"Fragmentation of kidney and ureteral stones including LASER technology"

TULANE UROLOGY

Evaluation – What imaging is needed

- Plain radiography (inability to detect radiolucent stones)
- Renal ultrasonography (limited sensitivity for stones less than 2 to 3 mm in size) - Initial imaging study of choice for pregnant patients
- Unenhanced helical CT scanning = standard imaging modality
  - Information on stone burden, location, collecting system anatomy, relational anatomy of kidney and ureter, and perinephric findings
  - Check Hounsfield units, stones less than 1000 Hounsfield units and skin to stone distance 9 to 10 cm or less have better treatment outcomes
  - Watch out for radiation exposure

When to use ESWL

Indications

- Renal and ureteral stones less than 2 cm in size
  - Stones between 1 to 2 cm should have composition and stone location taking into account
- Proximal ureteral stones (distal ureteral stones have lower stone free rates compared to URS)
- Can be performed anywhere along the length of the ureter or kidney, although preferred in proximal ureter and kidney
- Patients who are not able to receive general anesthesia
- Low HU stones (less than 900-1000 HU)
- Skin to stone distance less than 10 to 11 cm

Contraindications

- Staghorn calculi
- Lower pole stone (Relative contraindication due to decreased clearance of stone fragments after procedure)
- Uric acid stones (Able to fragment uric acid stones but difficult to visualize on x-ray)
- Cystine and brushite stones (shockwave resistant)
- Obesity
- Anatomic characteristics acute infundibulopelvic angle, narrow or long infundibula and multiple infundibula
- Anatomic abnormalities such as calyceal diverticuli, kidney rotation, kidney fusion
- Pregnancy
- Aortic aneurysm (increased risk of bleeding)
- Infected stones

Shockwave lithotripsy

- Shockwaves have positive pressure component and negative pressure component
  - Positive pressure component AKA compressive phase can produce pressures from 20-100 mPa
  - Negative pressure components can produce pressures of –5 to –15 mPa
- Repetitive administration of shockwaves create small fractures and targeted stone, over course of treatment small cracks grow and eventually lead to stone fragmentation
- Fragmentation (comminution) can occur due to several mechanisms
  - Shear stress: shockwave passes into stone and interacts with lateral walls of stone causing stress
  - Small fracture: Shockwave enters stone and reflects from rear of stone, shockwave reflects back to anterior stone resulting in tensile stress
  - Super focusing: Application of stress within stone due to geometry of stone, shockwave reflects within stone
  - Squeezing: Shockwave within stone propagates more rapidly than shockwave in fluid outside stone causing circumferential stress
  - Cavitation: Small bubbles grow in fluid surrounding stone Response to large negative pressure component of shockwave and as bubbles collapsed micro jet of fluid impacted stone surface

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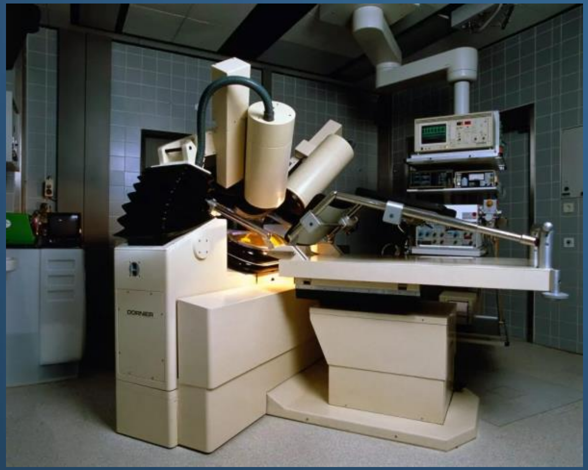
- Fatigue: Imperfections within stone concentrate stresses, this leads to micro-cracks then macro-cracks then fragmentation

History

- 1971 first in vitro crumbling of kidney stone with shockwaves in Germany
- 1980 Dornier lithotripter HM 1 treated patient with kidney stone in Munich
- 1983 Dornier HM 3 introduced in Germany

