First in vitro Experiments using a New Reflector to concentrate Shock Waves for ESWL

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Abstract: Electrohydraulic lithotripters use ellipsoidal reflectors to concentrate the energy generated in one of their foci (F1). Our new reflector is obtained by combining two sectors of two rotationally symmetric ellipsoidal reflectors with different separations between their foci F1 and F2. These sectors are joined together in such a way, that the F1 foci coincide, creating a separation between the F2 foci. The shock wave is divided, by reflection, into two shock fronts converging towards two, rather than one, F2 foci. Pressure measurements, and experiments using kidney-stone models, indicate that the new design could be more efficient in breaking up renal stones.

INTRODUCTION

Extracorporeal Shock Wave Lithotripsy (ESWL) is considered to be a safe and reliable procedure, and tend to be used on an outpatient basis (1, 2). Electrohydraulic lithotripters, used to perform ESWL, induce shock waves by electrical breakdown of water between two electrodes, located at the closest focus (F1) to a parallellipsoidal reflector. Shock waves are created at F1, reflected off the mirror and concentrated at the other focus (F2), where the patient’s calculus should be positioned. The shock wave enters the body with little attenuation, gets focused on the stone and fractures it. A water bath or cushion couples the shock wave to the patients body. Treatment efficacy and patient pain and trauma depends, to a certain extent, on the reflector. Despite the fact that ESWL has been used since 1980, several modifications have been made to improve the technique and the lithotripters (3). This article describes pressure measurements and in vitro experiments with a new composite reflector, comparing its performance to that of a conventional reflector using an experimental shock wave generator. The purpose of the new reflector is to divide the initial shock wave in two parts and temporally and spatially dephase them in order to improve stone disintegration.

MATERIALS AND METHODS

A composite reflector, obtained by combining two sectors of two rotationally symmetric ellipsoidal reflectors with different separations between their foci (F1, F2) and (F1', F2') was constructed (4-6). One sector has a major axis of 278 mm and a minor axis of 156 mm; the other one has a 313 mm major and a 166.4 mm minor axis. The new reflector is obtained by joining together both sectors in such a way that the F1 and F1' foci coincide, creating a separation between F2 and F2'. In order to evaluate the performance of this reflector, it was compared with a conventional reflector having the geometry used in the HM3 and HM4 non-modified lithotripter, manufactured by Dornier Medizintechnik GmbH in Germering Germany (7). Both reflectors were tested by installing them separately in an experimental shock wave generator named MEXILIT. With this device it is possible to reproduce the electrohydraulic shock wave generation of an extracorporeal lithotripter. A description of the experimental device is given elsewhere (8).

A total of 30 standardized AST stone models, with the shape of a rectangular prism, manufactured by High Medical Technologies AG in Kreuzlingen, Switzerland, were one by one exposed to 800 shock waves generated at 22 kV, using a capacitance of 80 nF, with each reflector. All models were placed horizontally and centered at the focal line of the reflectors with a clamp fastened to the position control system of the MEXILIT. The stone models were placed at F2 when using the conventional reflector and between F2 and F2' when using the new reflector. Before and after shock wave exposure, all models were dried in an oven, stored in a sealed container and weighted. The amount of material lost due to the shock waves was determined by subtracting the final weight of each model from its initial weight.
Pressure measurements were made with needle probe hydrophones manufactured by Imotec GmbH, D-5102 Würselen, Germany, having a rise time of 20 ns. Signals coming from these gauges were sent to a Tektronix (Tektronix, Inc., Beaverton, Oregon) 2430A digital oscilloscope. Measurements were carried out on both reflectors at three different positions. For each position 150 pressure signals were recorded. The maximum peak compressional and rarefactual signals and the rise times were obtained.

EXPERIMENTAL RESULTS

Using the conventional reflector, each model lost an average of about 0.5 g during shock wave exposure and an average of about 0.7 g with the new reflector. Both reflectors produced a crater at the shock wave entrance site of the models, as well as severe pitting, produced by cavitation, inside and around this crater. The shape of all craters, made with the same reflector, was similar, having a diameter of approximately 10 mm for the conventional and 15 mm for the new reflector. A statistical analysis revealed that these differences are significant. The amount of pitting was observed to be higher on the models exposed to shock waves generated using the new reflector, however no method was developed yet to quantify this difference.

Pressure measurements performed 1.8 mm above F2, at F2, and 1.8 mm below F2 for the conventional and at F2', between F2' and F2, and at F2, for the new reflector revealed a maximum compressional (about 720 bar) and also rarefactual (about 250 bar) peak at F2 for the first and a maximum compressional (about 625 bar) and rarefactual (about 150 bar) peak between F2' and F2 for the second reflector. The shortest rise time was achieved with the conventional reflector at F2, being about half as long as the shortest rise time obtained with the new reflector. No statistical significant difference could be detected between the rise times obtained with the new reflector at the three mentioned positions. All compressional pressure pulses measured when using this reflector, showed to have a double peak separated less than one microsecond. The first peak had an average amplitude being about 40% smaller than the amplitude of the second peak.

DISCUSSION

Short rise times and high pressure are considered to be convenient for ESWL. Nevertheless, our results indicate that spatial and temporal dephasing of the shock wave front also plays a significant role in stone fragmentation, producing fast varying compressions and rarefactions. Other double shock wave generating devices have also been proposed (9), achieving enhanced stone fragmentation. In this case shock waves reaching F2 are only dephased in time. Since the goal of ESWL is to provide stone fragmentation with the least amount of tissue damage, experiments with animals are being done to determine whether the new reflector produces less tissue damage, however no statistically significant results have been obtained so far.

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REFERENCES