Extracorporeal shock wave lithotripsy of gall stones: an in vitro comparison between an electrohydraulic and a piezoceramic device


Abstract
A comparative study of the effectiveness of two types of lithotripter in fragmenting gall bladder stones is reported. The machines used were a Piezolith 2300, which generates shock waves by the piezoceramic principle, and a Dornier MPL 9000, which produces the shock waves by underwater spark discharge. With each machine, corresponding stones of 45 pairs of weight and volume matched calculi (median volume 0.5 cm³, median diameter 10-5 mm) obtained at cholecystectomy were treated. All stones were successfully disintegrated (fragments smaller than 2 mm) with up to 5400 (median 628) shocks with the Piezolith and 3450 (median 428) shocks with the MPL 9000 lithotripters. With the Piezolith, operating at the highest power setting, a 1-65 fold median higher number of shocks was required for stone fragmentation than with the MPL 9000 at a medium power setting. Stone volume seemed to be the only determinant which affected ease of fragmentation; composition and density of the stones as assessed by computed tomography did not seem to be governing factors.

Since the first reports on the initial successes of renal stone lithotripsy,¹ shock wave technology has developed rapidly. Various lithotripters have become available commercially and in 1985 the first patients with biliary stones were treated by extracorporeal shock wave lithotripsy.²

The two most common types of lithotripter used in the treatment of gall stones are the spark gap machines³⁴ and the piezoceramic machines.⁵¹¹ No direct, systematic comparison between the two systems has been carried out, however. We therefore performed an in vitro study to compare a piezoceramic lithotripter (Piezolith 2300, Richard Wolf GmbH) with a commonly used spark gap lithotripter (MPL 9000, Dornier Medizintechnik GmbH). It was the primary aim of the study to compare the effectiveness of the two systems in fragmenting human gall bladder stones. Secondly, we examined the influence of radiological stone characteristics on the disintegration process.

Methods
Forty five sets of gall bladder stones were collected at cholecystectomy and stored in physiological saline at 4°C until lithotripsy. The storage time varied between one month and two years. There was no evidence that the storage period influenced the ease of disintegration. The stones were kept in physiological saline at 4°C for the transport between Sheffield and Munich. A matched pair from each set was selected so that the volume and weight did not differ by more than 10% (Table). Volume was determined by hydrostatic weighing.

Computed tomograms were performed on all stones to assess calcification and density. All scans were performed by the same Siemens Somatom DRH. The stones were placed in a container and immersed 3 cm into distilled water. The whole container was scanned with 2 mm slices (125 kV, 720 mas, scan time 5 seconds). On the slice with the largest stone diameter, the border of the calculus was marked by a cursor to determine the region of interest. The computed tomographic densities in this region were processed by computer and the mean value expressed in Hounsfield units (HU).

Lithotripsy was performed with the Piezolith 2300 (Richard Wolf GmbH) at the highest setting (setting 4) and with the MPL 9000 (Dornier Medizintechnik GmbH) at 18 kV (80 nF, which was equivalent to the mean power used in patient treatment in former studies).²³ The individual stones were placed in a specially constructed test apparatus (Fig 1) which consisted of a plastic basket (2 mm grid) for supporting the stones, placed in a water filled container fitted with a silicone rubber base to allow passage of the shock waves. The apparatus was immersed in the Piezolith bowl or, for the MPL 9000, placed in contact with the water cushion so that it lay within the focus of the shock waves. Shock waves were applied until all of the fragments had passed through the 2 mm grid.

After fragmentation, samples of 1 to 1.5 mg were subjected to infrared spectrophotometry (Perkin Elmer 377) in order to obtain a qualitative and quantitative estimate of the composition. They were classified as cholesterol stones when the cholesterol content was greater than 70%.

Results
One stone from each of the 45 pairs of stones was treated in each lithotripter. The pairs were
A

B

Figure 1: Schematic drawing of the study design for the in vitro experiments. Each gall stone from a matched pair from the same gall bladder was placed into a basket with a 2 mm mesh. The deepest point of the basket was manoeuvred into the focus of the lithotripter. This allowed fragments larger than 2 mm and stones to stay in the focal volume. The stone was treated by a piezoceramic device (Wolf Piezolith 2300, A) or a spark gap machine (Dornier MPL 9000, B) until all the fragments had passed out of the basket.

similar in respect of volume, computed tomo-gram assessed density, and chemical composition (Table). There were 39 pairs of non-calcified and five pairs of calcified cholesterol stones as

well as one pair of pigment stones in the study group. All were successfully fragmented (passage of all particles through the 2 mm grid) with up to 5400 shocks with the Piezolith and up to 3450 shocks for the MPL 9000 (Fig 2, Table).

