengths.

2 : Interaction of Lasers with Biological Tissues

A. Mechanisms of Interaction

- **Absorption:** The tissue absorbs laser energy, leading to heat generation.
- **Scattering:** Redirection of light within tissue, which affects penetration depth.
- **Reflection:** A portion of the laser light is reflected at the tissue surface.
- **Transmission:** Some laser light passes through the tissue without interaction.

B. Biological Effects

- **Photothermal Effect:** Heat generated to destroy targeted tissues.
- **Photomechanical Effect:** Shockwaves produced by rapid heating can disrupt cells.
- **Photochemical Effect:** Interaction with photosensitive agents .

3: Applications of Lasers in Cancer Treatment

A. Photothermal Therapy (PTT)

- **Mechanism:** Laser energy heats and destroys cancer cells.
- **Common Lasers Used:** Infrared and near-infrared lasers for deeper tissue penetration.
- **Applications:** Skin cancer, prostate cancer.

B. Photodynamic Therapy (PDT)

- **Mechanism:**
 - A photosensitizing agent is administered and accumulates in cancer cells.
 - Laser light activates the agent, producing reactive oxygen species (ROS) that kill cells.

- **Advantages:**
 - Minimally invasive.
 - Selective targeting of cancer cells.
- **Challenges:**
 - Limited light penetration in deep tissues.

C. Laser-Induced Interstitial Thermotherapy (LITT)

- **Mechanism:**
 - A fiber optic laser probe is inserted directly into the tumor.
 - Laser heats the tumor, causing localized destruction.
- **Applications:** Liver, brain, and pancreatic cancers.

D. Laser Surgery

- **Mechanism:** High-intensity laser beams precisely cut or remove cancerous tissue.
- **Advantages:**
 - Precision with minimal damage to surrounding tissue.
 - Reduced bleeding and faster recovery.
- **Applications:** Early-stage lung cancer, cervical cancer.

4: Advantages and Challenges of Laser Therapy

A. Advantages

- Non-invasive or minimally invasive.
- High precision and control.
- Reduced risk of infection and shorter recovery times.
- Can be combined with other treatments (e.g., chemotherapy, radiation).

B. Challenges

- Limited penetration depth for certain wavelengths.
- High initial cost of equipment.
- Requires skilled operators.
- Potential damage to surrounding healthy tissues if not carefully controlled.

5: Future Directions

A. Advances in Laser Technology

- Development of tunable lasers for better targeting.
- Use of ultrafast lasers to minimize collateral damage.

B. Integration with Nanotechnology

- Nanoparticles as targeted delivery systems for heat or photosensitizing agents.
- Improved selectivity and efficacy in deep-seated tumors.

C. Personalized Medicine

- Customized laser treatments based on genetic and molecular profiling of tumors.

Conclusion

Lasers represent a powerful tool in the fight against cancer, leveraging physics to improve precision, efficacy, and patient outcomes. By understanding the principles of laser-tissue interaction and the various therapeutic techniques, we can appreciate the interdisciplinary nature of this field and its potential for future advancements.

Discussion

1. What does LASER stand for?

- A. Light Amplification by Stimulated Emission of Radiation
- B. Light Amplified Radiation
- C. Linear Amplified Stimulated Emission
- D. Light Absorption System
- E. Laser Active Source

Correct answer: A

2. Laser light is monochromatic because it has:

- A. High power
- B. Single wavelength
- C. Wide beam
- D. Multiple colors
- E. Random phase

Correct answer: B

3. Coherence in laser light means:

- A. High energy
- B. Same direction
- C. Same phase
- D. Broad spectrum
- E. Short pulse

Correct answer: C

4. Directional laser beams are best described as:

- A. Divergent
- B. Scattered
- C. Highly focused
- D. Diffuse
- E. Random

Correct answer: C

5. Which component amplifies light in a laser?

- A. Power supply
- B. Optical cavity
- C. Fiber optic
- D. Cooling system
- E. Active medium

Correct answer: E

6. The energy source in a laser is used to:

- A. Cool mirrors
- B. Excite atoms
- C. Focus beam
- D. Guide photons
- E. Absorb light

Correct answer: B

7. Optical cavity mainly contains:

- A. Lenses
- B. Filters
- C. Mirrors
- D. Fibers
- E. Sensors

Correct answer: C

8. CO₂ laser belongs to which type?

- A. Solid-state
- B. Semiconductor
- C. Gas
- D. Dye
- E. Fiber

Correct answer: C

9. Nd:YAG laser is a:

- A. Gas laser
- B. Dye laser
- C. Semiconductor laser
- D. Solid-state laser
- E. Liquid laser

Correct answer: D

10. Laser diodes are:

- A. Gas lasers
- B. Solid lasers
- C. Dye lasers
- D. Fiber lasers
- E. Semiconductor lasers

Correct answer: E

11. Which laser type is tunable?

- A. CO₂
- B. Nd:YAG
- C. He – Ne
- D. Dye laser
- E. Diode

Correct answer: D

12. Absorption of laser light leads to:

- A. Heat generation
- B. Cooling
- C. Reflection
- D. Light loss
- E. Ionization

