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Differentiated approach to staghorn calculi using extra-corporeal shock wave lithotripsy and percutaneous nephro-lithotomy: an analysis of 151 consecutive cases

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Summary. From January 1984 to June 1986, 151 patients with partial or complete staghorn calculi were treated at our department either by extracorporeal shock wave lithotripsy (ESWL), percutaneous nephro-lithotomy (PCN) or a combination of both techniques. According to the stone burden, distribution of stone load, renal anatomy, radiodensity and chemical composition of the calculi, 31 patients (20%) underwent ESWL-monotherapy, 42 patients (28%) PCN-monotherapy, and 78 (52%) were treated by the combination (PCN+ESWL). The overall rate of severe complications amounted to 8%. Auxiliary measures were necessary in 35% after ESWL-monotherapy, 19% after PCN-monotherapy and 14% after the combination. Follow-up data with a mean observation time of 18 months were available for 89 patients: the stone-free rate for ESWL, PCN and the combination was 50%, 77%, and 60%, respectively. Recurrent stone formation occurred in 4% after PCN and in 6% after the combination. The incidence of urinary tract infection was significantly lower than before treatment (21% vs 36%).

Interventional therapy is generally accepted for the majority of staghorn calculi, since basic investigations by Blandy and Singh have shown that conservative management may lead to nephrectomy or dialysis in 50% of the patients, and resulted in a mortality rate of 30% [2]. Within the last 3 years, the management of renal calculi has changed dramatically, with the trend toward replacing open surgery by extracorporeal shock wave lithotripsy (ESWL) or percutaneous nephrolithomy (PCN). Nevertheless, staghorn calculi still remain a difficult challenge for the new technology. Principally, four therapeutic modalities for interventional management of staghorn calculi are in current use:

- ESWL-monotherapy [5, 8, 11–13]
- PCN-monotherapy [4, 11]
- the combination of PCN and ESWL [1, 6, 7, 10, 16, 20], and
- open renal surgery (i.e., radial or anatrophic nephro-lithotomy, pyelocalycotomy [2, 3, 13, 21]).

Based on $2\frac{1}{2}$ years of experience with a differentiated approach to these techniques, applied according to stone burden, distribution of stone load, renal anatomy, radiodensity and chemical composition of the calculi, the advantages and disadvantages of the different strategies are demonstrated.

Material and methods

From January 1984 to June 1986, 168 patients (mean age 51.3 years, range 10–81 years) presented with 175 cases of staghorn calculi. In a retrospective study, the therapeutic approach, postoperative complications and follow-up results after 18 months (range 6–36 months) were evaluated.

According to stone burden and the number of stone-filled calyces, the calculi were classified as *partial staghorn* (occupying the renal pelvis and at least two branched calyces) and *complete staghorn* (filling at least all but two calyces). Based on this definition, 100 patients presented with a partial and 75 with a complete staghorn stone (Table 1). In all, 11 patients (5 partial and 6 complete staghorns) were managed *conservatively* due to a non-functioning kidney in 4 cases, advanced age in 4 cases, associated cardiac disease in 1, Jehovas' witness in 1, and the presence of a uric acid stone in another case.

Indications for interventional therapy

The choice of interventional treatment was determined by the stone burden, distribution of stone load, renal anatomy, radiopacity and chemical composition of the calculi (Table 2). It has to be emphasized that these are only rough criteria with do not allow exact discrimination in every case.

ESWL-monotherapy was preferred in cases of minor stone burden, peripheral stone load (i.e., multiple calyceal calculi) and a narrow renal

Table 1. Therapeutic approach to staghorn calculi ($N = 175$)

Procedure	N	Partial staghorn	Complete staghorn
ESWL-monotherapy	31	26	5
PCN-monotherapy	42	34	8
Combination	78	31	47
Open surgery	13	4	9
Conservative	11	5	6
Total	175	100	75

