INTRODUCTION

Despite medical treatment, in the presence of renal dysfunction, intractable colicky pain and persistent urinary tract obstruction, ureteric stone, should be promptly managed [1].

In academic centers, the endoscopic management is one of the most important therapies for ureteral stones [2].

During the past 2 decades, as major technical improvements, ureteroscopy (URS) is the first choice of treatment for ureteral stones in nearly all locations [3].

The introduction of smaller flexible and semirigid URS has led to safer and more efficacious treatment method. Indeed, URS has become one of the most important techniques in the treatment of urolithiasis [4].

The laser, particularly holmium: yttrium aluminum garnet (Ho: YAG), is the most efficient system for treatment of all kinds of calculi in all locations [5].

Ho: YAG laser, is the gold standard for flexible and rigid URS [6].

Recent development in the design of endoscopic instruments & URS have enabled the ureteroscopy to replace the open surgery treatment of urolithiasis as minimally invasive modality [7].

Ho: YAG laser is reliable method for the treatment of ureteral calculi especially in proximal and impacted ureteric calculi, but it's expensive and not available in most urologic centers [8].

Ureteroscopic lithotripsy incorporates abundant subtypes, such as laser lithotripsy (LL), pneumatic lithotripsy (PL), ultrasonic and electrohydraulic lithotripsy. Among them, laser and pneumatic lithotripsy are two major approaches favored by urologists [9].

The success rate of laser for fragmenting urinary calculi range from 80 to 95% [10].

AIM OF THE WORK

To assess the efficiency of laser lithotripsy in management of ureteric stones regarding lithotripsy time, stone clearance, need of ureteric stent and possible complications.

REVIEW OF LITERATURE

A short history and simplified Physics of Laser

In 1917, Albert Einstein first proposed the theory of stimulated emission: the process by which photon (a packet of light energy) with correct amount of energy could disturb an excited atom and cause it to drop to a lower energy level, in turn leading to creation of another identical photon. The original photon interacting with the atoms and the photon subsequently released will be discharged simultaneously and will therefore have an identical wavelength and direction of propagation [11].

The first giant leap was the development of MASER (microwave amplification by stimulated emission of radiation). Microwaves are electromagnetic waves with fairly long wave-lengths (1mm to 1m). Gordon and Colleagues tested the first MASER in 1954, where stimulated emission at microwave wave-length (in this case 12.5mm) was demonstrated in an oscillator [12].

The step from MASER to LASER (light amplification by stimulated emission of radiation) took 3 years. The idea was to extend the principle of stimulated emission from microwave wave-lengths to much shorter wave-lengths, also including the optical range or visible spectrum of around 390 – 750 nm. For this, one would need to build an optical oscillator and could generate coherent light by amplifying stimulated emission [13].

In 1960, Theodore Maiman was the first to succeed and built the first LASER using ruby crystals as an active medium [14]. It is the active medium (also referred to as lasing medium) in a laser that determines the wave-length (and therefore color) and frequency of light that it emits. The wave-length and frequency are inversely proportional to one another.

The gas was used as an active medium in early lasers such as nitrogen (N), carbon dioxide (CO2), helium (He) and neon (Ne). Liquids as medium soon followed: the so-called dye laser, because the lasing agent is an organic dye [15].

The advantage of dye lasers is being able to generate amplified light with a wider range of wave-lengths. Some are even tunable. In 1964, one of the earliest solid-state lasers utilized Nd:YAG (neodymium-doped yttrium aluminum garnet) as a medium; this still popular today [16].

The evolution of laser is summarized in chronologic Table 1.

The laser output classification of particular practical importance in urology is that of pulsed wave (PW) versus continuous wave (CW). During operation by CW, the output of the laser is continuous and of constant amplitude. The clinical effect is a more controlled interaction with the tissue. On the other hand, PW operation delivers forceful bursts of laser energy, which is useful for stone fragmentation [17].

