Separation of cavitation and renal injury induced by shock wave lithotripsy (SWL) from SWL-induced impairment of renal hemodynamics.

Andrew P. Evan*, Lynn R. Willis†, Bret A. Connors*, James A. McAteer*,
James E. Lingeman‡, Robin O. Cleveland¶, Mike Bailey¶ and Larry A. Crum¶

*Department of Anatomy & †Department of Pharmacology & Toxicology, Indiana University, &
‡Methodist Hospital of Indiana, Inc., Indianapolis, IN 46223; ¶Applied Physics Laboratory,
University of Washington, Seattle, WA, 98105

Abstract: SWL to one kidney causes localized tissue damage and impairment of tubular secretion (TS), but reduces renal plasma flow (RPF) in both kidneys. We studied the effect of kilovoltage (kV) and inversion of the waveform (IW) on the localized and bilateral effects of SWL (unmodified Dornier HM3). Six-week-old anesthetized pigs were subjected to conventional SWL (2000 shocks at 12 or 24 kV), SWL with IW (2000 shocks at 24 kV), or sham-SWL. Conventional SWL reduced RPF at each kV. TS was reduced at 24 kV but not at 24 kV. SWL with IW (reduced cavitation) caused minimal tissue damage, no reduction of TS, and reduced RPF. Sham-SWL altered no variable. Shock wave voltage and cavitation may be related to SWL-induced tissue injury and reduced TS, but neither may be related to the SWL-induced reduction of RPF.

INTRODUCTION

The application of 2000 shock waves (SW) at 24 kV to one kidney of experimental animals causes localized damage to renal blood vessels and tubules in that kidney(1), reduces blood flow to both kidneys(2), and impairs renal tubular secretion and overall extraction of organic anions in that kidney(3). These studies examined the effect of SW kV and inverted wave forms (IW) on SWL-induced impairment of renal hemodynamics and tubular function.

METHODS

Four groups of female pigs, 6 weeks old, were anesthetized and prepared for renal clearance experiments. Catheters were placed for infusion of fluids, measurement of blood pressure, bilateral measurement of renal para-aminohippurate extraction (Eau), and bilateral collections of urine. Three 15-minute baseline collections of urine and mid-point blood samples were followed by Group 1: SWL (2000 SW at 12 kV); Group 2: SWL (2000 SW at 24 kV; Group 3: 2000 SW at 24 kV with a "pressure-release" reflector that inverted the waveform; or Group 4: sham-SWL. Two more sets of three 15-minute clearance collections were obtained at 1 and 4 hours after SWL or sham-SWL. All SW were applied with an unmodified Dornier HM3 lithotripter to the lower pole calyx of the right or left kidney. F2 was aligned with the targeted region by fluoroscopy with contrast media injected into the renal hilus.

Steady-state concentrations of polyfructosan (PF) and PAH were infused. Urine and plasma were analyzed for PF and PAH by standard methods. Clearances of each were calculated, respectively, for glomerular filtration rate (GFR) and renal plasma flow (RPF). PAH in renal venous and arterial blood estimated Eau as an index of tubular secretion. RPF=(PAH clearance) / (Eau). The criterion for statistical significance was P<0.05. The protocol was approved by the IACUCs for Indiana University and Methodist Hospital of Indiana.

RESULTS

SWL at 12 and 24 kV (Groups 1 and 2) significantly reduced RPF in the shocked kidneys at 1 hour, but not at 4 hours post-SWL (Figure 1). GFR was likewise reduced in the shocked kidneys, and RPF was reduced, albeit to a lesser degree, in the unshocked kidneys (data not shown). Sham-SWL had no effect on GFR or RPF. Eau was not significantly changed by sham-SWL or by 2000 shocks at 12 kV to one kidney, but was significantly reduced at both 1- and 4-hour determinations after 2000 shocks at 24 kV (Figure 2).
SWL (2000 shocks at 24kV) applied to the lower pole calyx of 3 kidneys in the presence of the IW reflector produced no visible lesions at F2 and no reduction of E\textsubscript{PAH} (Figure 3). In contrast, RPF was reduced at 1 hour post-SWL in both kidneys in 2 of the 3 pigs (data not shown).

![Figure 1](image1.png)  ![Figure 2](image2.png)  ![Figure 3](image3.png)

**FIGURE 1.** Effects of SWL (2000 shocks at 12 & 24 kV) on renal plasma flow. (* p<0.05)

**FIGURE 2.** Effects of SWL (2000 shocks at 12 & 24 kV) on PAH extraction. (* p<0.05)

**FIGURE 3.** Effect of inverted waveform shock waves on PAH extraction.

**DISCUSSION**

The experiments comparing the effects of 2000 SW at 12 or 24 kV on renal function suggest a possible relationship between shock wave voltage and impairment of E\textsubscript{PAH}, but they suggest no such relationship between kV and GFR or RPF. The unilateral and apparently voltage-related effects of SWL on E\textsubscript{PAH} infer that changes in E\textsubscript{PAH} are related to SWL-induced injury since the lesion induced by SWL is always confined to the shocked kidney. (1) The voltage-independent, bilateral reduction of RPF may reflect the SWL-induced release of a circulating vasoconstrictor independent of tissue injury. The results obtained with the IW reflector support this notion since detectable, bilateral impairment of GFR and RPF occurred in the shocked kidneys in 2 of 3 pigs, but with no lesions at F2 and no alteration of E\textsubscript{PAH}. Since the IW reflector generates less cavitation (based on invitro measurements) than the conventional reflector for the HM3 lithotripter, the present results suggest that cavitation may be associated more with the occurrence of SWL-induced tissue injury and less with SWL-induced renal vasoconstriction.

**ACKNOWLEDGMENTS**

This project was supported in part by the Institute for Kidney Stone Disease, Methodist Hospital of Indiana, and by USPHS Grant PO1-DK43881.

**REFERENCES**