Modulith SLX F2

Dornier HM-1

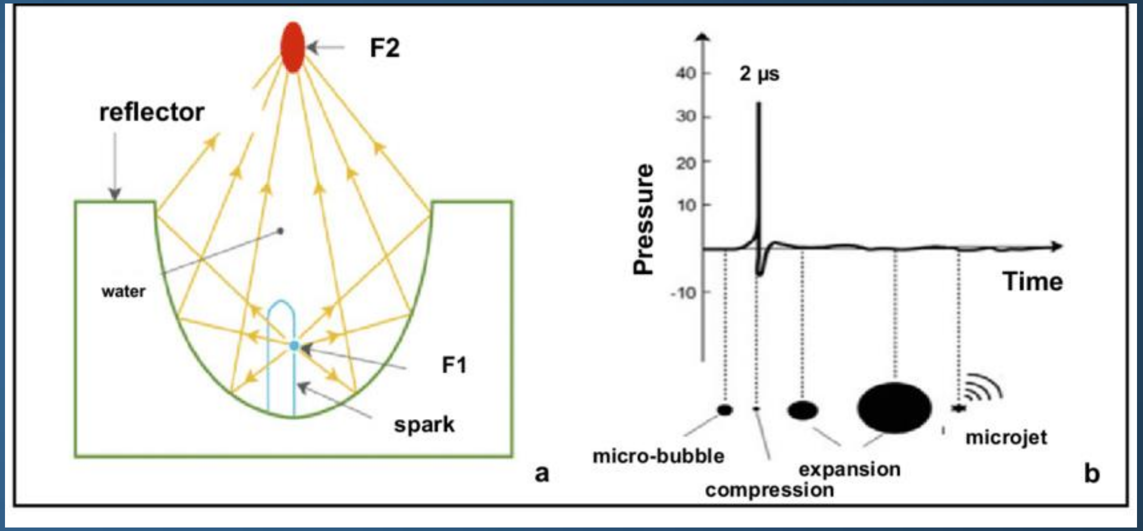


Dornier HM-3

Dornier Delta-3

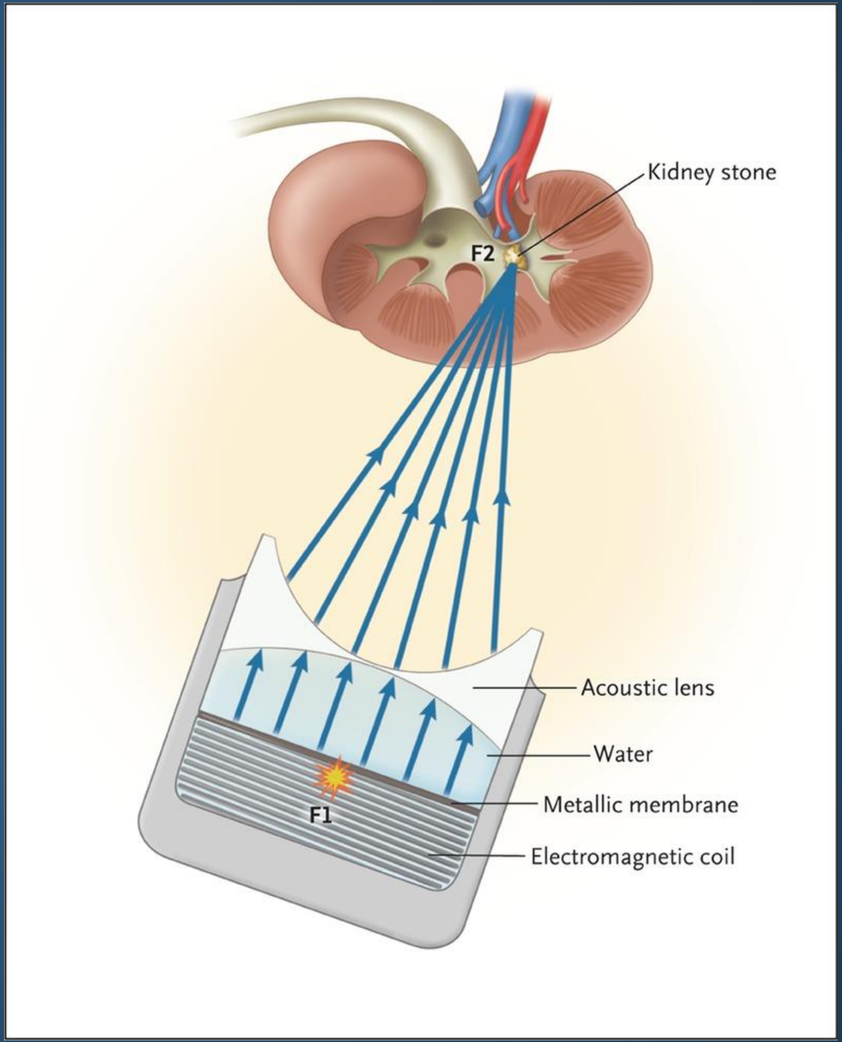
Generators: Electrohydraulic Lithotripter (EHL)