In order to fully appreciate important aspect such as thermal effect, penetration depth, and reflection, a basic understanding of light tissue interaction of laser is required. These technical terms have major clinical significance. When laser meets tissue, a percentage of the laser beam will be reflected. The reflected radiation is lost and may also cause unintended thermal damage to surrounding areas. The most important interaction of laser light with tissue is the absorption. In order to achieve absorption, a chromophore is required: body chromophores accessible for laser light include blood, water and melanin [17].

The absorbed laser light is converted to heat and depending on the amount of heat, the clinical effect will be tissue vaporization or coagulation. Absorption depth is dependent on the wave-length of laser. Figure 1 (Fig.1) illustrates the absorption spectrum of melanin, hemoglobin and water for specific laser wave-lengths [17].

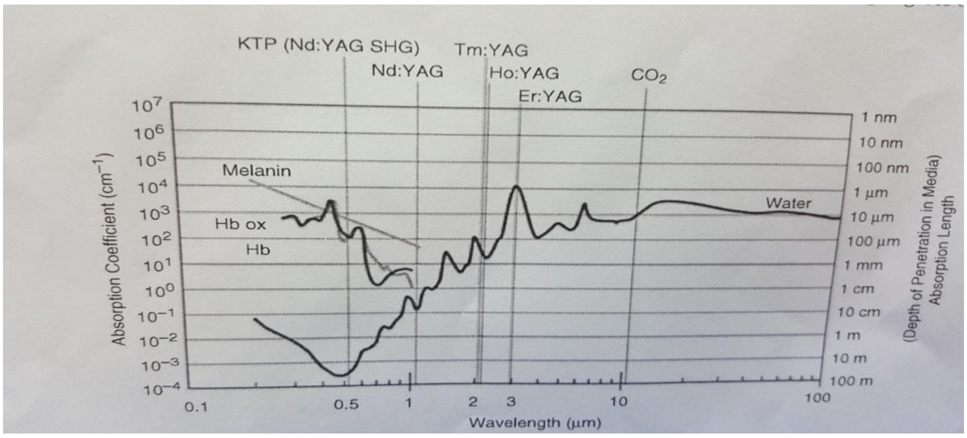

Fig. (1): Absorption spectrum of melanin, hemoglobin and water for specific laser wavelengths [17].

Table (1): Timetable

1917	Theory of spontaneous emission By Albert Einstein
1951	Amplified electromagnetic radiation By V.A.Fabrikant
1954	Maser By Gordon, Zieglel and Townes
1957	Creation of acronym``laser`` By Gould
1960	First commercially available laser By Maiman
1961	First gas laser By Javan,Bennett and Herriott
1966	First In Vivo experiments in urology By Parsons
1968	First patient in urology By Mulvaney and Beck

The interaction mechanism of laser to biological tissue has a wide range of possibilities as shown in table 2.

Table (2): Interaction mechanism of laser to biological tissue

Photothermal	Photodisruption
Photochemical	Photoelectrical
Photomechanical	Photopyrolysis
Photodissociation	
Biological stimulation	
Coagulation	
Vaporization	

With great enthusiasm lasers occupied their place in medicine. Research was a continuation of two directions in the medical research: that of photocoagulation and that of studying the hazard of radiation. And in many subspecialties of medicine it became an important device for both diagnosis and therapy soon after its first introduction. 1964, first experiences with ruby-CO2-Nd: YAG and argon lasers were published. Since medical doctors are usually not trained in the field of physics and physicists or engineers are usually not aware of medical problems, the development of lasers opened a complete new basis of cooperation [18].

