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Medical Laser Applications

Third Stage

Lec 8

Photodynamic therapy

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Photodynamic Therapy (PDT)

Introduction

Photodynamic therapy (PDT) is a minimally invasive medical treatment that uses a combination of light, a photosensitizing agent, and oxygen to selectively destroy abnormal cells, such as cancerous or precancerous cells. This therapy has applications in oncology, dermatology, and ophthalmology, among other fields.

Involves light-sensitive medicine and a light source to destroy abnormal cells. It can be used to treat some skin and eye conditions, as well as certain types of cancer.

Photodynamic therapy uses a drug that is activated by light, called a photosensitizer or photosensitizing agent, to kill cancer cells. The light can come from a laser or other source, such as LEDs.

Photodynamic therapy is also called PDT.

Photodynamic therapy is most often used as a local treatment, which means it treats a specific part of the body.

Why it's done ?

Photodynamic therapy is used to treat a variety of conditions, including:

- Pancreatic cancer.
- Bile duct cancer, also known as cholangiocarcinoma.
- Esophageal cancer.
- Lung cancer.
- Head and neck cancers.
- Certain skin diseases, including acne, psoriasis, nonmelanoma skin cancer and precancerous skin changes, known as actinic keratosis.
- Bacterial, fungal and viral infections.

How photodynamic therapy treats cancer

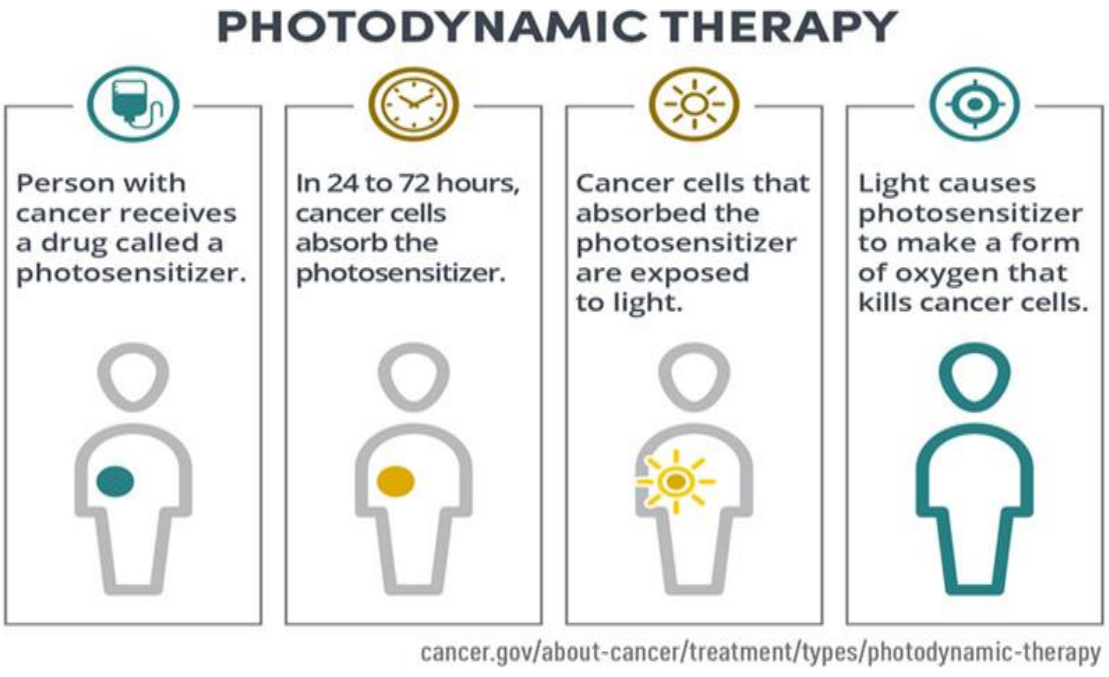
When cells that have absorbed photosensitizers are exposed to a specific wavelength of light, the photosensitizer produces a form of oxygen, called an oxygen radical, that kills them.

Photodynamic therapy may also damage blood vessels in the tumor, which prevents it from receiving the blood it needs to keep growing. And, it may trigger the immune system to attack tumor cells, even in other areas of the body.

How photodynamic therapy is given

Photodynamic therapy is a multi-step process. First, the patient will receive a photosensitizer. The drug may be taken by mouth, spread on the skin, or given through the vein **(IV)**, depending on where the tumor is in the body. After 24 to 72 hours, most of the drug will have left normal cells but remain in cancer or precancer cells. Then your tumor will be exposed to the light source.

How the light is applied depends on where the tumor is. For skin tumors, the light is aimed right at the cancer. For tumors in the throat, airways, and lungs, your doctor will insert an endoscope down your throat.