- Mechanism of action: Underwater Spark discharge create spherical Shockwave that is focused using ellipsoid reflector
  - High voltage applied to 2 opposing electrodes positioned 1 mm apart, High-voltage spark discharge causes explosive vaporization of water at electrode tip
- Very effective at breaking stones
- Wide pressure fluctuations from shock to shock and short electrolyte



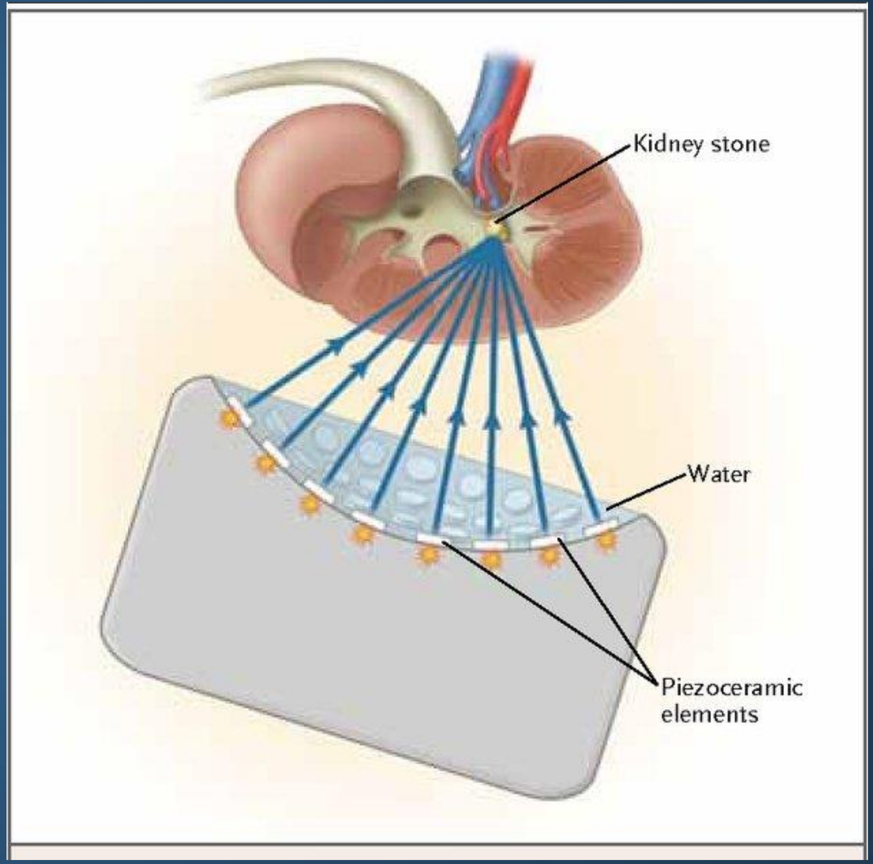
Generators: Electromagnetic generator

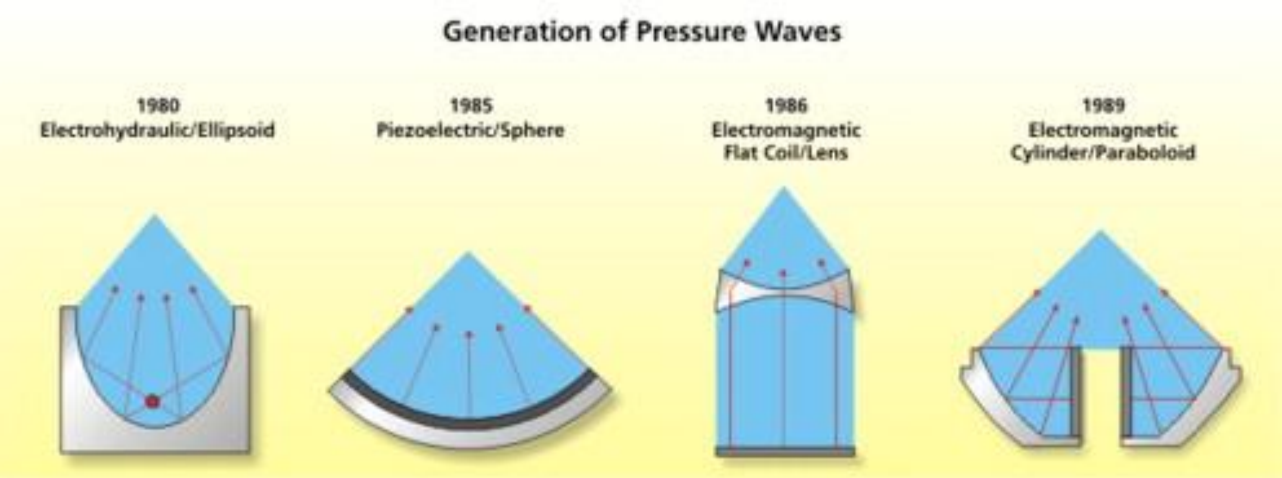
- Mechanism of action: Produces either flat plane waves focus by acoustic lens or cylindrical waves focus by parabolic reflector
