INTRODUCTION

Since the introduction of ESWL by chaussy in 1980, the therapeutic strategy for urolithiasis has completely changed.Dr. Christain chaussy of the univeristy of Munich was the first to pulverize renal in humans using a new concept termed extracorporeal shock wave lithotripsy. Using this technology, he determined that patients could have renal or ureteral stones removed without the need of an incision or skin puncture. Due to its noninvasiveness, the concept quickly gained widespread and became the treatment of choice for the vast majority, of urinary stones. The first lithotripter model (Dornier hm-1) was soon replaced by the HN-2 IN 1982,AND the HM-3in 1984.the HM-3 was first used in the United states on February 23, 1984 at Methodist Hospital in Indianapolis ***(Tiede et al., 2003).***

SWL technology has evolved sing nifcantly in the last two decades. Initially, the technical improvement in the lithotripters was mad based on empirical experience to provide user convenience and device multfunctionality. Recently, a significant progress in the basic research of SWL has stone comminution and tissue injury. It is now recognized that stone comminution is a multifaceted progressive process in volves synergistic of tow fundamental mechanisms namely, stress wave induced dynamic fracture and cavitation erosion ***(Zhu et at., 2002a)***. In addition, tow mechanisms have been proposed to be responsible for tissue injury: shear stress due to shock front distortion and cavitation induced the blood vessels ***(Zhu et at., 2004 a).***

First a single unit Ellipsoidal reflector was inserted to modify the profile of the SW to suppress the cavitation selectively in tissues along the propagation path of SWs and thus decreasing the vascular injury. Second, a piezoelectric annular array (PEAA) generator eas inserted to produce an auxiliary SW to intensify the collapse of SW – induced bubbles near the target stone for improved comminution ***(Zhou and Coworkers., 2004).***

Further evaluation efficacy and of safety of dual pulse SWL was presented by ***Loske and coworkers (2005).*** in their study a piezoelectric, lithotripter was modified to produce pairs of successive (tandem) SWs with adjustable inter – Pules time delay with no need for an extra generator. Another novel approach is the bidirectional synchronous twis – pulse technique which generates SWs simultaneously fromseparate reflectors through tow axes in non – opposing directions to the same F2 ***(Sheir et al., 2003).***

Since its introduction by chaussy et al in 1980, has become the preferred treatment for renal calculi of <2 cm in diameter. The outcome of ESWL depends on many factors, including size,location composition, fragility,the shock wave generator and the presence of obstruction or infection After the introduction by Dreter of the concept of fragility, stone composition has emerged as the main factor influencing the efficacy of ESWL Different techniques have been used to assist in determining the chemical composition of urinary in vivo. Such tests include PH, identifying and characterizing urinary crystals, th presence of urea – splitting organisms,bone densitometry and radiographic studies CT with on enhancement by contrast medium (NCCT) has long been used clinically to evaluate causes of radiolucent filling defects using measurement of substance density in Hounsfield units (HU) to distinguish calculi from tumors or blood clots As it provides greater density discrimination than a conventional plain a abdominal film it is now the preferred method to evaluate patients with ranal colic it's ability to detect density differences as low as 0.5% has been exploited to determine the composition and fragility of urinary stones. The density of the ston varies with composition and affects the fragility of a calculus which ultimately governs the clinical outcome in ESWL Hence it is vital to Know the fragility of calculus before ESWL to increase the efficacy and reduce the number of hospital visits and thus cost. We evaluated the role of NCCT, using attenuation value, in determining the fragility and clearance of calculi in patients treated with ESWL ***(Naramoda et al., 2005).***

Although plain abdominal x-ray film has been accepted as the irst line diagnostic tool in the follow up after ESWL with its cheap and practical use, the helical CT was found to be more valuable in the diagnosis of residual stone fragment which has not been found in plain abdominal x-ray. The routine use of helical CT can give more accurate information in patients control after ESWL for both adult and pediatric patients ***(Kupeli et al., 2005).***