The physicists and engineers who invented and worked with the laser recognized its hazard immediately. The first papers about the laser’s risks appeared in Science on 10 November 1961. It was known that the CO2 laser vaporized tissue, the Nd: YAG created a coagulative necrosis within tissue, and the visible lasers (ruby, argon, etc.) served as hemostatic coagulators. Because the biological effect of a laser is dependent on the laser wave-length, energy density and tissue absorption, doctors needed to develop an understanding of the principles of light transmission, scatter reflection and absorption. Theoretically, surgeons could manipulate the laser beam's width and energy density to obtain a demanded effect, but medical scientists did not understand the laser well enough to define these parameters. The determination of the indications for and best method of use of the laser has been the focus of laser research since 1965 [18].

Present status

Until today, lasers play an important role in surgery, ophthalmology, dentistry and dermatology and also in many other fields.

The lasers are widely used in urology and being the first choice of tool in some areas, such as endoscopical calculi treatment or lithotripsy [19]. First case report on laser treatment in urology dated back to 1968 [20]. Drawbacks of the standard transurethral resection of prostate (TURP) are potentially high blood loss, transurethral resection syndrome and various other complications. During the past 2 decades, several forms of laser treatment protocols have been introduced to overcome this problem. Some of them did not stand the test of time. The continuous wave Nd: YAG laser was widely used. Its deeply penetrative wave-length coagulates and subsequently vaporizes prostate tissue to reopen the lumen. But it was just the deep penetration that caused undesirable side effects and subsequently led to the elimination of Nd: YAG laser from the treatment of prostates.

Three different lasers are competing today on the market: Holmium: YAG lasers, solid state lasers, such as the frequency doubled Nd: YAG laser (KTP) and the Thulium: YAG laser have replaced older types of lasers. Laser lithotripsy was first introduced commercially in the late 1980s with the pulsed-dye laser, which uses 450 nm of light delivered through optical quartz fibers. This was a non-thermal safe laser that produced plasma between the tip of the fiber and the calculus, disintegrating stone with a photo-acoustic effect. The small flexible probes were complimentary to both the flexible and semi rigid ureteroscopes and could disintegrate most urinary calculi, including cystine. Besides those major fields of applications, lasers became the treatment of choice in ureteral or urethral strictures, tumour enucleation of the kidney, condylomata and many others.

Types of Lasers in Urology

Currently, the most commonly used laser in urology are the following:

1- Ho: YAG (Holmium: yttrium-aluminum-garnet)

2- KTP:YAG (Potassium titanyl phosphate)

3- LBO YAG (Lithium borate)

4- Tm:YAG (Thulium)

5- Diode laser

Many other types of lasers were used in past. However, their use was discontinued due to a large number of complications [21, 22, 23].

Characteristics of particular individual laser

Ho: YAG laser is a pulsed type of laser and emits energy that is absorbed by the water. It is characterized by pulse duration of 350 ms (microsecond) and wave-length of 2140nm. In the prostate tissue the depth of the penetration is only 0.4mm. Therefore, the thermal damages and depth of necrosis is limited. Ho: YAG laser causes rapid coagulation of small and medium-sized vessels to the depth of about 2 mm. Prostate can be precisely incised, dissected and enucleated, because this laser requires contact with tissue.

Ho: YAG laser is mainly used for lithotripsy, procedures on the prostate, ablation of urothelial tumors and for lower and upper urinary tract strictures incision [24].

In the past, the Nd: YAG (Neodymium) laser was the most commonly used laser and therefore is the most studied one.

It is characterized by wavelength of 1046nm and tissue penetration more than 1 cm. It causes considerable thermal tissue injury and deep coagulative necrosis. Nd: YAG laser can be used for contact ablation or interstitial laser coagulation (ILC) of the prostate and noncontact “visual laser ablation of prostate” (VLAP). After procedure, edema occurring frequently, leads to irritative lower urinary tract syndrome (LUTS) and urinary retention which often requires longtime catheterization.