Correct answer: A

13. Scattering mainly affects:

- A. Laser color
- B. Beam coherence
- C. Penetration depth
- D. Power output
- E. Wavelength

Correct answer: C

14. Reflection occurs mainly at the:

- A. Cell nucleus
- B. Blood vessel
- C. Cytoplasm
- D. Mitochondria
- E. Tissue surface

Correct answer: E

15. Transmission means laser light:

- A. Passes through
- B. Is reflected
- C. Is absorbed
- D. Generates heat
- E. Produces shockwaves

Correct answer: A

16. Heat-based tissue destruction is called:

- A. Photochemical effect
- B. Photomechanical effect
- C. Photothermal effect
- D. Optical effect
- E. Quantum effect

Correct answer: C

17. Shockwaves are associated with:

- A. Photomechanical effect
- B. Photochemical effect
- C. Photothermal effect
- D. Optical scattering
- E. Reflection

Correct answer: A

18. PDT relies on:

- A. Heat only
- B. Mechanical force
- C. Electric fields
- D. Photosensitive agents
- E. Ultrasound

Correct answer: D

19. Photothermal Therapy works by:

- A. Free radicals
- B. DNA repair
- C. Drug release
- D. Immune activation
- E. Heating cells

Correct answer: E

20. PTT commonly uses:

- A. UV lasers
- B. Visible lasers
- C. Infrared lasers
- D. X-rays
- E. Gamma rays

Correct answer: C

21. Near-infrared lasers are used because of:

- A. Low cost
- B. High color purity
- C. Deep penetration
- D. High reflection
- E. Short wavelength

Correct answer: C

22. PDT activates agents to produce:

- A. Heat
- B. Reactive oxygen species
- C. Ions
- D. Sound waves
- E. Plasma

Correct answer: B

23. PDT is considered:

- A. Highly invasive
- B. Minimally invasive
- C. Non-selective
- D. Painful
- E. Obsolete

Correct answer: B

24. Main limitation of PDT is:

- A. Limited penetration
- B. Toxic drugs
- C. High cost
- D. Long recovery
- E. Bleeding

Correct answer: A

25. LITT uses:

- A. Fiber optic probe
- B. Radiation source
- C. External laser beam
- D. Ultrasound probe
- E. Magnetic field

Correct answer: A

26. LITT delivers laser energy:

- A. On skin surface
- B. Through blood
- C. Via inhalation
- D. Directly into tumor
- E. Through IV

Correct answer: D

27. LITT is commonly used for:

- A. Skin cancer
- B. Brain tumors
- C. Bone cancer
- D. Eye tumors
- E. Blood cancer

Correct answer: B

28. Laser surgery primarily uses:

- A. Low power beams
- B. Scattered light
- C. RF waves
- D. Pulsed ultrasound
- E. High-intensity beams

Correct answer: E

29. Major advantage of laser surgery is:

- A. Low cost
- B. Wide damage
- C. High precision
- D. Long recovery
- E. Deep bleeding

Correct answer: C

30. Laser surgery reduces:

- A. Accuracy
- B. Infection risk
- C. Equipment cost
- D. Skill requirement
- E. Laser power

Correct answer: B

31. Early-stage lung cancer can be treated with:

- A. Laser surgery
- B. Chemotherapy
- C. PDT only
- D. Hormone therapy
- E. Immunotherapy

Correct answer: A

32. One major advantage of laser therapy is:

- A. Long treatment time
- B. Low precision
- C. Short recovery
- D. High invasiveness
- E. Severe pain

Correct answer: C

33. A key challenge of laser therapy is:

- A. Poor control
- B. Limited penetration
- C. Low temperature
- D. Weak targeting
- E. Long pulses

Correct answer: B

34. Laser equipment is often:

- A. Portable
- B. Low cost
- C. Disposable
- D. Expensive
- E. Manual

Correct answer: D

35. Laser treatments require:

- A. Skilled operators
- B. Automated systems
- C. Minimal training
- D. AI control only
- E. No supervision

Correct answer: A

36. Ultrafast lasers help to:

- A. Increase bleeding
- B. Reduce precision
- C. Minimize damage
- D. Increase penetration
- E. Heat tissue more

Correct answer: C

37. Tunable lasers allow:

- A. Fixed wavelength
- B. Better targeting
- C. Lower efficiency
- D. Higher reflection
- E. Random emission

Correct answer: B

38. Nanoparticles in laser therapy improve:

- A. Cost
- B. Size
- C. Selectivity
- D. Reflection
- E. Noise

Correct answer: C

39. Nanotechnology helps treat:

- A. Only skin tumors
- B. Superficial tumors
- C. Blood disorders
- D. Benign tumors
- E. Deep tumors

Correct answer: E

40. Personalized laser therapy is based on:

- A. Age only
- B. Tumor genetics
- C. Tumor size only
- D. Laser color
- E. Body weight

Correct answer: B