An endoscope is a thin, lighted tube that can help the doctor see inside the body. Once the endoscope is in place, the doctor threads a fiber optic cable that transmits light through it to reach the treatment areas.

Mechanism of Action

1. The photosensitizer is administered to the patient either intravenously, orally, or topically.
2. After an incubation period (24 to 72 hours),during which the **PS** accumulates in the target cells, the area is exposed to a specific wavelength of light.
3. Upon light activation, the PS undergoes a photochemical reaction, transferring energy to oxygen molecules to generate ROS.
4. These ROS induce oxidative stress, leading to apoptosis (programmed cell death) or necrosis (cell lysis) in the target tissue.
5. Vascular damage and immune responses contribute to further destruction of abnormal cells.

Principles of PDT

PDT is based on three essential components:

1. **Photosensitizer (PS):** A light-sensitive compound that, when exposed to a specific wavelength of light, produces reactive oxygen species (ROS) that damage cellular structures.
2. **Light Source:** A laser or LED that emits light at a wavelength absorbed by the photosensitizer, typically in the red or near-infrared spectrum.
3. **Oxygen:** Molecular oxygen present in the tissue reacts with the activated photosensitizer to produce ROS, leading to cell destruction.

Types of Photosensitizers

Photosensitizers are classified into three generations:

- **First-generation:** Examples include hematoporphyrin derivative (HpD), which was among the earliest used PS compounds.
- **Second-generation:** These have improved selectivity and lower side effects. Examples include Photofrin, Foscan, and Temoporfin.
- **Third-generation:** These are modified for better targeting, such as nanoparticles or antibody-conjugated PS.

Light Sources in PDT

The choice of light source depends on the application and the depth of penetration required:

- **Lasers:** Provide precise control over wavelength and intensity. Common types include diode lasers.
- **LEDs:** Used for broader applications with lower cost and easier handling.
- **Fiber-optic systems:** Used for treating internal organs by delivering light through catheters.

Applications of PDT

PDT is used in various medical fields, including:

- **Oncology:** Treatment of cancers such as lung, esophageal, skin, and bladder cancers.
- **Dermatology:** Treating actinic keratosis, psoriasis, and acne.
- **Ophthalmology:** Managing conditions like age-related macular degeneration (**AMD**).
- **Antimicrobial Therapy:** Used for bacterial, viral, and fungal infections.

Advantages of PDT

- Minimally invasive and targeted treatment
- Low systemic toxicity
- Repeatable without cumulative side effects
- Minimal damage to surrounding healthy tissue

Limitations and Challenges

- Limited penetration depth of light (typically 1-2 cm)
- Photosensitivity side effects (patients must avoid sunlight for some time)
- Requires oxygen, limiting its effectiveness in hypoxic tumors

Future Prospects in PDT

- Development of novel photosensitizers with improved targeting
- Combination therapies with chemotherapy or immunotherapy
- Advancements in nanoparticle-mediated **PDT** for enhanced delivery

Conclusion

Photodynamic therapy is an innovative and evolving treatment modality with significant potential in various medical applications. Its selective action, minimal invasiveness, and ability to be repeated without severe side effects make it a valuable tool in medical physics and clinical practice.