- Highly controlled shocks, shocks are consistent
- Wide area of induction over body causes less pain
- Generator is durable
- Increased risks of subcapsular hematoma due to highly focused intrarenal energy



Generators: Piezoelectric generator

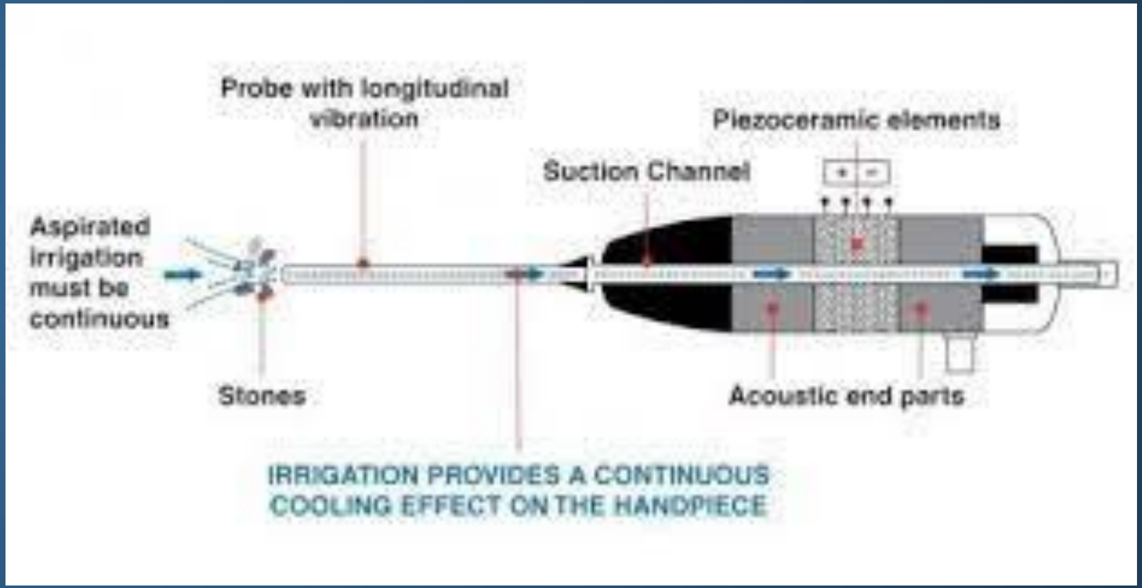
- Mechanism of action: Planar shockwaves with directly converging shock fronts
- Has good focusing accuracy
- Longer service life, less electrode changes
- Minimal pain due to low energy density at skin
- Power delivered is magnitudes less than other generators





