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Key Words
ESWL monotherapy
Staghorn calculi
Morphometric analysis

Abstract
Forty-eight patients with large renal staghorn calculi of more than 35 mm in maximum length on plain X-rays were treated by extracorporeal shock wave lithotripsy (ESWL) monotherapy for a period of 2 years. Thirty patients, with a follow-up of more than 6 months after the last treatment, were included in this study. The surface area of the calculi was 1,290 mm^2 on average. Based on plain X-rays, 9 cases (30%) became free of calculi while 12 patients (40%) had a small amount of residual fragments (less than 100 mm^2 in area). Adding these cases to those in which all the residual calculi were eliminated, the total turned out to be 21 cases (70%) and the treatment of staghorn calculi with ESWL was thus considered to have been fairly effective in the present series. The remaining 9 cases (30%) contained a considerable amount of residuals (more than 100 mm^2). The present study in the ESWL of large staghorn calculi revealed no clear relationship between the surface area of the stones and evacuation of the fragments. The amount of the residual fragments was significantly small when either the renal collecting system was less than 2,000 mm^2 in area ($p < 0.05$), or when the ureteropelvic junction (UPJ) was equal or greater than 5 mm in diameter ($p < 0.02$) according to intravenous pyelography (IVP) before treatment. The complications associated with this treatment were minimal, with a high fever in only 3 patients that were treated easily by antibiotic therapy. ESWL monotherapy thus appears to be effective for the treatment of staghorn calculi, while causing few complications. Thus, cases showing less than 2,000 mm^2 in area for the collecting system or those showing an equal to or greater than 5 mm diameter of UPJ on IVP before treatment, are all thought to be good candidates for ESWL monotherapy.

Introduction

Since 1982, extracorporeal shock wave lithotripsy (ESWL) has been introduced into clinical application for the treatment of renal and ureteral calculi [1]. As seen in some previous reports [2–4], the staghorn calculi were initially thought to be too large to be treated by ESWL monotherapy. Recently, however, several papers [5, 6] have reported that ESWL monotherapy with either HM3 (Dornier Medizintechnik GmbH, Germering, FRG) or Lithostar (Siemens, Erlangen, FRG) was in fact capable of treating renal staghorn calculi. However, they did not refer to the relationship between the success rates of ESWL and the morphological condition of the kidneys.

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We have treated patients with variegated renal calculi since 1986. Among them, we have analyzed the success rates for the treatment of staghorn calculi in association with the morphological condition of the renal collecting system. In order to elucidate whether ESWL monotherapy is truly an effective alternative for the treatment of staghorn calculi and to decide on the indications for this therapy, a retrospective analysis of ESWL monotherapy in our ESWL center was conducted as described herein.

Materials and Methods

For 2 years from April 1988 to March 1990, 69 cases were diagnosed as having large staghorn calculi, more than 35 mm in maximum length. Among them, 17 patients were treated with ESWL combined with percutaneous nephrolithotomy (PNL), and 4 were treated with PNL alone. Subsequently, 48 patients were treated with ESWL monotherapy. However, 18 were discarded from the study, because follow-up failed in them, 11 of whom had shown small residual fragments and 1 had fairly large stone fragments at discharge. However, those 12 patients had been missed. Follow-up study was too short for 6 patients when the study period was closed. Finally, 30 patients were admitted to this study.

The mean observation period was 12.9 months. Other than the 48 patients mentioned above, 17 were treated with ESWL in combination with PNL, and 4 were treated with PNL alone. The 30 other patients studied consisted of 21 complete and 9 partial staghorn calculi, as show in table 1, consisting of 10 males and 20 females. Their mean age was 50.8 years, ranging from 28 to 72 years. The calculi were present on the right side in 16 patients and on the left side in 14 patients. Both before and after treatment, an IVP was routinely adopted to visualize the anatomical structure of the upper urinary tract. The angle formed with the medial silhouette line of the ureter and superior silhouette line of the renal pelvis was measured as shown in figure 1, and it was designated as the ureteropelvic angle A (UPA-A). Similarly, the UPA-B was measured using the lateral line of the ureter and an inferior line of the renal pelvis. The areas of stones were measured on plain X-ray films. Measurements were recorded using an image analyzing system (Cosmozone 2S, Nikon, Tokyo, Japan). The angles and areas obtained in this way were taken into consideration as factors that would influence the results of the treatment. According to previous reports [7], a 6F ureteral stent was placed prior to ESWL in all patients. For the initial ESWL treatment, HM3 was utilized. Lithostar was also used in 8 patients as an auxiliary choice. The results of treatment were evaluated on the basis of plain X-ray film and IVPs both before and after treatment.