Some precautions concerning possible damages from ESWL on the growing kidney have been raised in children Pre-operative evaluation included history, physical examinations, blood analysis, urinalysis, urine culture, intravenous urography. after treatment with ESWL follow up by renal ultrasound, blood pressure monitor, laboratory testes, plain x-rey and dimercaptosuccinic acid **(DMSA)** Found no renal scaring and no change in the renal function or blood pressure to pre-operative values. Renal ultrasound revealed no growth difference between treated and untreated The long term follow up after ESWL did not show any signs of damage to the growing kidney ***(Brinkmann et al., 2001., 2005).***

AIM OF THE WORK

The aim of this study is to stand on the recent advancement in ESWL technology and its impact on the outcome of ESWL as a modality of treatment of stone diseases.

HISTORY OF ESWL

It has been known for centuries that sound waves are focusable. The acient Greeks used this knowledge to conversations of their imprisoned enemies. High – energy SWs have been recognized for many years. Examples of high energy- SWs include the potentially window – shattering sonic boom created when aircafits pass beyond the speed of sound. Engineers at Dornier Medical Systems in what was then West Germany, during research on the effects of SWs on military hardware, demonstrated that SWs are reflectable and, therefore, focusable the possibility of application of SWs human tissue was discovered when, by chance, a test enigeer touched a target body at the very moment of impact of a high- velocity projectile. The engineer felt a sensation similar to an electric shock although the contact point at the skin showed no damage at all ***(Hepp, 1984).*** (***Qouted from Mohamed Abd al Ghany MD study 2008).***

In 1969, Dornier began studying the effects of SWs on tissues, specifically, to determine if SWs generated by projectiles hitting the wall of a tank would damage the lungs of atank crew member leaning against the same wall.During this study, Dornier engineers developed techniques to reproducibly generate SWs and fount that SWs generate in water could pass through living tissues, except for the lung without discernible damage but that brittle materials were destroyed. At this point, a possible medical application becomes apparent. If SWs could safely pass through tissues but fragment brittle materials perhaps they could be used to break up kidney. Stones.

Subsequently, Dornier engineers found that the lower- energy SWs appropriate for medical application could be generated by an electric spark discharge underwater and predictably reproduced ***(Lingeman et al., 2007).***

In 1972, based on these preliminary studies performed by Dornier Medical systems, an agreement was reached with Egbert Schmiedt, director of the urologic clinic at the University of Munich, to proceed with further investigations of the therapeutic potential of this technology. the first patient was treated with ESWL in aprototype termed human machine (HMI) lithotripter of February 20,1980(Fig.1) Initially, only one or two patients were treated pe month under very restricted indication (i.e,small,non-obstructing, renal pelvic stone)and the results were encouraging ***(Chaussy etal.,1980)*** (***Qouted from Mohamed abd el ghany MD study 2008).***

Figure (1): Dornier HMI lithotripter ***(Quoted from Rassweiler et al. 2001).***

Therefore, more extensive clinical trials were undertaken using another prototype (HM2) which was much simpler machine to operate because the electrode could be changed without removing the patient from the water bath and the success was impressive ***(Chaussy and Schmidt, 1984)*** ***(Qouted from Mohamed abd al ghany MD study 2008).***

Following minor modification, Dornier introduced its first commercially produced spark gap lithotripter, the HM3 **(Fig. 2)** in 1983 and gainted FDA approval in 1984.

Figure (2): Dornier HM3 lithotripter ***(Quoted from Rassweiler et al., 2001).***

Shortly after the introduction of HM3, new energy sources such as piezoelectric in 1986 and electromagnetic generators in 197 were introduced ***(Wilbert et al., 1987)*** ***(Qouted from Mohamed abd al ghany MD study 2008).***

These new generators were used in the 2nd generation lithotripters like Siemens Lithotripters,Edap LT01, and Wolf piezolith 2200.These lithotripters used water cushion or partial water bath for coupling and either X-ray or US system for stone localization.

