Title
The Effect of Extracorporeal Shock Wave Lithotripsy on the Microbiological Flora of Urinary Calculi

Journal
Investigative Urology, 144(3)

ISSN
0021-0005

Authors
Stoller, Marshall L
Workman, Steven J

Publication Date
1990-09-01

DOI
10.1016/s0022-5347(17)39538-1

Peer reviewed

0022-5347/90/1443-0619$02.00/0
THE JOURNAL OF UROLOGY

Vol. 144, September
Printed in U.S.A.

THE EFFECT OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY ON THE MICROBIOLOGICAL FLORA OF URINARY CALCULI

MARSHALL L. STOLLER* AND STEVEN J. WORKMAN

From the Department of Urology, University of California School of Medicine, San Francisco, California

ABSTRACT

To determine whether extracorporeal shock wave lithotripsy can sterilize infection stones and, thus, decrease the recurrence rate we investigated its impact on the microbiological flora of staghorn calculi. Fragments from 17 staghorn calculi retrieved percutaneously were divided into paired sets. One set was fractured by extracorporeal shock wave lithotripsy at 18 kv. and with increasing numbers of shock waves up to 1,000. One set was fractured mechanically with a surgical clamp. Bacterial cultures were then compared between the 2 groups.

Of the 17 staghorn calculi 10 showed significant bacterial growth (59%). The number of colony-forming units was not significantly different between stones fragmented by lithotripsy and those that were mechanically fractured. Furthermore, exposing fragments to an increasing number of shock waves did not alter the colony count. We conclude that extracorporeal shock wave lithotripsy has no discernible effect on the microbiological flora of infected staghorn calculi. (*J. Urol., 144: 619–621, 1990*)

Extracorporeal shock wave lithotripsy (ESWL†) currently is the preferred treatment for most urinary stones.[1] Its current role in the treatment of staghorn calculi is to fragment residual calculi after percutaneous debulking.[2,3] With this multimodality therapy, kidneys harboring staghorn calculi can be rendered free of stones in 59 to 92% of the cases as documented by radiographic evaluation at 3 months.[4] Before the era of endourology and ESWL, rates free of stones of roughly 75% could be achieved with an open operation.[5,6] Painstaking procedures were taken to assure removal of the smallest residual fragments because of the belief that they could serve as a reservoir for bacteria or nidi for future stone growth and an increased recurrence rate.[7] Thus, any treatment that might eliminate such bacteria would have a positive impact upon stone recurrence rates. Therefore, we designed an experiment to study the effect of ex vivo ESWL on the bacteriological flora of staghorn calculi.

MATERIALS AND METHODS

Harvesting of stones. A total of 17 staghorn calculi (renal pelvic stones extending into at least 2 infundibula) was removed by an open operation in 4 patients and by percutaneous nephrostolithotomy in 13. Struvite accounted for 25 to 75% of each stone. At least 1 piece of each of the 17 stones was selected for further fragmentation by mechanical means (average weight 169 mg. with a standard deviation of 46 mg.) and another for fragmentation by ESWL (average weight 176 mg. with a standard deviation of 96 mg.) with the Dornier HM3 unit. In most cases the samples chosen for the 2 methods of fragmentation were neighbors to each other, being smaller portions of a larger fragment removed at operation and, thus, representative of the same region of the stone as a whole.

Mechanical fragmentation. Stones selected for mechanical fragmentation were crushed between the jaws of a surgical Mayo clamp until the resultant residue consisted of gravel less than 1 mm. in diameter and an additional collection of finer powder akin to the material produced and passed during clinical ESWL. This took approximately 3 minutes. The residual stone material was suspended in 10 ml. sterile 0.9% saline and a 0.05 ml. sample of this suspension was quantitatively cultured.

Accepted for publication March 21, 1990.
*Requests for reprints: Department of Urology, U-575, University of California, San Francisco, California 94143-0738.
† Dornier Medical Systems, Inc., Marietta, Georgia.