KTP: YAG laser, is derived from Nd: YAG laser, also called green light laser. Passing the invisible Nd: YAG beam via a KTP crystal, doubles the frequency and halves the wavelength from1064nm to 532nm. Selectively, its energy is absorbed by hemoglobin, but not by water. The depth of penetration is about 0.8mm. It is characterized by a very good control of hemostasis. It is possible to perform operations in noncontact use called photo-selective vaporization of tissue, because energy of KTP laser is absorbed only by hemoglobin. Necrosis of the tissue localized beneath the vaporized area is limited, due to shallow absorption rate. Other advantage is an almost bloodless course of procedure. It is mainly used in transurethral resection of prostate (TURP).

The thulium: YAG laser produces continuous, 2000 nm wave. Energy is only absorbed by water as in Ho: YAG laser, and slightly shorter wavelength of Tm: YAG laser decreases the depth of penetration to 0.25 mm. The Tm: YAG laser is used for transurethral resection, vaporization, or enucleation of prostate.

The LBO: YAG laser is derived from KTP laser. Both lasers has equal wavelength. However, LBO:YAG laser has an accelerated and a more efficient energy transfer and enhanced working distance (from 0.5 mm for KTP to 3 mm for LBO) [25]. In comparison to KTP-laser, a marked decrease in hemostatic ability is a significant disadvantage of this laser [26].

Diode lasers have been available for long-time, yet, their clinical application has been limited. Diode lasers emit a beam of wave-length between 940 to 1470 nm. As a result of absorption of their energy by both water and hemoglobin, good hemostatic and vaporisative effects are obtained [21].

Data differs considerably regarding the penetration depth of diode lasers between particular reports. Some reports on a 980 nm diode laser demonstrate its better hemostatic effect during prostate vaporization in comparison to 120 W LBO laser, however, higher incidence of complications, such as postoperative irritative symptoms and epididymitis, is noted [27].

Laser lithotripsy

In 1987, the initial reports on the use of the pulsed dye laser for calculus fragmentation was appeared [28]. This was a very promising new technology enabling endoscopic disintegration of more than 80 – 90% of calculi and urothelial injury being rare. Drawbacks were expensive disposables (coumarin dye) and very high initial costs, in addition trouble with disintegration of hard stones composed of calcium oxalate monohydrate (COM) and cystine [29].

The next step in laser lithotripsy was FREDDY (frequency double double-pulse Nd: YAG) laser and consists of a KTP crystal incorporated into a Nd: YAG laser [30]. This enables the laser to produce two pulses: a 20% green light component at a wave-length of 532nm and an 80% infrared component at a wave-length of 1064nm. This combination works in synergy to enable highly effective calculus disintegration, mainly via a mechanical shockwave with very little thermal effects. Another advantage when using this laser is the extremely low risk of ureteral wall damage [31]. Unfortunately, the “hard” types of stones also present a challenge to this laser, as in case of pulsed dye lasers [32]. Another problem when using this laser is that it is only able to effectively fragment dark or colored calculi that absorb the green wave-length. Some urologists later referred to it as the 50% laser because only about 50% of calculi could be treated with it.

In 1991, the Alexandrite laser was introduced and even though initial results were promising, there was never widespread acceptance of this laser for use as a lithotripter [33].

Owing to the high costs when investing in a urological laser, the ideal would be to have a system with applications in different pathological conditions. The drawback of the FREDDY lasers negligible effect on soft tissue is that it can be exclusively used for calculus procedures.

The Ho: YAG laser is used for benign prostatic hyperplasia (BPH) surgery and this laser become one of the most commonly used for lithotripsy [34].

Fragmentation required direct contact of laser tip with the calculus and occurs through a photo-thermal effect [35]. Minimal retropulsion effect during calculus fragmentation is a major advantage of this laser [36]. Its ability to disintegrate all kinds of the stone, including COM, cystine and brushite, puts this laser at the top of food chain [37]. The Ho: YAG laser can either reduce calculi to tiny fragments that are easily cleared from the collecting system with outflow or irrigant, or larger calculi can be broken up and fragments removed using grasping forceps (Fig 2) or baskets (Fig 3) [38].