Later, the 3rd generation lithotripters with the advantages of combind localization systems and multifuncational use were developed ***(Rassweiler et al., 2001)***. Examples of this generation include siemens lithostar plus, Wolf piezolith 2500, stoez Modulith Sl 20, and EDAPLT02, with the saturation of markets with these costly lithotripters and tightening healthcare budgets, more compact and economical machines (e,g Direx Tripter X) were developed. These machines are mobile, use an external C-arm for localization and though perhaps less efficacious, are relatively inexpensive ***(Lingeman, 1995)*** ***(Qouted from Mohamed abd al ghany MD study 2008).***

PHYSICS OF ESWL

Introduction:

Extracorporeal Shock-Wave Lithotripsy (ESWL) is the leading technique used in urology for the non-invasive treatment of kidney and ureteric stones. The stone is comminuted by thousands of ultrasound shocks, into fragments small enough to be naturally passed. Since the technique was introduced in the 1980 different generations of lithotripters have been developed ***(Fedele et al., 2004).***

Since 1984, ESWL has been the treatment of choice for symptomatic upper urinary tract stones, when the first-generation machines, featuring spark-gap Electrodes were introduced. The shock waves can be conceptualized as a cone with the skin forming its_base and the intended target (the stone) being at the apex. ESWL fragmentation is likely a result of the force of the pressure wave on the stone. Positioning of the patients is simplified, and additional endoscopic procedures (ureteral stent placement or removal) can be performed simultaneously because these machines incorporate a universal urologic table ***(Minevich et al., 2001).***

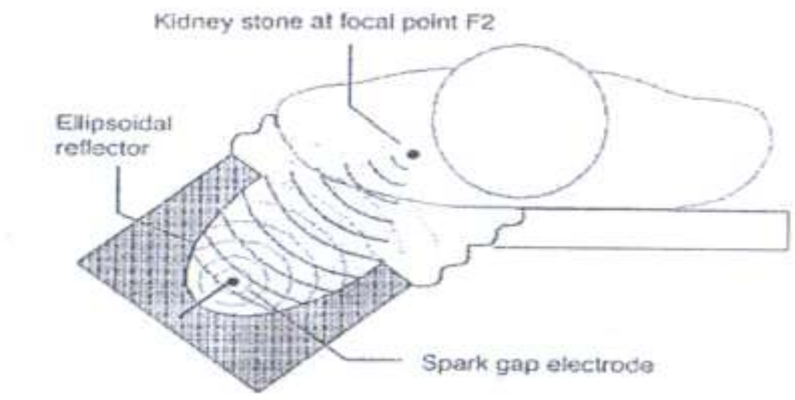

Figure (3): Principles of ESWL

To decrease the pain experienced by the patient, which is a function of the size of the focal point, the amount of energy focused at that point, and the surface area over which the shock wave enters, new second- and third-generation machines with electromagnetic generators were introduced ***(Lampel et al., 2001).***

Definition of Shock Waves:

In physical terms, shock waves are high-energy waves with high amplitude, characterized by extremely short build up times. Acoustic shock waves used for medical applications are generated by processes that are similar to explosions, displacing the mass surrounding them, such as detonations of explosives ***(Chaussy et al., 1982).***

Physical principles of SWs:

Despite the tremendous number of lithotripters available, all of these devices rely on the same laws of acoustic physics.