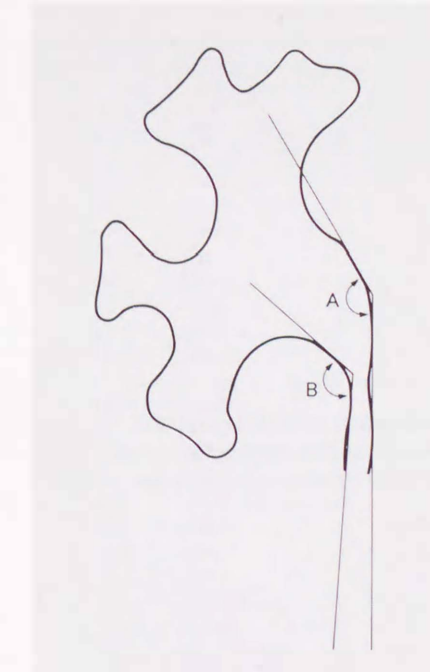

Fig. 1. Scheme used for measurement of ureteropelvic angle. A = Upper; B = lower.

Table 1. Thirty patients (age 28–72, mean 50.8) with large staghorn calculi treated by ESWL monotherapy

Sex	male	10
	female	20
Side	right	16
	left	14
Type	complete	21
	partial	9

Results

As shown in table 2, the maximal lengths of the calculi ranged from 35 to 94 mm (the mean value was 61 mm). The area of calculi obtained from the standard anteroposterior abdominal plain X-ray film ranged from 447 to 2,910 mm^2 (with a mean value of 1,270 mm^2). The area of the collecting system, as measured from the IVPs, ranged from 947 to 3,943 mm^2 (with a mean value of 2,200 mm^2). The average angle which formed at the medial silhouette line of the ureter and superior silhouette line of the renal pelvis was 178.4° at the UPJ (UPA-A), while the average for the UPA-B measured using a lateral line of the ureter and inferior line of the renal pelvis was 138.1°. The mean difference in angles between the UPA-A and the UPA-B was 40.3°. After the last ESWL, the patients were observed for 6 to 29 months (mean duration: 13.0 months). At the last observation, the area of

Table 2. Measurements of large staghorn calculi on plain X-ray film and the collecting system on IVP

Maximum length of the calculi, mm	35–94	(61)
Area of the calculi, mm²	447–2,910	(1,270)
Area of the collecting system, mm²	947–3,943	(2,200)
Diameter of the PUJ, mm	1–14	
Angle of the UPA-A	131.3–227.6°	(178.4)
Angle of the UPA-B	82.9–170.8°	(138.1)
Difference between the UPA-A and the UPA-B	–1.3–113.1°	(40.3)

Mean values in parentheses.

Table 3. Correlation of residual fragments and the measurements on X-ray film taken before treatment (mean ± SD)

Measurements	Range	Patients	Area of the fragments, mm²	
Area of the calculi	<1,000 mm²	13	0.60 ± 0.80	n.s.
	>1,000 mm²	17	1.98 ± 3.19	
Area of the collecting system	<2,000 mm²	13	0.27 ± 0.45	$p < 0.05$
	>2,000 mm²	17	2.24 ± 3.11	
Diameter of the PUJ	<5 mm	12	2.67 ± 3.56	$p < 0.02$
	≧5 mm	18	0.53 ± 0.78	
Area of the UPA-B	<140°	15	0.94 ± 1.54	n.s.
	≧140°	15	1.83 ± 3.21	
Difference between the UPA-A and UPA-B	<45°	19	1.23 ± 2.15	n.s.
	≧45°	11	1.65 ± 3.12	