Ultrasonic Lithotripter

- Ultrasound is a soundwave in frequency greater than 20,000 Hz
- Ultrasound transducer probe generates sound waves by means of piezoelectric effect
- Generator delivers alternating polarity electrical current to piezoelectric crystals with ultrasound probe causing transformation and shape of crystals and conversion of electrical energy to mechanical energy to create linearly oscillating surface at high frequency
- Probe oscillates in linear fashion with similar frequency to crystals, causing frictional forces which leads to temperature Elevation and mechanical disruption, Ultrasonic energy exerted to stone
  - Works through contact with stone directly
- Good safety profile as waves are generally weak except when converging
- Complications occur when ultrasonic energy applied to adjacent tissue from target site, causing inadvertent heating and potential destruction of nontargeted tissue such as ureter or kidney, can experience temperatures in excess of 200 ° C)



Laser (light amplification by simulated emission of radiation)

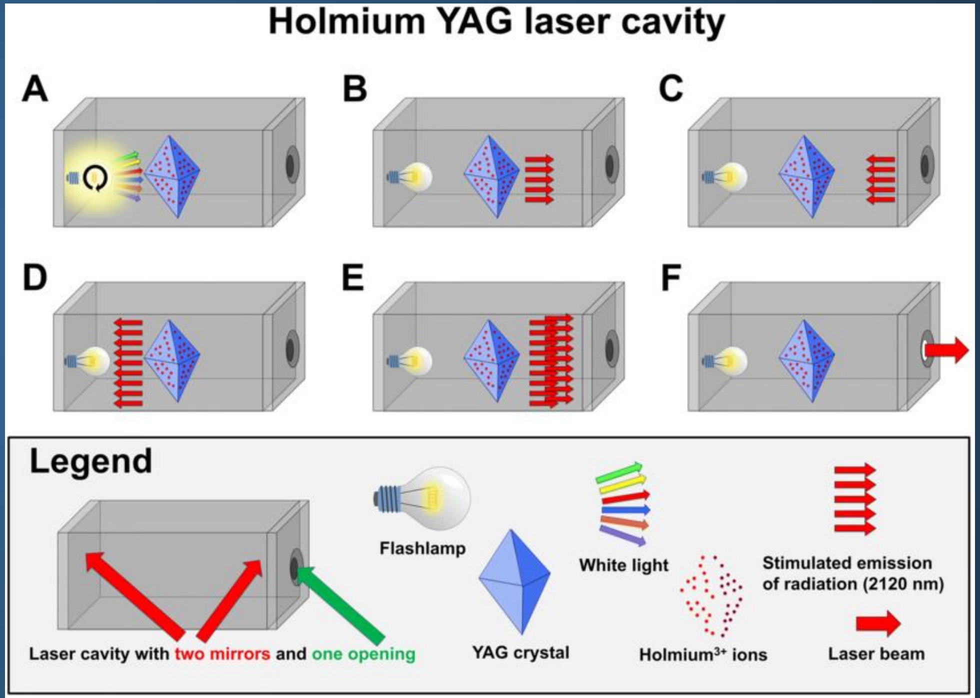
- External energy is applied to electrons which are brought out of their resting states to higher energy states
  - Initiating energy can be electrical, optical, or chemical
  - Most medical lasers use electricity to create bright light
- Electron spontaneously return to resting state, when this happens photon(s) of energy are emitted
- This is characteristic of the admitting atom (i.e. holmium, Neodymium:yttrium-aluminum-garnet aka Nd:YAG, CO_2)
- If emitted photon strikes another atom already at higher state, stimulated emission occurs
- Medical lasers use active mediums through which continued stimulated emission and build up of energy allows for controlled release of energy either in a continuous or pulsed mode
- Delivery through laser resonator via
  - Collimated/non-divergent (always in parallel)
  - Monochromatic (same wavelength)
  - Coherent (waves travel in phase)