There was a linear relation between the number of shocks required for successful fragmentation and stone volume (Fig 2). No such relation was seen between computed tomodensitometry (HU) assessed density and fragmentation (Fig 3). The Piezolith at settings 4 required a median of 1-65 times (p<0-001) as many shocks as the 40 1000

MPL 9000 at 18 kV to achieve the same degree of success for stone breakage. This ratio was not constant, however, and showed no relation between stone volume (Fig 4), diameter, or computed tomodensitometry assessed density. The shape of the fragments was similar (Fig 5).

Discussion

Our in vitro study shows that small to medium sized single stones can be disintegrated by both systems. Stones of up to 4 cm were fragmented

Figure 2: Volume of gall stones and number of discharges required to obtain 2 mm fragments with (A) piezoceramic device (Piezolith 2300, A) and (B) a spark gap machine (MPL 9000, B).

Figure 3: Density of gall stones assessed by computed tomography and number of discharges required to obtain 2 mm fragments with (A) piezoceramic device (Piezolith 2300, A) and (B) a spark gap machine (MPL 9000, B). HU=Hounsfield units.
Figure 4: Volume of gall stones (mean value of matched pair) and ratio of discharges required to obtain 2 mm fragments (Piezolith A, MPL 9000, B).

Figure 5: A pair of matched gall stones (A) before and (B) after lithotripsy with a Piezolith 2300 (5400 shocks, A) and an MPL 9000 (3450 shocks, B).

Successfully with relative ease by both machines. Disintegration was significantly dependent on stone volume but not on computed tomogram assessed density for both systems. This confirms earlier observations.13,14

It must be emphasised that the conditions in this study were virtually ideal, in that there was practically no interface attenuation. Also, the 2 mm stone fragments did not accumulate in the path of the shock waves but dropped away from the field of high pressure through the basket, allowing efficient delivery of energy to the larger fragments. Therefore these results must be viewed with caution before extrapolating to the in vivo situation. The finding that the piezoceramic system at the highest power setting required a median of 1.65 times as many shocks as the spark gap system at a medium power setting would be expected from their focal volumes. The focal volume (50% isobar) under the in vitro conditions we used is probably in the range of 0.22 cm³ for the MPL 9000 and 0.03 cm³ for the Piezolith lithotripter. The peak positive pressure should be around 1000 bar and 1000 to 1200 bar for the MPL 9000 and Piezolith devices, respectively, when measured with PVDF membrane hydrophones. Thus, due to the larger focal volume, the MPL 9000 probably delivers a higher total energy per pulse to the stones than the Piezolith. This is important for larger stones and explains the higher number of shocks required with the Piezolith. This explanation does not, however, resolve the question as to why there was no correlation between the ratio of shocks required and stone volume. Since there was also no correlation between computed tomogram assessed density or cholesterol content of the stones, other factors are probably dominant in determining susceptibility to lithotripsy. Stone structure and matrix are possible features— for example, the number of defects within the stone structure could affect disintegration if they...
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act as origins of fracture lines in the early part of the breakage process. Whatever the mechanism, our study seems to indicate that the two systems cause stone destruction by a similar process. Microscopic analysis of the stone residue showed that the shape and size of the fragments (Fig 5) were similar after destruction by the piezoceramic and the spark gap system.

In conclusion, we found that small to medium sized gall bladder stones can be disintegrated in vitro into 2 mm fragments by both systems. The piezoceramic system needs more shocks than the spark gap system to achieve the same degree of fragmentation when both machines are operated at the power settings used for patient treatment. The ratio was neither constant nor consistent, however, for various stone sizes. Disintegration was dependent on stone volume but not on computed tomogram assessed density.

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ADDENDUM
After this study was completed an upgraded version of the Piezolith 2300 with higher energy per shock wave became available.