residual calculi on plain X-ray ranged from 0 to 1,115 mm². The mean value plus SD was 138.3 + 255.5 mm². Nine cases (30%) had become completely free of calculi on the plain X-ray film. Twelve patients (40%) had a small amount of residual fragments of less than 100 mm² in area on the X-rays, and 9 cses (30%) contained a considerable amount of residual measuring more than 100 mm². Table 3 shows the relationship between the residual amount of disintegrated calculi and an analysis of the X-rays taken before treatment. The information included the areas of the calculi, the area of the collecting system, the diameter of the UPJ, the UPA-A and the UPA-B, and the differences between the UPA-A and the UPA-B. A significant correlation could be noticed in the area of the collecting system and the diameter of the UPJ in relation to the residual stone rate. Namely, in cases showing the area of the collecting system to be less than 2,000 mm², the amount of residual stones was significantly smaller than that in cases showing an area of over 2,000 mm² ($p < 0.05$). In addition, in cases showing a diameter of the UPJ equal to or more than 5 mm, the amount of residual stones was significantly smaller than that in cases showing them to be below 5 mm. Details of the ESWL treatment by HM3 are shown in table 4. The number of sessions averaged 3.7, ranging from 1 (4 patients) to 8 (1 patient). The mean total number of shock waves was 6,794. The number of shock waves in one session ranged from 1,000 to 2,200, with a mean of 2,070. After ESWL monotherapy, auxiliary ESWL by Lithostar was also performed on the 8 patients with residual calculi.

The patients with a large number of residual fragments were once discharged after their obstructive symptoms had improved, and then were rehospitalized when residual small fragments were spontaneously eliminated and only large ones remained. The number of hospitalizations ranged from 1 to 5. The total period of hospitalization varied from 13 to 136 days (mean 55.2 days). As an additional therapy, transurethral ureterolithotripsy (TUL) was adopted in order to get rid of the arrested fragments of broken calculi.

Results of stone analysis showed predominance of infectious stones (56.7%), which included struvites, carbonate apatite and hydroxyl apatite. Oxalate stones were second in frequency (33.3%) as shown in table 5. No patients with cystine stones were treated. No significant relationship could be observed between stone composition and evacuation of the stones.

