University of Al-Mustaqbal
College of Science
Department of Medical Physics

AL- Mustaqpal University

Science College

Dep. Medical physics

Medical Laser Applications

Third Stage

Lec 9

Laser Lithotripsy

Asst. lec. Ali Salman Hamadi

Introduction

Laser lithotripsy is an advanced, minimally invasive technique used in the medical field to break down kidney, ureteral, and bladder stones using laser energy. This method has revolutionized urology and nephrology by providing a safer and more effective alternative to traditional stone removal techniques such as extracorporeal shock wave lithotripsy (ESWL) and open surgery.

Fundamentals of Lithotripsy

Lithotripsy refers to the process of breaking stones within the urinary tract into smaller fragments, making them easier to pass naturally or be removed via medical procedures. Traditional lithotripsy techniques include:

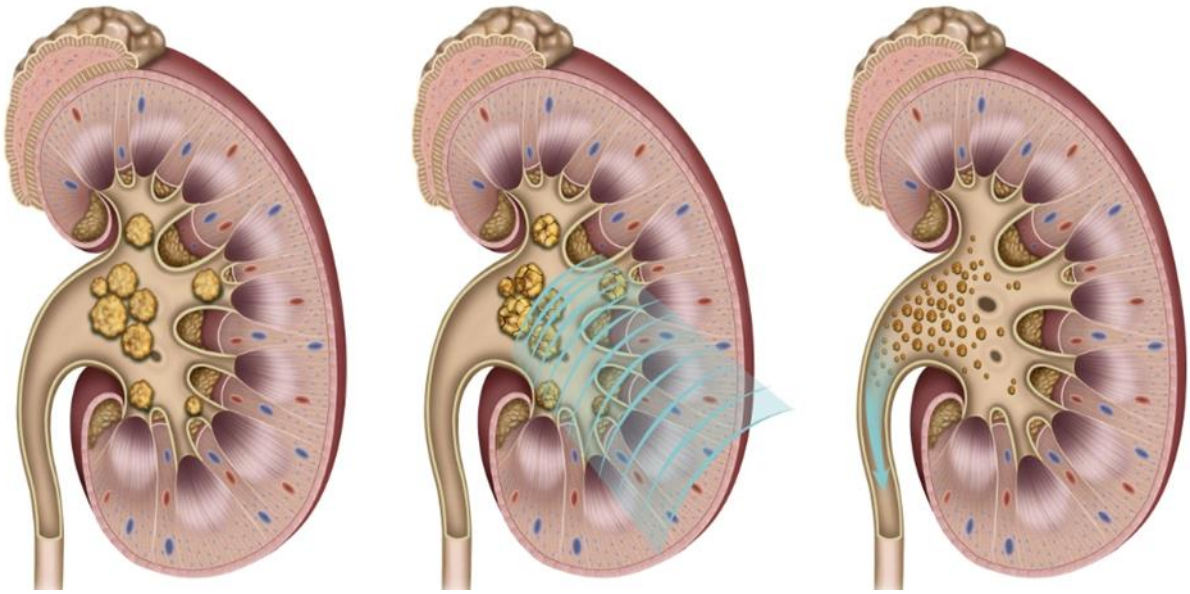
- **Extracorporeal Shock Wave Lithotripsy (ESWL):** Uses focused shock waves to fragment stones.
- **Ultrasonic Lithotripsy:** Uses ultrasonic energy to break down stones.
- **Laser Lithotripsy:** Uses laser energy to fragment stones.

Principles of Laser Lithotripsy

Laser lithotripsy is performed using a **holmium:yttrium-aluminum-garnet (Ho:YAG) laser**, which is highly effective in fragmenting stones regardless of their composition. The fundamental principles involve:

1. **Laser-Tissue Interaction:** The Ho:YAG laser emits a high-intensity pulsed infrared beam at a wavelength of **2.1 µm**, which is strongly absorbed by water and biological tissues.
2. **Stone Fragmentation Mechanism:** When laser pulses are delivered through a fiber-optic probe inside a flexible ureteroscope, they create a photothermal effect, causing the stone to disintegrate into fine particles.

3. **Bubble Formation and Collapse:** The laser energy generates small plasma bubbles within the urinary tract. These bubbles expand and collapse rapidly, generating mechanical stress that aids in breaking down stones.
4. **Fragmentation vs. Dusting Techniques:**
    - **Fragmentation Mode:** The laser breaks the stone into small pieces that can be extracted.
    - **Dusting Mode:** The laser pulverizes the stone into fine dust that can be expelled naturally through urination.



Equipment and Procedure

Key Components of the Laser Lithotripsy System:

- **Holmium:YAG laser unit**
- **Fiber-optic delivery system**
- **Flexible or rigid ureteroscope**
- **Irrigation system for clear visualization**

Procedure:

1. The patient is placed under anesthesia.
2. A flexible ureteroscope is inserted through the urethra into the ureter or kidney to locate the stone.
3. A laser fiber is introduced through the working channel of the ureteroscope and positioned in contact with the stone.
4. Laser pulses are applied to fragment or dust the stone.
5. The fragments are either extracted using a basket or left to pass naturally.
6. The procedure is completed, and the patient is monitored for complications.

Advantages of Laser Lithotripsy

- **Highly effective** against all stone types.
- **Minimally invasive**, reducing the risk of infection and complications.
- **Precise targeting**, minimizing damage to surrounding tissues.
- **Low retreatment rates** compared to ESWL.
- **Reduced hospital stay** and faster recovery.