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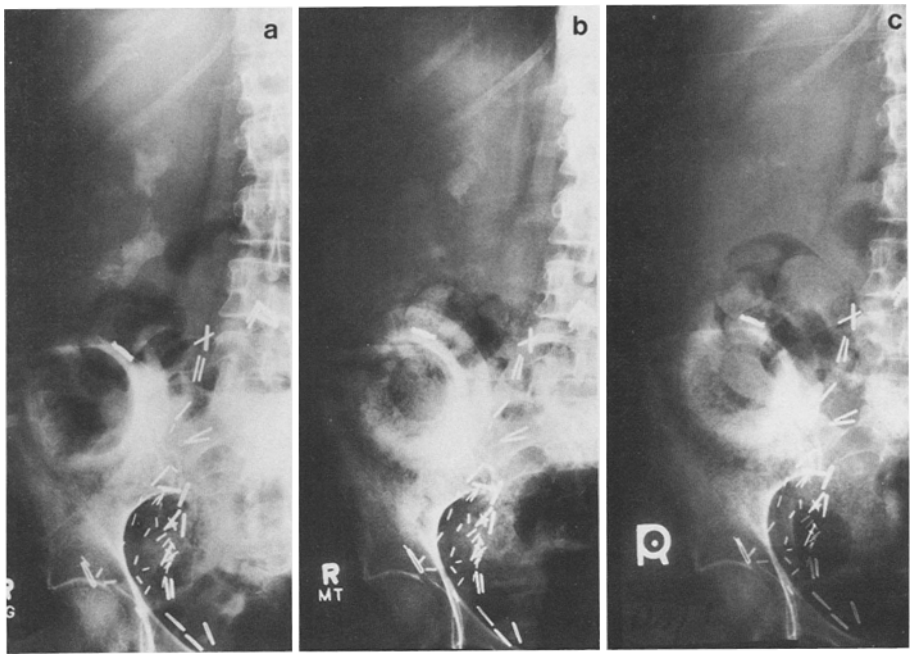

Fig. 1a–c. ESWL-monotherapy for partial staghorn stone of a patient with ileal conduit: plain film of the abdomen **a** before ESWL; **b** 3 days after the first ESWL-session treating the pelvic and lower calyceal part; **c** 3 days after the second ESWL-session treating the upper calyceal part. Only some stone dust is left in the upper calyx

Table 2. Criteria for choice of treatment for staghorn calculi

Criteria	ESWL-monotherapy	PCN-monotherapy	Combination (PCN + ESWL)
Stone burden	Minor	Major	Major
Distribution of stone load	Peripheral	Central	Central + peripheral
Renal collecting system	Narrow	Dilated	Narrow/dilated
Radiopacity	Sufficient	(In-) sufficient	Sufficient
Chemical composition	No cystine	–	–

collecting system (Fig. 1). Moreover, patients with enhanced risk or other difficulties related to percutaneous surgery (i.e., hepatosplenomegaly, aortic aneurysm, cardiosclerosis, urinary diversion, children) underwent ESWL alone.

Indications for PCN-monotherapy were cases of major stone burden with central (= pelvic) stone load and an enlarged renal collecting system when complete stone removal by a single PCN session seemed feasible. Furthermore, slightly opaque calculi, nephrolithiasis with associated secondary ureteropelvic junction (UPJ) stenosis and cystine calculi were treated by PCN alone (Fig. 2).

The combination of PCN and ESWL was performed in cases of major stone burden with central *and* peripheral stone load presenting without anatomical disorders that afforded surgical repair (i.e., primary infundibular or UPJ-stenosis, horseshoe kidney (Fig. 3).

Open surgery was performed in 13 patients due to a non-functioning kidney in 8 cases, UPJ-stenosis in 3, pyonephrosis and septicemia in 2, and a horseshoe kidney in another case. Nine patients underwent nephrectomy, whereas pyelo- and/or nephrolithotomy was performed in 4 patients.

The techniques of percutaneous nephrolithotomy and of extracorporeal shock wave lithotripsy have been described in detail previously [7, 8, 16]. In the combined approach, PCN was performed as a one-stage procedure with the patient under general anesthesia using retrograde balloon occlusion catheters in all cases. Access was usually through the lower pole posterior calyx with removal of the lower calyceal and pelvic stone burden. On occasion, multiple punctures and tracks (maximally 3) were made. The mean operating time was 75 min (range 30–240 min). After a rest period of 4 days, the remaining calyceal stone parts were treated using the Dornier HM-3 lithotriptor. In the majority of cases, one or two sessions (maximally 4) were necessary for complete disintegration. A low generator voltage (15–16 kV) was usually applied initially to avoid scattering of larger fragments. Toward the end of the treatment session, generator voltage was increased to 20–22 kV. Maximally, 3000 impulses were released per session.