Table 4. Patients treated by ESWL monotherapy

Patient	Stone dimensions		Type of staghorn	Area of collecting system mm²	Diameter of PUJ mm	PUJ angle (PUA)			Treatment			Results of residual stone fragment			
	MD mm	surface mm²				A	B	A-B	sessions of ESWL	shock waves	TUL	months follow-up	involved calyx	MD mm	surface area mm²
T.K.	35	447	partial	2,921	8	160.5	82.9	77.6	2	3,250	0	9	middle, lower	17	293
K.S.	40	569	partial	1,009	6	148.6	107.2	41.4	2	4,300	0	8	none	0	0
T.N.	44	635	complete	2,666	5	227.6	158.1	69.5	2	4,100	0	6	all	7	68
T.N.	53	643	complete	1,191	4	198.8	157.0	41.8	1	2,200	0	19	lower	8	43
K.U.	47	672	partial	1,808	8	177.2	119.1	58.1	1	2,200	0	6	all	11	143
T.M.	45	714	partial	947	13	194.6	122.4	72.2	1	2,000	0	23	lower	6	17
M.N.	57	743	complete	1,401	1	196.6	157.7	38.9	2	3,300	0	16	none	0	0
T.Y.	44	751	partial	212	14	145.0	134.5	10.5	3	5,900	0	11	lower	13	68
M.M.	46	788	partial	1,437	4	175.9	110.4	65.5	2	4,300	0	10	lower	8	35
K.N.	44	793	complete	171	7	221.7	108.6	113.1	1	2,100	1	29	none	0	0
S.S.	39	816	partial	1,905	5	194.9	133.3	61.6	3	5,900	0	7	none	0	0
N.N.	72	909	partial	1,227	1	178.1	168.7	9.4	2	2,400	0	9	lower	3	3
H.K.	63	990	complete	1,898	2	226.2	161.2	65.0	5	8,800	0	14	lower	19	108
S.A.	49	1,029	complete	1,776	5	198.6	162.6	36.0	7	10,700	2	12	none	0	0
T.Y.	50	1,029	partial	1,818	5	165.6	119.0	46.6	5	10,200	0	15	none	0	0
R.S.	79	1,276	complete	1,999	6	177.2	159.8	17.4	4	7,500	0	19	none	0	0
T.S.	57	1,297	complete	2,104	5	159.9	118.6	41.3	2	3,800	0	6	upper, lower	11	158
M.U.	78	1,306	complete	2,168	5	177.8	160.4	17.4	5	9,750	0	6	lower	15	40
H.K.	53	1,347	complete	2,955	1	153.2	135.2	18.0	5	9,500	0	14	middle, lower	32	586
S.N.	59	1,449	complete	3,001	7	163.8	165.1	–1.3	5	7,800	0	6	lower	15	129
I.O.	93	1,481	complete	2,063	4	153.8	144.5	9.3	4	7,100	0	6	lower	10	42
T.S.	67	1,482	complete	2,267	2	191.5	152.5	39.0	3	5,100	0	6	middle, lower	9	44
M.H.	74	1,578	complete	2,008	4	155.4	146.2	9.2	6	10,500	0	11	lower	36	345
M.Y.	49	1,607	complete	2,642	1	161.5	135.0	26.5	2	4,000	0	20	middle, lower	12	76
K.E.	66	1,687	complete	2,248	9	162.1	91.0	71.1	6	11,400	0	11	lower	9	32
K.Y.	84	2,180	complete	2,551	2	211.0	158.7	52.3	4	3,700	1	19	middle, lower	42	1,115
K.I.	70	2,190	complete	3,943	7	199.3	166.5	32.8	6	12,850	0	13	none	0	0
M.S.	80	2,375	complete	3,234	12	137.6	119.6	18.0	6	10,470	2	18	none	0	0
R.Y.	91	2,494	complete	3,447	3	208.0	170.8	37.2	8	15,750	0	16	middle, lower	53	802
I.F.	94	2,910	complete	3,428	6	131.3	116.5	14.8	6	12,950	0	24	lower	2	3
Average	61	1,270		2,200	6.1	178.4	138.1	40.3	3.7	6,794		13.0		11.3	138.3
SD	17.0	626		744	1.70	25.87	24.22	25.94		3,801		6.17		13.2	255.5

MD = Maximum diameter.

The most frequent complication was a high fever of over 38 °C, which was seen in 3 patients. The fevers were easily controlled, however, with antibiotic therapy. No subcapsular hematoma was encountered although ultrasonographic examinations were carried out on all patients both before and after treatment. Before treatment, there were 27 patients (90.0%) with mild pyuria (a leukocyte count, over 5/hpf), and 16 patients (53.3%) with severe pyuria (massive leukocytes). After ESWL treatment, 12 of 16 cases of severe pyuria improved, while 4 patients still demonstrated persistent severe pyuria. Regarding urine cultures, persistent significant bacteriuria was found in 13 patients before treatment. Bacteria frequently seen in the urine of patients before treatment were *Escherichia coli* in 4 cases and *Proteus mirabilis* in 4 cases. *Serratia marcescens*, *Klebsiella oxytoca*, *Morganella morganii*, *Enterococcus* and *Flavobacterium* were encountered in 1 case, respectively, while 2 cases of nonfermentative bacteria were detected. After treatment, *Enterococcus* was detected in 1 patient and *S. marcescens* in another.

Table 5. Analysis of stone composition

Infection-related[1]	17 (56.7)
Calcium oxalate	10 (33.3)
Uric acid	1 (3.3)
Unknown	2 (6.7)

[1] Includes struvite, carbonate apatite, hydroxyl apatite.

As for renal function, BUN and creatinine were examined both before and after treatment. The mean value ± SD of BUN was 13.5 ± 4.5 mg/dl before treatment and 12.6 ± 3.9 mg/dl after treatment, while that of creatinine was 0.81 ± 0.22 and 0.73 + 0.24 mg/dl. Neither of the differences were statistically significant.