Laser Continued

- Laser characteristics
  - Energy: Capacity to do work
  - Frequency: Cycle of laser energy delivered over a Period of time
  - Power: Rate at which energies delivered
  - Power density: Watts per area at target surface
- Delivery can be end fire (energy admitted through tip) or side fire (energy discharge at an angle)
- Energy travels along laser fiber through internal reflexion

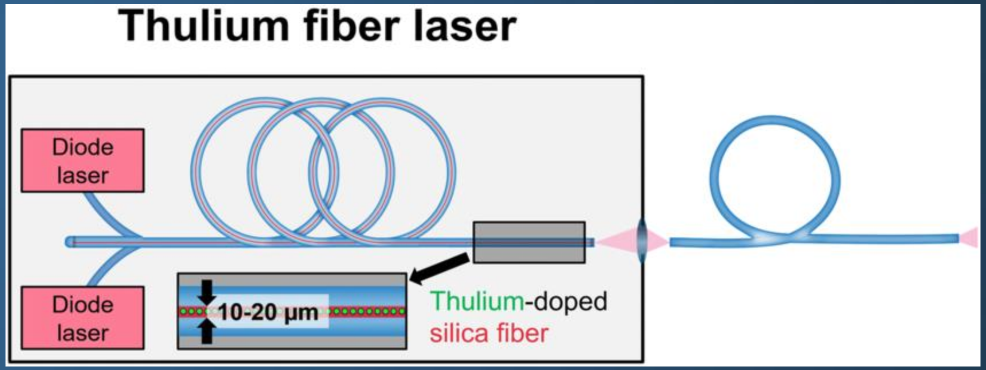
Holmium Laser

- Used for prostate, stones, strictures, bladder tumors
- Solid-state pulsed wave laser
- 2140 nm
- Strongly absorbed by water
- For the thermal effect: Direct laser energy absorption causes chemical decomposition and ablation
- Thermal chemical: Vaporization of water inside stone pores lead to stone bursting from inside
- 2 major considerations: Efficiency of fragmentation and retropulsion
- Total energy (Watt) = pulse energy (joules) x frequency (hertz)
- Pulse Width
  – Short pulse width --> More fragmentation, more retropulsion
  – Long pulse width --> Less efficiency, less retropulsion
- Technique
  – Fragmentation: High energy (1-2 J), low frequency (6-10 Hz), short pulse
  – Dusting: Low energy (0.2 to 0.5 J), high-frequency (Greater than 40 Hz), long pulse
  – Noncontact aka popcorning: Moderate energy (1 to 1.5 J), moderate frequency (10 to 15 Hz)
  – Moses: Dual phase - First phase creates vapor channel, second phase delivers energy to stone less impeded by intervening fluid
    - Contact mode (0 to 1 mm), Distance mode (2 mm)
    - Benefit reduce retropulsion, higher stone ablation, shorter time and fragmentation mode



Thulium Laser

- Diode laser
- 1940 nm
- Match high and low water absorption peaks and tissue, can provide higher efficiency
- Smaller laser fiber due to more focused spatial beam profile
- Pulse energy 0.25 to 6 J, pulse frequency 5 to 2200 Hz, pulse width 200 to 12,000 µs, variable fiber sizes
- Compact and more easily cooled
- Less retropulsion, more efficient, faster stone breaking time compared to holmium



Common lasers in urology

- KTP–potassium titanyl phosphate (Greenlight laser)
  - 532 nm wavelength, 80/120/1 80 W units available
  - Continuous-wave delivery of energy, side fire laser fiber
  - Used for prostate ablation
- Nd:YAG
  - 1064 nm wavelength (near)
  - Deep penetration among clinical lasers
  - Continuous or pulsed
- Carbon dioxide
  - 10,000+ nanometer wavelength, 15 and 25 W Systems
  - Continuous-wave, pulse, and super-pulse options
  - Articulating arm with and fired energy delivery
  - Used mainly for skin lesions including genital warts