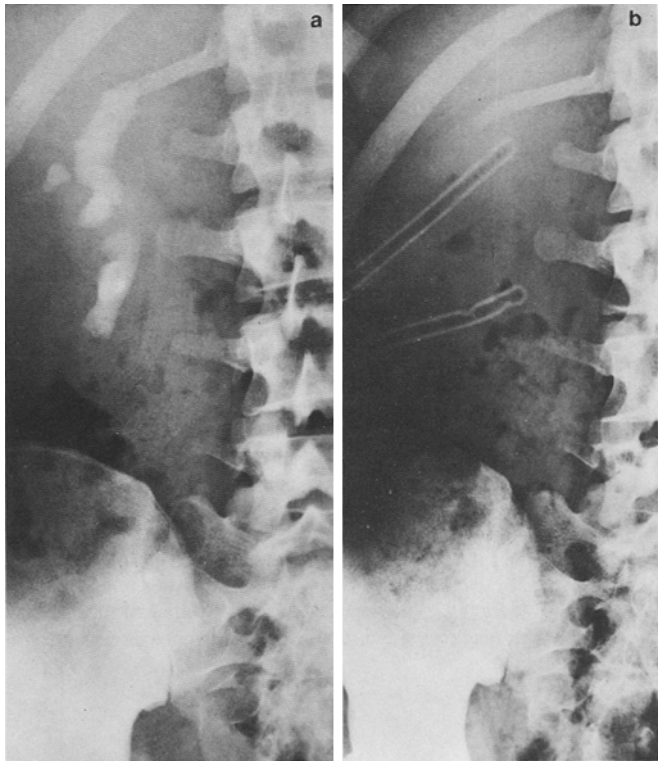

Fig. 2a, b. PCN-monotherapy for a partial staghorn calculus (cystine): plain film of the abdomen **a** before PCN; **b** 2 days after PCN. Complete stone removal was achieved via two percutaneous tracks