Discussion

Concerning the treatment of renal staghorn calculi, the total elimination rate of residual stones in the present study seemed to be inferior to previous reports [5–7]. This may be attributable to our subjects having comparatively larger staghorn calculi than reported elsewhere. Yet, we attained a total disappearance of the calculi in 9 (30%) out of 30 cases. The longest diameter of the residual fragments has been taken into account previously for the success rate of ESWL therapy [3, 8, 9]. However, it seemed very difficult to calculate the longest diameter of the residual fragments, because most of the residual fragments had accumulated into the lower calyces after ESWL therapy, which made it hard to measure the largest fragments among them. In addition, it seemed much more appropriate to measure the total volume of the residual stones. However, it was also very difficult and complicated to measure the precise volume of the residual calculi. Therefore, I developed a simple way to evaluate the effectiveness of the therapy by measuring the area of residual fragments on plain X-rays. By this method, it was found in 12 cases (49%) that the amount of residual fragments was small, less than 100 mm^2. Adding these cases to those in which all the residual calculi were eliminated, the total turned out to be 21 cases (70%) and thus the treatment of staghorn calculi with ESWL was considered to have been fairly effective in the present series.

Some authors have reported that ESWL treatment became more effective when PNL was combined with ESWL for the treatment of staghorn calculi [10, 11], but the additional PNL did not seem to shorten the hospital stay. Moreover, it has been said that treatment by ESWL alone was less likely to bother the patients [5], whereas Miller et al. [12] reported that ESWL combined with PNL showed a higher stone-free rate than ESWL monotherapy.

In the present cases, there were no complications of subcapsular hematomas. Only 3 cases were suspected of having urosepsis with a high fever, but none of them required PNS. They all recovered with conservative treatment. In most of the present cases, a concomitant urinary tract infection improved, and such factors support the evidence that ESWL monotherapy is a highly effective and a safe remedy for staghorn calculi.

The common understanding that is now generally accepted is that the size of the calculi before treatment plays a major role in determining the efficacy of ESWL. In the present series, however, there was little correlation regarding the size of the calculi before treatment, which was in agreement with the report of Gleeson and Griffith [8]. Using an image analyzing system, Lam et al. [13] stated that stone surface area provided a useful basis to predict the possibility of evacuation and to compare the data among the institutions. However, the present study in the ESWL of large staghorn calculi revealed no clear relationship between the surface area of the stones and evacuation of the fragments.

Before this study, we supposed that the blunter the angle between the renal pelvis and long axis of the ureter was made, the easier was the predicted evacuation of the calculi. However, as far as we could determine, there was no significant correlation between the angles and the amount of the calculi evacuated.

The prognosis of patients treated with ESWL has been considered to vary widely depending upon the shape of the renal calculi and the renal collecting system. There have, however, only been a few reports concerning the two factors mentioned above. With regard to the area of the pelvis and renal calyx, Pode et al. [10] reported that the stone residual percentage became larger when the area exceeded 2,000 mm^2. Di Silverio et al. [11] reported that ESWL monotherapy was recommended in patients with no dilatation of renal pelvis or calyces. They also recommended ESWL combined with PNL in patients with dilatation in which over 70% of the calculi could be removed through a single tract. If the removal of 70% or more by this method was presumed difficult, surgical operation was the next alternative [11]. In both reports, the relationships between the concrete measured values and the amount of residual stones were not shown. From the above data, we considered that the determining factors for the result of treatment were the size, shape and components of calculi, their location, as well as the function of the pelvis and the shape of the upper urinary tract.

In the present study, we examined the changes in the X-rays both before and after ESWL to look for any correlation among the shape of the renal pelvis, as well as the shape of the calculi and the evacuation of fragmented calculi. The results showed that the effect of treatment had more to do with the size of the pelvis and calyces as well as the diameter of the UPJ than with the size of the calculi.

That is, in cases in which the area of the pelvis and calyces were over 2,000 mm^2 or where the diameter of the UPJ was less than 5 mm, the amount of the residual fragments seemed to be significantly large, and the treatment by ESWL alone would be expected to provide a less than sufficient result. Therefore, the combined technique of PNL seems worthy of consideration for those cases mentioned above.

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