SWs consist of a sharp peak in positive pressure followed by a trialing negative wave, generated extracorporeally and passed through the body to fragment stones. SWs readily propagate from a water bath or water medium to the human body because they are traveling in similar densities. However, they change in density from water to calculus results in stone fragmentation ***(Weizer et al., 2005).***

SWs moves faster than the speed of the sound and although they generate large pressures, slight compression and deformation of a material is induced A typical pressure pulse involves an initial short and steep compressive front with pressure of about 40MPa followed by a longer, lower amplitude negative tensile pressure of 10MPa, with the entire pulse lasting 4µs ***(Lingeman etal., 2007).***

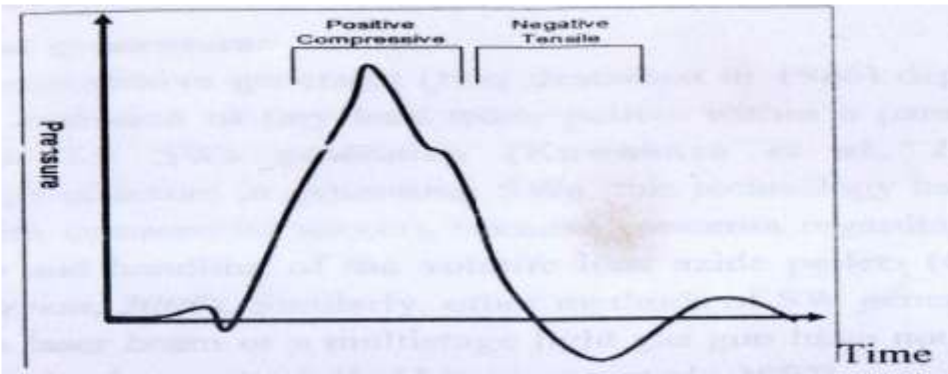

Figure (4): Typical pattern of a shock wave generated by a lithotripter ***(Quoted from Weizer et al., 2005).***

All lithotripters share 4 main features: 1) an energy sours to generate the SW, 2) a devise to focus the SW at a focal point, 3) a coupling medium and 4) a stone localization system.

Types of SWL generator:

1- Electrohydraulic (spark gap) generator:

In this system, high voltage is applied to two opposing electrodes positioned one mm apart producing an underwater spark discharge.This high voltage spark discharge causes the explosive vaporization of water at the electrode tip generating a spherically expanding SW The clear advantage of this generator is its effectiveness in breaking stones ***(Lingeman et al., 2002)***. Disadvantage is substantial pressure fluctuation from shock to shock and a relatively short electrode life. Another issue to consider is that as the electrode deteriorates, it wears down, and a 1-mm shist of electrode tip off F1 can displace F2 up to 1cm off the target ***(Lingeman et al., 2007).***

Generation of pressure waves:

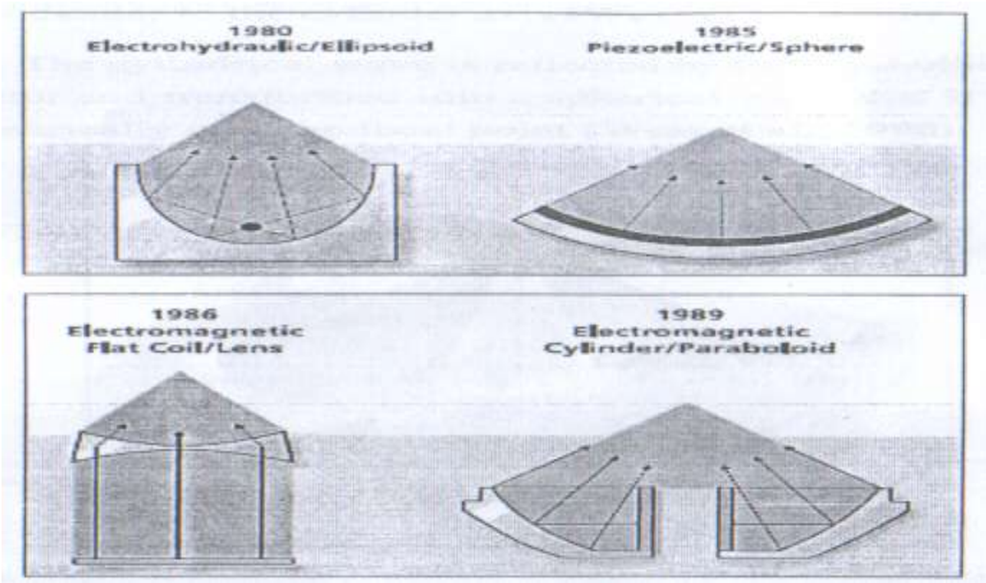

Figure (5): Generation principle of shock waves.