Limitations and Risks

- Potential for **thermal damage** to surrounding tissues.
- Risk of **ureteral injury** or perforation.
- May require **multiple sessions** for larger stones.
- Equipment costs and **technical expertise** required.

Recent Advances and Future Directions

- **Thulium Fiber Laser (TFL):** A promising alternative to Ho:YAG with better efficiency and finer dusting capability.
- **Artificial Intelligence (AI) in Lithotripsy:** AI-assisted navigation for improved stone localization and laser control.
- **Improved Fiber-Optic Technology:** Enhanced fiber durability and flexibility for better maneuverability.
- **Robotic-Assisted Lithotripsy:** Increasing precision and automation in laser stone fragmentation.

Conclusion

Laser lithotripsy is an essential tool in modern urology, offering a precise and minimally invasive approach for treating urinary stones. The integration of laser physics and medical technology makes it an important topic for students in the field of **medical physics**, providing them with insights into **laser-tissue interactions, energy delivery mechanisms, and clinical applications**.

Discussion Questions:

1. How does **Ho:YAG** laser compare to other lithotripsy techniques in terms of efficacy and safety?
2. What are the main factors influencing the success of laser lithotripsy?
3. What future advancements could further improve laser lithotripsy procedures?

Discussion

1. Laser lithotripsy is mainly used to treat:

A. Gallstones

B. **Urinary stones** ☑

C. Lung tumors

D. Brain clots

E. Bone fractures

2. Laser lithotripsy is considered:

A. Highly invasive

B. Open surgery

C. **Minimally invasive** ☑

D. Cosmetic only

E. Diagnostic method

3. The most commonly used laser in laser lithotripsy is:

A. CO_2 laser

B. Excimer laser

C. Nd:YAG

D. **Ho:YAG** ☑

E. Argon laser

4. The wavelength of Ho:YAG laser is approximately:

A. 532 nm

B. 1064 nm

C. **2.1 µm** ☑

D. 10.6 µm

E. 800 nm

5. Ho:YAG laser energy is strongly absorbed by:

A. Bone

B. Air

C. Fat

D. **Water** ☑

E. Calcium

6. Lithotripsy means:

A. Stone formation

B. Stone removal

C. Stone analysis

D. **Stone fragmentation** ☑

E. Stone imaging

7. ESWL uses:

A. **Shock waves** ☑

B. Ultrasound probes

C. Laser pulses

D. Radiofrequency

E. X-rays

8. Ultrasonic lithotripsy uses:

A. Light energy

B. Shock waves

C. Heat only

D. **Ultrasonic energy** ☑

E. Magnetic fields

9. Laser lithotripsy delivers energy through:

A. Metal needle

B. Electric wire

C. Glass tube

D. Plastic catheter

E. **Fiber optic** ☑

10. The laser fiber is guided using:

A. MRI

B. CT scanner

C. Endoscope only

D. Ultrasound

E. **Ureteroscope** ☑

11. The main stone-breaking effect is:

A. Photoelectric

B. Photochemical

C. **Photothermal** ☑

D. Photoacoustic

E. Photobiological

12. Bubble formation contributes mainly to:

A. Imaging

B. Cooling

C. Illumination

D. **Mechanical stress** ☑

E. Drug delivery

13. Dusting technique produces:

A. **Fine particles** ☑

B. Sharp pieces

C. Stone blocks

D. Large fragments

E. Solid mass

14. Fragmentation mode aims to:

A. Vaporize stones

B. Dissolve stones

C. Compress stones

D. Harden stones

E. **Create extractable pieces** ☑

15. Laser lithotripsy is effective against:

A. Soft stones only

B. Calcium stones

C. Uric stones

D. Cystine stones

E. **All stone types** ☑

16. One major advantage over ESWL is:

A. More pain

B. Lower precision

C. **Lower retreatment** ☑

D. Longer recovery

E. Higher radiation

17. A key risk of laser lithotripsy is:

A. Blindness

B. Infection only

C. Kidney failure

D. **Thermal injury** ☑

E. Cardiac arrest

18. Large stones may require:

A. No treatment

B. One pulse

C. ESWL only

D. **Multiple sessions** ☑

E. Observation

19. The irrigation system is used for:

A. Cooling patient

B. **Clear vision** ☑

C. Drug delivery

D. Stone removal

E. Laser focusing

20. The patient is usually under:

A. Local cooling

B. No anesthesia

C. Sedation only

D. **Anesthesia** ☑

E. Hypnosis

21. A newer alternative to Ho:YAG is:

A. **Thulium fiber laser** ☑

B. Argon laser

C. Diode laser

D. CO_2 laser

E. Ruby laser

22. Thulium fiber laser is known for:

A. Higher pain

B. **Better dusting** ☑

C. Less precision

D. Deeper penetration

E. Lower efficiency

23. AI in lithotripsy helps in:

A. Stone growth

B. Energy loss

C. Patient sedation

D. **Laser control** ☑

E. Pain induction

24. Robotic-assisted lithotripsy improves:

A. **Precision** ☑

B. Manual effort

C. Stone hardness

D. Cost only

E. Radiation dose

25. Laser lithotripsy is important for medical physics because it combines:

A. Chemistry and biology

B. Surgery and drugs

C. Imaging and AI

D. **Laser physics & medicine** ☑

E. Anatomy and pathology