Fragmentation by ESWL. The corresponding set of stones selected for fragmentation by ESWL was placed in sterile radiolucent plastic culture tubes containing 10 ml. sterile saline. These stones were positioned at the F2 focus of the Dornier HM3 shock wave lithotriptor under fluoroscopic guidance. A total of 600 shock waves (approximately 7 minutes) was delivered at 18 kv., after which all stones appeared to be fragmented to an extent similar to those that had been mechanically crushed. This residual material was suspended in the saline solution and a 0.05 ml. sample was removed for bacterial culture. Additional fragments from 6 stones with established bacterial colonization were exposed to a total of 1,000 shock waves at 18 kv. During this course 0.05 ml. samples were cultured at each multiple of 200 shocks to assess a possible dose-related effect of the shock waves on the microbiological flora of these stones. A time control culture also was performed, culturing the suspension after 200 shocks and repeating the culture of the same suspension 10 minutes later, the time required to administer a total of 1,000 shocks.

Stone culture technique. Quantitative stone cultures were performed by techniques to distinguish bacteria within the substance of the stones from surface contamination. Our method included slight variations from previously described techniques.[8] In short, each stone was washed successively in 4 test tubes containing 10 ml. sterile saline before fragmentation by either ESWL or mechanical crushing. A 0.1 ml. sample of the final wash was cultured quantitatively onto blood and MacConkey's agar plates. After fragmentation, the stone residue was resuspended in 10 ml. sterile saline and 0.1 ml. samples of these solutions were similarly cultured. After a 24-hour incubation period colony counts were performed and bacterial density was expressed as colony-forming units per mg. stone. Surface contamination was corrected for by subtracting the number of colony-forming units in the final wash from the growth yield of the entire stone after fragmentation.

Statistical analysis. Bacterial growth after both types of fragmentation was compared by the paired t test. Growth with 1,000 shock waves was compared at each 200-wave increment with the F test for analysis of variance for repeated measures. There were 29 degrees of freedom for this analysis.

RESULTS

We subjected 17 matched pairs of stone fragments to either mechanical or ESWL fragmentation. The stones in 10 of these

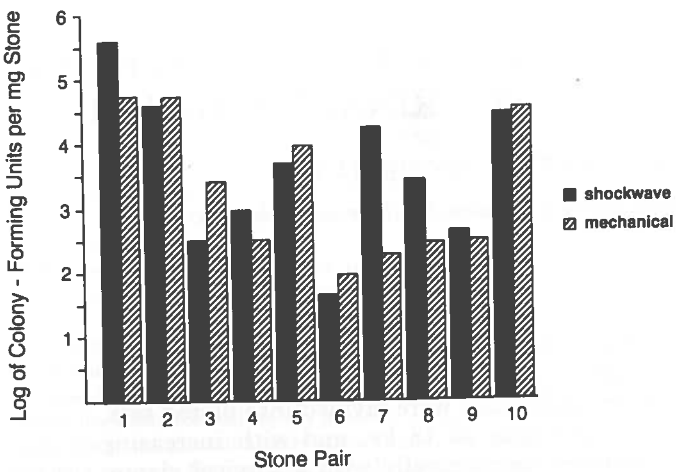

FIG. 1. Bacterial density relative to type of fragmentation in each of 10 stone pairs with positive cultures.

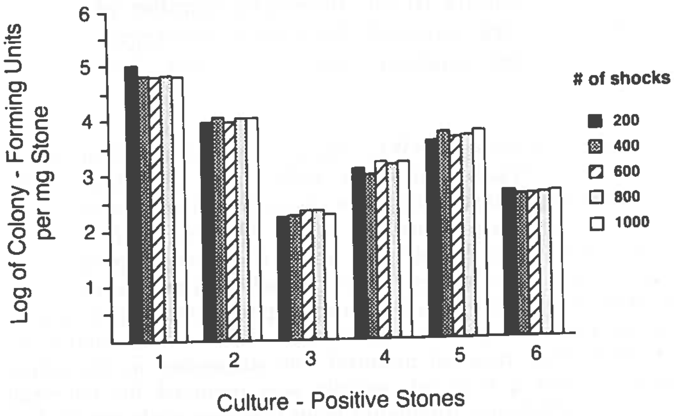

FIG. 2. Bacterial density relative to number of ESWL shock waves in each of 6 stones with positive cultures.

pairs (59%) yielded positive bacterial cultures. In no case did the stone exposed to 1 method of fragmentation produce a positive culture when its match did not.