Discussion

1. PDT is best described as:

A. Surgical removal
B. Chemotherapy
C. Light-based therapy
D. Radiation therapy
E. Hormonal therapy

Correct answer: C

2. PDT requires all EXCEPT:

A. Light
B. Oxygen
C. Photosensitizer
D. Heat
E. Target tissue

Correct answer: D

3. The drug used in PDT is called:

A. Photosensitizer

B. Chemotherapeutic

C. Antibiotic

D. Analgesic

E. Steroid

Correct answer: A

4. PDT mainly treats:

A. Whole body
B. Local area
C. Brain only
D. Blood diseases
E. Bone disorders

Correct answer: B

5. PDT light source can be:

A. Ultrasound

B. Microwave

C. Gamma ray

D. X-ray

E. Laser

Correct answer: E

6. PDT is commonly used in:

A. Cardiology

B. Oncology

C. Nephrology

D. Endocrinology

E. Orthopedics

Correct answer: B

7. PDT can treat which skin condition?

A. Vitiligo

B. Burns

C. Eczema

D. Acne

E. Warts

Correct answer: D

8. PDT treats cancer by producing:

A. Heat

B. Electrons

C. Oxygen radicals

D. Hormones

E. Enzymes

Correct answer: C

9. The oxygen involved in PDT is:

A. Molecular

B. Ionic

C. Atomic

D. Liquid

E. Solid

Correct answer: A

10. PDT damage to tumors includes:

A. DNA mutation

B. Blood vessel damage

C. Bone fracture

D. Nerve growth

E. Cell fusion

Correct answer: B

11. PDT may activate:

A. Immune system

B. Nervous system

C. Digestive system

D. Skeletal system

E. Endocrine system

Correct answer: A

12. Photosensitizers accumulate mainly in:

A. Normal cells

B. Cancer cells

C. Muscle cells

D. Nerve cells

E. Bone cells

Correct answer: B

13. Typical incubation time is:

A. 1–3 hours

B. 6–12 hours

C. 2 weeks

D. 5–7 days

E. 24–72 hours

Correct answer: E

14. PDT light wavelength is usually:

A. UV

B. Blue

C. Green

D. Red / NIR

E. Gamma

Correct answer: D

15. Internal tumors are treated using:

A. Syringe

B. Catheter

C. Endoscope

D. Scalpel

E. Stent

Correct answer: C

16. Light delivery inside the body uses:

A. Fiber optics

B. Plastic tube

C. Copper wire

D. Steel rod

E. Glass plate

Correct answer: A

17. PDT primarily causes:

A. Cell growth

B. Cell fusion

C. Oxidative stress

D. Thermal burn

E. Mutation

Correct answer: C

18. Programmed cell death is called:

A. Necrosis

B. Apoptosis

C. Lysis

D. Inflammation

E. Repair

Correct answer: B

19. Cell lysis is known as:

A. Apoptosis

B. Necrosis

C. Division

D. Regeneration

E. Differentiation

Correct answer: B

20. PDT is based on how many components?

A. One

B. Two

C. Three

D. Four

E. Five

Correct answer: C

21. Which is NOT a PDT component?

A. Oxygen

B. Light

C. Photosensitizer

D. Heat

E. Reactive oxygen species (ROS)

Correct answer: D

22. ROS stands for:

A. Reactive oxygen species

B. Reduced oxygen state

C. Rapid oxidation system

D. Reactive organic salt

E. Random oxygen signal

Correct answer: A

23. First-generation PS example:

A. Photofrin

B. Foscan

C. Temoporfin

D. HpD

E. Nanoparticle PS

Correct answer: D

24. Second-generation PS are known for:

A. High toxicity

B. Poor selectivity

C. No oxygen need

D. No light need

E. Improved selectivity

Correct answer: E

25. Third-generation PS use:

A. UV light

B. Antibodies

C. Heat

D. Radiation

E. Surgery

Correct answer: B

26. Common laser used in PDT:

A. CO_2

B. Nd:YAG

C. Diode

D. Excimer

E. Ruby

Correct answer: C

27. LEDs in PDT are:

A. Expensive

B. Complex

C. Toxic

D. Invasive

E. Low cost

Correct answer: E

28. PDT penetration depth is about:

A. Whole body

B. 5–10 cm

C. 0.1 mm

D. 10–20 cm

E. 1–2 cm

Correct answer: E

29. PDT effectiveness is reduced in:

A. Oxygen-rich tissue

B. Hypoxic tumors

C. Normal tissue

D. Skin lesions

E. Eye tissue

Correct answer: B

30. PDT side effect includes:

A. Hair loss

B. Bone pain

C. Photosensitivity

D. Anemia

E. Nausea

Correct answer: C

31. PDT damage to healthy tissue is:

A. Minimal

B. Extensive

C. Severe

D. Permanent

E. Unavoidable

Correct answer: A

32. PDT can be repeated because:

A. High toxicity

B. No accumulation

C. High cost

D. Long recovery

E. No cumulative effects

Correct answer: E

33. PDT in ophthalmology treats:

A. Cataract

B. Glaucoma

C. Myopia

D. AMD

E. Astigmatism

Correct answer: D

34. PDT treats infections by:

A. Heating

B. Cutting

C. ROS generation

D. Antibiotics

E. Vaccination

Correct answer: C

35. PDT is considered:

A. Highly invasive

B. Nonselective

C. Minimally invasive

D. Experimental only

E. Surgical

Correct answer: C

36. PDT light must match:

A. PS absorption

B. Tumor size

C. Tissue color

D. Blood flow

E. Skin thickness

Correct answer: A

37. PDT is NOT mainly used for:

A. Lung cancer

B. Skin cancer

C. Bone cancer

D. Esophageal cancer

E. Head and neck cancer

Correct answer: C

38. PDT drugs leave normal cells after:

A. Minutes

B. Hours

C. Weeks

D. 1–3 days

E. Months

Correct answer: D

39. Nanoparticles in PDT improve:

A. Heat delivery

B. Targeting

C. Surgery

D. Radiation dose

E. Imaging only

Correct answer: B

40. PDT belongs mainly to:

A. Medical chemistry

B. Pharmacology

C. Nuclear medicine

D. Biochemistry

E. Medical physics

Correct answer: B