# Shockwave Lithotripsy

Lithotripsy (Chaussy *et al.* (1980), Bailey *et al.* (2003), Coleman *et al.* (1987)) is the therapy that focuses shockwaves at a target site within the body in order to remotely disintegrate kidney and gall stones. With the patient submerged in a water bath (so that the surroundings closely match the acoustic impedance of the body), shockwaves are focused at the site of the stone and multiple shocks are then administered in order to break the stone into pieces small enough to be ejected by the body. Cavitation may or may not play a role in the disintegration of the stone; it can also cause substantial collateral tissue damage. For an excellent review of lithotripsy research the reader is referred to Bailey *et al.* (2003).

Figure 1: Artificial stone fractured by shockwave lithotripsy [47].

Figure 2: Artificial renal stone exhibiting damage (courtesy of Erin Hatt, Dept. of Anatomy and Cell Biology, Indiana University).

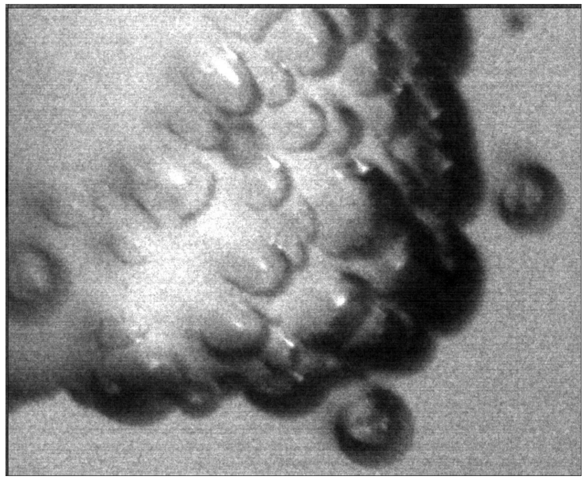

Figure 3: Cavitation bubbles near surface of an artificial stone (courtesy of D. Sokolov, M.R. Bailey, Center for Industrial and Medical Ultrasound, U. Washington).

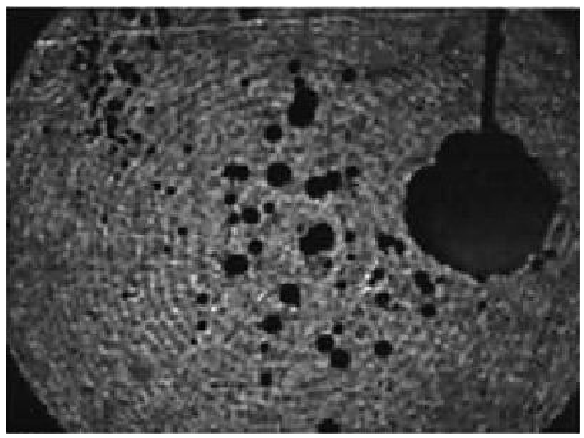

Figure 4: Typical shockwave lithotripsy bubble cloud near stone (larger black object) (from (Zhu *et al.* (2001))).

Lithotripsy using shock waves has a long history (Sturtevant (1996)). Figure 1 exemplifies the fracture of an artificial stone by lithotripsy using strong shock waves. It seems likely that this form of communition results from shock-induced stresses rather than cavitation. On the other hand, the damage shown in figure 2 seems to be quite characteristic of cavitation. Frequency dispersion prevents the shock waves from being more narrowly focused and consequently the focal volume is often significantly larger than the target stone. Figure 3 shows the formation of cavitation bubbles on an artificial stone in a shock wave lithotripter. Another illustration, figure 4, exemplifies how widespread the cavitation can be in a focal volume significantly larger than the target stone (the larger black object on the right). Consequently the cavitation generated by the shockwaves causes substantial collateral tissue damage in conventional lithotripsy. Double pulse shock wave lithotripsy can help reduce this focal volume (Sokolov *et al.* (2001)).

Various techniques have been investigated in order to try to refine lithotripter design. These usually have the competing objectives of limiting the collateral damage by confining the cavitation to a well-defined region while at the same time generating the most damage potential. These are partially competing objectives and the strength of the shockwaves (or ultrasound) is usually limited by the need to minimize collateral damage. However, knowledge of the intricacies of bubble dynamics suggests some superior strategies. Thus, for example, in shockwave lithotripsy multiple pulses [19] may be better than single pulses.

As another example, we would note the strategy devised by Matsumoto *et al.* (2003) who found that a period of high frequency ultrasound followed by a few low frequency cycles can be very effective. The high frequency period generates a cloud of small bubbles in the focal region by the process of rectified diffusion. The subsequent low frequency pulses then cause the collapse of this cloud in the manner described by Wang and Brennen (1994, 1999).