2-Electromagnetic generator:

The first of the two electromagnetic systems is characterized by a strong pulsed current flowing through a flat coil, thus generating a rapidly changing magnetic field. An opposing magnetic field is induced in the metal membrane above the coil, thus causing the membrane to be pushed away from the coil. The initially flat waves are focused by means of a lens that is arranged above the coil. The cylindrical source2 patented by STOR MEDICAL also employs the electromagnetic principle of shock wave generation ***(Wess et al., 1990).***

The heart of this system is a cylindrical coil. The cylindrical membrane is pushed away from the coil.the cylindrical membrane is pushed away by the induction of amagnetic field and accelerated radically outwords by a pulsed current, thus initially generating a cylindrical wave perpendicular to the cylinder axis ***(Wess et al., 1990).***

The cylindrical wave is reflected by the paraboloidal type reflector and transformed into a spherical wave that is focused concentrically onto the focal point ***(Wess et al., 1990).***

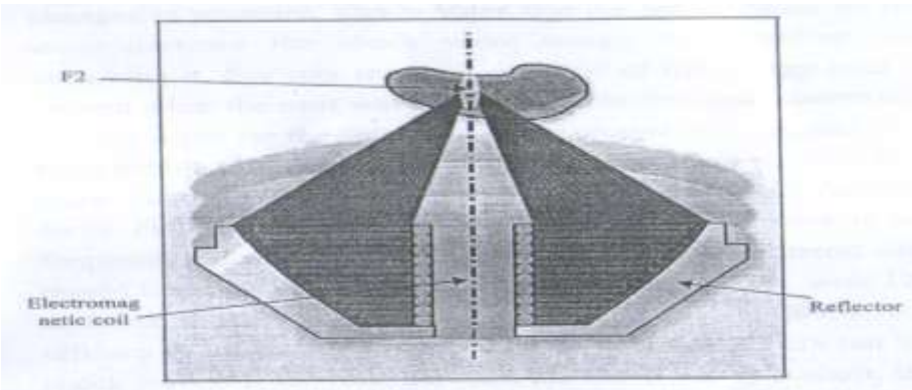

Figure (6): Patented storz medical cylindrical source.Schematic view of an electro-magnetic Shockwave generator that uses a parabolic reflector to focus the shockwave.An electromagnetic coil is used to generate the Shockwave

The use of the cylindrical source described above has brought about significant benefits in clinical practice. Firstly, the cylindrical design offers sufficient space for the integration of an in-line localization unit. Secondly, the required energy is introduced into the patient's body over a large skin area, thus reducing pain to a minimum. The particular geometry of this system allows a precisely defined focal point with high energy densities to be obtained. The cylindrical source can be built in such a way that the focal point is located well clear of the therapy head. This allows the shock waves to penetrate deep into the tissue to allow treatment of obese patients also ***(Wess et al., 1990).***

The cylindrical source is easily adapted also for cardiac indications. Today's lithotripters are increasingly equipped with electromagnetic sources ***(Wess et al., 1990).***

3-Piezoelectric generator:

Piezoelectric SWs are generated by the sudden expansion of ceramic elements excited by a high voltage pulse. While each of these elements moves only slightly in response to a pulse of electric energy, the summation of the simultaneous expansion of multiple elements results in a high energy SW. The spherical focusing mechanism of piezoelectric lithotripters provides a wide point of SW entry at the skin surface which causes minimal patient discomfort but at the same time with the smallest amount of energy at F2 compared to other energy sources ***(weizer et al., 2005).***