Lithotripsy and Related Techniques for Gallstone Treatment

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PREFACE

This book comprises the contributions to the Third International Symposium on Biliary Lithotripsy held in September 1990 in Munich. The first extracorporeal shock-wave lithotripsy in a patient with gallstones had been performed in Munich only 5 years before. In our time of rapid developments, 5 years is long enough to establish the strengths and weaknesses of a young method and to see competing and related methods evolve. This book therefore encompasses not only extracorporeal shock-wave lithotripsy but also other therapies for treatment of gallstones, such as direct solvent dissolution, new interventional techniques, and laparoscopic cholecystectomy. These are important issues for health care, because cholelithiasis is one of the most prevalent diseases, affecting approximately 10% of the adult population in the United States and in Europe.

The trend toward noninvasive therapy of gallstone disease started by extracorporeal shock-wave lithotripsy has stimulated the development of other procedures. However, of all methods except oral bile acid dissolution, shock-wave lithotripsy remains the least invasive. It must, however, be used critically and judiciously in selected patients. Those who have uncritically hoped that lithotripsy could make surgery obsolete in the majority of patients have been wrong from the beginning. They have nourished hopes that cannot be fulfilled. Naturally, those who shared these hopes are disappointed. Such unfounded hopes and their disappointment are a well-known phenomenon that leads to oscillation in the response of physicians and patients to new drugs and treatments. We hope the results and discussions compiled in this book will help lithotripsy find a realistic place. The same is true for other new therapeutic methods for gallstone disease, some of which are still in a "honeymoon" period and have not yet found their position among available therapies.

It is important to not overemphasize any single procedure, be it dissolution, fragmentation, or removal of the stones by endoscopy, laparoscopy, or surgery, but to treat the entire patient, not only the stone. In our judgment, biliary lithotripsy and other therapies will coexist in the future and treatment plans will be tailored to the needs of the individual patient. This book reflects this approach by discussing a variety of treatment options.

Finally, we must not forget during our discussions of the physics of shock waves and new machines that, as physicians, we must understand more than the results of biomedical research. We must deliver medicine in a humanistic tradition, knowing that research and new technologies are only a means to an end. As Albert Einstein pointed out, concern for man must always be the chief interest of all technical efforts.

We hope this book will provide useful information for clinicians in various disciplines and will stimulate progress in the treatment of gallstone disease. The editors are grateful to all of the contributors, and hope that interdisciplinary exchange of ideas and experience on an international level will continue.

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CONTENTS

Chapter 1

Influence of Output Setting on Acoustic Field of a Shock Wave Lithotriptor

A. J. Coleman
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J. E. Saunders

The output setting and the number of pulses administered are typically the only variables under control of the lithotriptor operator and are widely used in the literature to specify the acoustic exposure from a lithotriptor. This paper describes what happens to the acoustic field of a lithotriptor when the output setting is altered.

Varying the output setting of a lithotriptor typically involves altering the acoustic energy supplied to the transducer per pulse, E_{el}. Although for a constant number of shocks N this parameter has proved to vary closely with stone-fracturing efficiency[6] and cell damage,[5] it is easy to show that it is not adequate as an exposure parameter in lithotripsy. Brummer et al.,[2] for example, have studied cell killing under different shock wave exposure conditions, but for a constant value of E_{el}, in relation to pressure rise time (t_r), peak positive pressure (p^+), peak negative pressure (p^-), and positive and negative half-cycle durations (t^+ and t^-). They show that increasing the oxygen content of the water between the cell sample and the shock wave source can reduce cell killing and that both p^+ and t^- at the sample are decreased, probably as a result of the loss of energy in cavitation production in the water. They also demonstrate that both cell killing and p^+ increase as the water temperature is increased. If, however, the water oxygen content and temperature are kept constant, it may be useful to examine how acoustic parameters vary with E_{el}, since typical clinical and experimental studies involve examining the biologic response at different output settings.

This study considers, in particular, theoretic predictions of changes in peak focal pressures (p_f^+ and p_f^-), pressure rise times (t_r), and spatial distributions of pressure that result from simple alteration of the source output. The results have been obtained by using a one-dimensional frequency domain model based on the so-called KZK equation, and this theoretic approach, in which the lithotriptor beam is assumed to be Gaussian, is described in detail by Coleman et al.[3]

CHANGES IN ACOUSTIC FIELD

The output of the lithotriptor is typically set by altering the voltage *(U)* used to charge the capacitor *(C)* in a discharge circuit giving $E_{el} = (CU^2)/2$. It is convenient, however, for the calculations to define the output of a lithotriptor in terms of the temporal peak pressure on the beam axis at the aperture p_{ap}^+ since this is used as one of the boundary conditions in the model along with the pressure-time variation (waveform) at the aperture. In practice, p_{ap}^+ varies approximately linearly with U.