The bacterial density after each type of fragmentation of the 10 stone pairs with positive cultures is shown in figure 1. In 5 pairs the stone treated by mechanical fragmentation had heavier bacterial growth than the stone exposed to ESWL, while in the other 5 the findings were the opposite. A comparison of the 2 methods of pulverization revealed no statistical difference in the bacterial densities of stones treated by these 2 techniques ($p = 0.4$).

Results for bacterial growth in 6 stones subjected to 1,000 shock waves in 200-wave increments are shown in figure 2. In each case most of the fragmentation occurred during the first 200 shocks and complete fragmentation was achieved by the time 400 shocks had been delivered. There was no trend toward either more or less bacterial growth with increasing exposure to shock waves ($p = 0.5$). Additionally, 3 suspensions cultured after 200 shocks and the same suspensions cultured after the time that would be required for 1,000 shocks showed no significant difference in bacterial growth.

DISCUSSION

Staghorn calculi are associated with infection by urease-producing organisms that create an alkaline environment conducive to struvite and apatite formation.[9] Our finding that fragments from 59% of the staghorn calculi yielded positive cultures for such bacteria is only slightly lower than previous reports.[8] Eradication of infection by urease-producing organisms has been considered critical to prevent stone recurrence, since bacteria within residual stone fragments would maintain the alkaline milieu that fostered the initial stone.

Long-term results after treatment for staghorn calculi with combined percutaneous and ESWL techniques are only now becoming available, since this approach has been applied clinically for a relatively short period. If ESWL has a bactericidal effect one might expect a decreased stone recurrence rate and multimodality therapy that includes ESWL could be superior to monotherapy without it (that is an open operation or percutaneous nephrolithotomy alone). Thus, the potential ability of ESWL to eradicate bacteria from infected calculi was studied.

We exposed pieces of infected staghorn calculi to fragmentation by ESWL. Although this was performed in vitro, we believe that the delivery of 600 shock waves at 18 kv. with the Dornier HM3 lithotriptor mimics the treatment that would be applied to residual calculi after percutaneous debulking of large staghorn stones in our clinical practice. It is possible that more energy was actually delivered to these stones because there would be no attenuation of the shock waves by interposed tissue as seen in clinical practice.

Our data show no antibacterial effect of ESWL compared with simple mechanical fragmentation between the jaws of a crushing surgical clamp. Furthermore, increasing the number of shocks by 200-wave increments up to a total of 1,000 showed no dose-related impact upon the bacterial viability. ESWL did not sterilize infected renal calculi. Therefore, when multimodal therapies result in residual fragments even after ESWL, we believe that long-term recurrence rates will be similar to those after traditional nephrolithotomy.

Data suggest that macroscopically identifiable residual calculi (visible on a postoperative plain abdominal film) exist in up to 9.7% of the kidneys treated for staghorn calculi with combined percutaneous and ESWL techniques.[3] Sterile stone debris after ESWL does not appear to be of clinical significance. Recently, Michaels and associates reported that fragmented stone debris allows for more effective sterilization with antibiotics due to the increased surface area from the pulverized stone.[10] Elbers and associates found that in vitro ESWL had no effect upon the viability of urease-positive calculogenic bacteria.[11] Our in vitro study is in agreement with these prior studies in that ESWL alone does not appear to sterilize infected urinary calculi.

In a larger study by Pode and associates recurrent bacteriuria correlated with residual gravel after ESWL treatment of stones associated with urinary tract infections.[12] Although infection was localized to the segment of the urinary tract containing the stone, cultures of the substance of the stone per se were not done. These investigators recommended that stones larger than 2 cm. in diameter should be removed percutaneously.

Shock wave energy delivered from the HM3 lithotriptor has significant impact upon urinary calculi, fragmenting them in most cases. The physical events that result in fragmentation at the F2 point include elevation of pressures to approximately 5,000 pounds per square inch (at 18 kv.)[13] and free radical production mimicking that produced by 1,100 rad ^{60}cobalt irradiation.[14] Furthermore, shock wave energy has been shown to be cytotoxic to tumor cells in vitro and in vivo in a marine model.[15] At the same time our data show that this same energy had minimal impact upon the viability of the associated microbiological flora of stones. How is this possible?