Pressure Rise Time

Figure 1–1 shows the predicted pressure waveform at the beam focus for $p_{ap}^{+} = 5$ MPa. It is assumed here that the pressure waveform at the aperture has the form of an exponentially damped sinusoidal pulse of the same zero crossing frequency as that measured on the Dornier HM3, and it is also assumed that the beam geometry is the same as that of the Dornier HM3. In all the calculations the beam is assumed to propagate initially in water and then in 6 cm of fluid with a similar attenuation to that of tissue, as is typical of the clinical use in lithotripsy treatment of kidney stones. Refraction and reflection at the water-tissue interface are ignored. The waveform in Figure 1–1 shows the characteristic features of the measured waveform from electrohydraulic (EH)-type lithotriptors including a steep rise in initial pressure (a shock front) followed by a slower negative-pressure excursion.[4]

In Figure 1–2 the positive part of the pressure waveform is expanded to illustrate the change in the rise time of the positive-pressure half-cycle at a variety of aperture pressures p_{ap}^{+}. It is noted that, in this case, a shock front forms only when the pressure reaches 3 MPa at the aperture.

This set of waveforms (Fig 1–2) shows that the output setting, other factors being equal, determines whether or not the wave becomes shocked at the beam focus in tissue. It is interesting to note that the output setting on an EH shock wave source cannot easily be turned down below a certain value since at low voltages the necessary electric discharge is inhibited. Measurements on the Dornier HM3, for example, give values of $p_{ap}^{+} > 3$ MPa even at the lowest setting (around 10 kV), and consequently, on

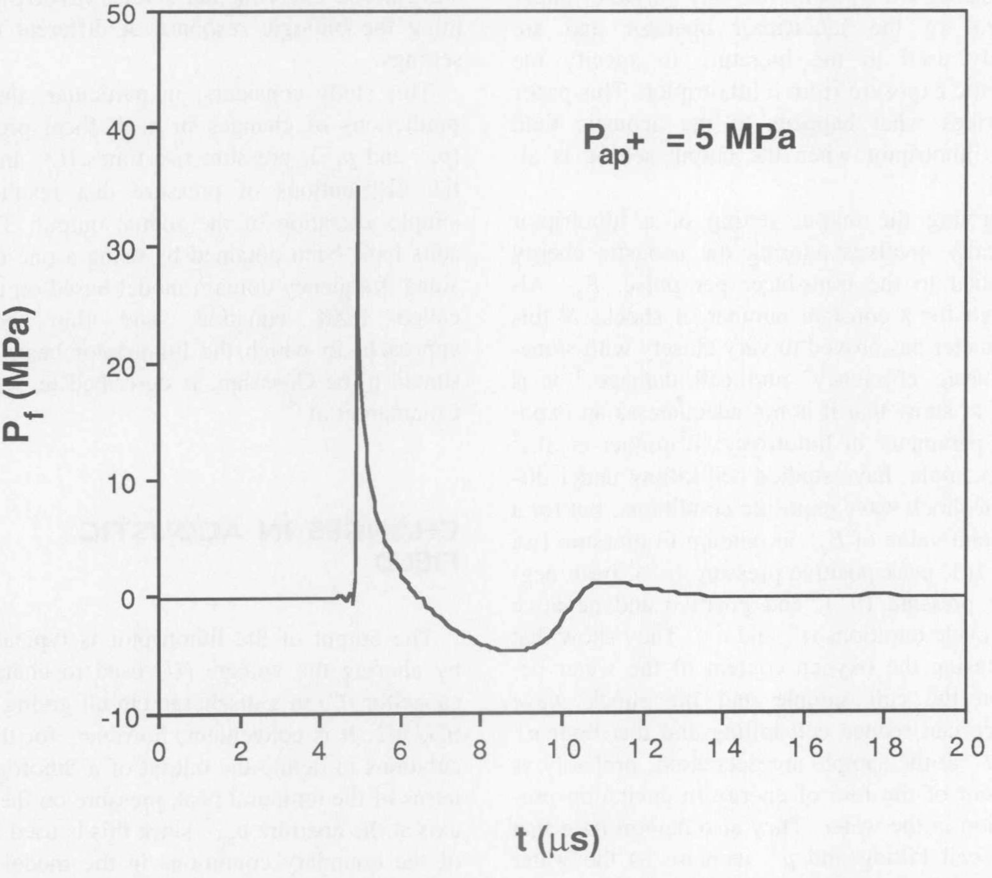

Fig 1–1.
A predicted pressure waveform at the beam focus of an electrohydraulic lithotriptor with the same beam geometry as the Dornier HM3 and pressure typical of 20 kV operation. The beam is assumed to propagate from water into 6 cm of tissue. The time scale represents 20 μs.