Calculi are crystalline structures that are prone to crack along planes of imperfection in the crystalline lattice. Therefore, stones with few imperfections (for example cystine or calcium oxalate monohydrate stones) are more difficult to fracture. Although urinary calculi are hard, they also are brittle (previously referred to as stone fragility).[16] A brittle substance, such as a piece of glass or a stone, is fractured easily by a sudden impact because it cannot tolerate even a small distortion or strain. In contrast, amorphous material is tough and, thus, more difficult to crack. Tough materials, such as biological tissues, can withstand a sudden impact by dissipating the energy into plastic deformation. It is possible that this reasoning underlies the dramatic destruction of urinary calculi while surrounding biological tissues, including bacteria, remain viable.

REFERENCES

1. Drach, G. W., Dretler, S., Fair, W., Finalyson, B., Gillenwater, J., Griffith, D., Lingeman, J. and Newman, D.: Report of the United States Cooperative Study of extracorporeal shock wave lithotripsy. J. Urol., **135:** 1127, 1986.
2. Schulze, H., Hertle, L., Graff, J., Funke, P.-J. and Senge, T.: Combined treatment of branched calculi by percutaneous nephrolithotomy and extracorporeal shock wave lithotripsy. J. Urol., **135:** 1138, 1986.
3. Kahnoski, R. J., Lingeman, J. E., Coury, T. A., Steele, R. E. and Mosbaugh, P. G.: Combined percutaneous and extracorporeal shock wave lithotripsy for staghorn calculi: an alternative to anatrophic nephrolithotomy. J. Urol., **135:** 679, 1986.
4. Lerner, S. P., Gleeson, M. J. and Griffith, D. P.: Infection stones. J. Urol., **141:** 753, 1989.
5. Wickham, J. E. A., Coe, N. and Ward, J. P.: One hundred cases of nephrolithotomy under hypothermia. J. Urol., **112:** 702, 1974.
6. Russell, J. M., Harrison, L. H. and Boyce, W. H.: Recurrent urolithiasis following anatrophic nephrolithotomy. J. Urol., **125:** 471, 1981.
7. Silverman, D. E. and Stamey, T. A.: Management of infection stones: the Stanford experience. Medicine, **62:** 44, 1983.
8. Fowler, J. E., Jr.: Bacteriology of branched renal calculi and accompanying urinary tract infection. J. Urol., **131:** 213, 1984.
9. Griffith, D. P. and Osborne, C. A.: Infection (urease) stones. Min. Electrol. Metab., **13:** 278, 1987.
10. Michaels, E. K., Fowler, J. E., Jr. and Mariano, M.: Bacteriuria following extracorporeal shock wave lithotripsy of infection stones. J. Urol., **140:** 254, 1988.
11. Elbers, J., Seline, P. and Clayman, R. V.: Effect of shock wave lithotripsy on urease-positive calculogenic bacteria. J. Endourol., **2:** 83, 1988.
12. Pode, D., Lenkovsky, Z., Shapiro, A. and Pfau, A.: Can extracorporeal shock wave lithotripsy eradicate persistent urinary infection associated with infection stones? J. Urol., **140:** 257, 1988.
13. Hunter, P. T., Finlayson, B., Hirko, R. J., Voreck, W. C., Walker, R., Walck, S. and Nasr, M.: Measurement of shock wave pressures used for lithotripsy. J. Urol., **136:** 733, 1986.
14. Morgan, T. R., Laudone, V. P., Heston, W. D. W., Zeitz, L. and Fair, W. R.: Free radical production by high energy shock waves—comparison with ionizing radiation. J. Urol., **139:** 186, 1988.
15. Russo, P., Stephenson, R. A., Mies, C., Huryk, R., Heston, W. D. W., Melamed, M. R. and Fair, W. R.: High energy shock waves suppress tumor growth in vitro and in vivo. J. Urol., **135:** 626, 1986.
16. Dretler, S. P.: Stone fragility—a new therapeutic distinction. J. Urol., **139:** 1124, 1988.