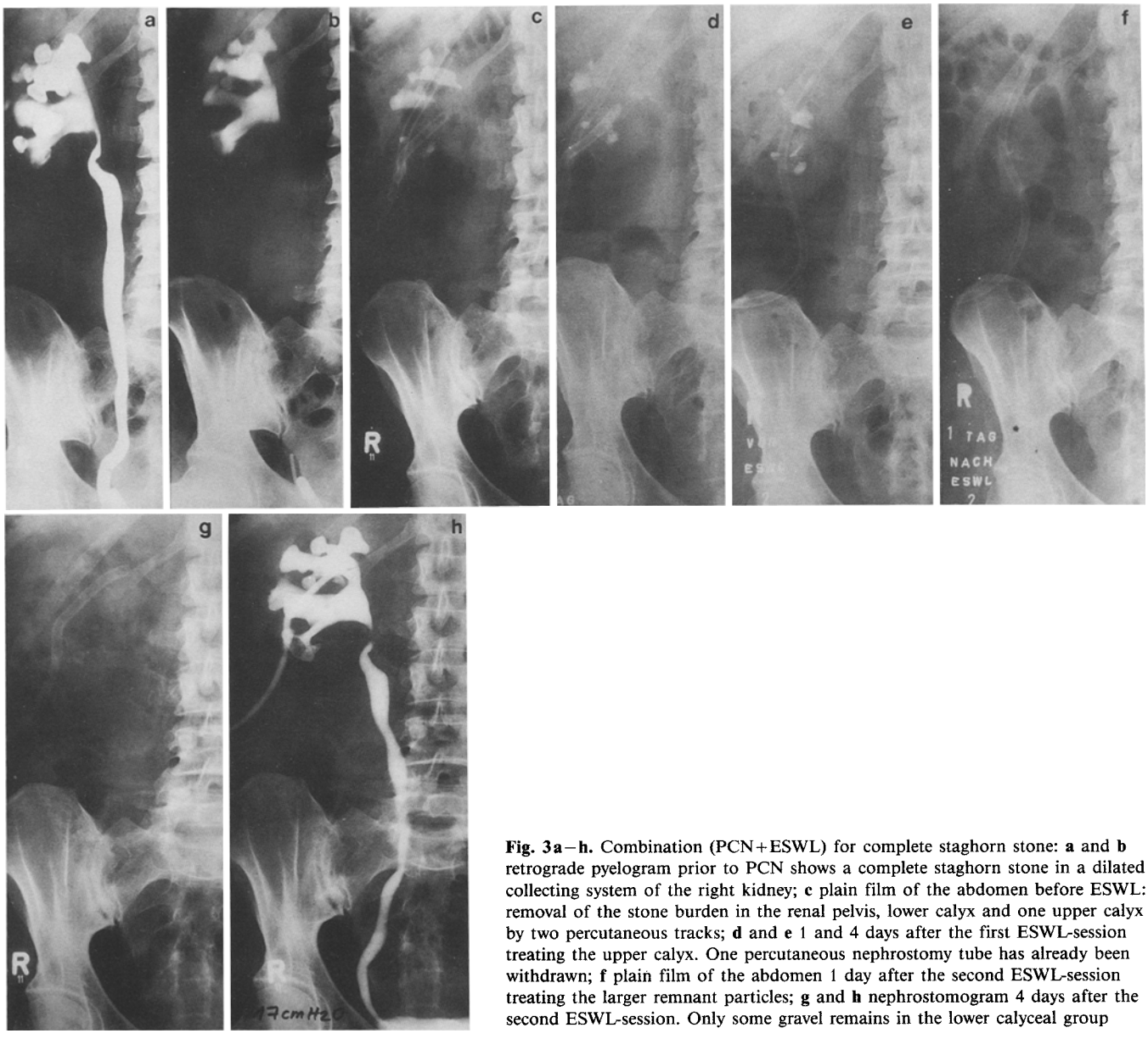

Fig. 3a–h. Combination (PCN+ESWL) for complete staghorn stone: **a** and **b** retrograde pyelogram prior to PCN shows a complete staghorn stone in a dilated collecting system of the right kidney; **c** plain film of the abdomen before ESWL: removal of the stone burden in the renal pelvis, lower calyx and one upper calyx by two percutaneous tracks; **d** and **e** 1 and 4 days after the first ESWL-session treating the upper calyx. One percutaneous nephrostomy tube has already been withdrawn; **f** plain film of the abdomen 1 day after the second ESWL-session treating the larger remnant particles; **g** and **h** nephrostomogram 4 days after the second ESWL-session. Only some gravel remains in the lower calyceal group

Routinely, 2×80 mg gentamycin was administered until sensitivities were available. Of 151 patients, 55 (36%), who were treated either by ESWL monotherapy, PCN-monotherapy or a combination of ESWL and PCN, presented with urinary tract infection prior to treatment (51% Proteus mirabilis, 13% Escherichia coli, 10% enterococcus, 9% providencia, 4% Pseudomonas and Klebsiella, 3% Staphglococcus aureus and citrobacter, 2% Enterobacter and 1% Serratia species).

Stone analysis revealed struvite calculi in 41%, calcium oxalate in 35%, calcium phosphate in 18%, uric acid in 5% and cystine in 1% of our patients.

Plain films of the abdomen and ultrasound were performed on the 1st, 3rd and 5th day following ESWL. If most of the fragments had passed and there were no signs of fever or ureteral obstruction documented by nephrostogram, the tube was clamped and withdrawn the following day.

Follow-up

Follow-up data were collected for a minimum of 6 months (mean: 18 months). For this purpose, radiographs were either taken at our department or reviewed by the consulting urologists. Moreover, the symptoms of patients (i.e., colic, pain, fever) and urine cultures were evaluated. Follow-up data for 89 patients (59%) were available. This group presented with comparable characteristics with respect to sex, mean age, stone distribution, urinary tract infection (UTI), and stone-free rate at time of discharge (Table 3). The diagnosis "stone-free" was made when no calcification or dust was present on the plain film of the abdomen and fragments were absent on the IVP and/or renal ultrasonography [15].

Results

Treatment data

The most important clinical treatment data are summarized in Table 4.

Table 3. Patient characteristics of follow-up group vs all patients treated by ESWL, PCN, or combination

	All patients ($N = 151$)	Follow-up group ($N = 89$)
Mean age (years)	50.3	50.2
Sex ratio (m:f)	1:1.6	1:1.5
Urinary tract infection	55 (36%)	30 (34%)
Partial staghorn	91 (60%)	59 (66%)
Complete staghorn	60 (40%)	30 (34%)
Stone-free at discharge	58 (35%)	28 (31%)

Table 4. Clinical results in the treatment of staghorn calculi

	ESWL-monotherapy ($N = 31$)	PCN-monotherapy ($N = 42$)	Combination (PCN + ESWL) ($N = 78$)
2nd session	7 (23%)	12 (29%)	78 (100%)
3rd session	3 (10%)	–	27 (35%)
> 3 sessions	–	–	14 (18%)
Colic	7 (23%)	3 (7%)	12 (15%)
Fever	7 (23%)	15 (36%)	29 (37%)
Blood transfusion	–	4 (10%)	13 (17%)
Auxiliary measures	11 (35%)	8 (19%)	11 (14%)
Complications	4 (13%)	4 (10%)	4 (5%)
– perirenal hematoma	1	–	1
– renal hemorrhage	–	2	1
– septicemia	3	1	1
– intestinal perforation	–	–	–
– mortality	–	1	–
Mean hospital stay (d)	11 (range 4–19)	13 (range 6–27)	20 (range 6–51)

ESWL-monotherapy ($N = 31$): The majority of calculi were partial staghorn stones (Table 1): only 5 complete staghorn calculi (including two children) were treated. In 7 patients (23%), a second session became necessary. A total of 26 auxiliary procedures were performed in 11 patients (35%), including percutaneous nephrostomy ($N = 10$), percutaneous nephrolithotomy ($N = 4$), retrograde ureteroscopy ($N = 4$), Zeiss-loop ($N = 3$), double-J stent ($N = 4$), and open surgery ($N = 1$). Seven patients (23%) had temperature elevations greater than 100 °F and/or suffered from colic or flank pain during passage of stone debris.

One perirenal hematoma developed after exposure of 2000 shock waves in a patient with concomitant hypertension, but could be managed conservatively. No blood transfusions were required. There were 3 instances of urosepsis that responded in 2 cases to medical management and percutaneous drainage. Nephrectomy became necessary in the third case due to persistent septicemia. The mean duration of hospital stay amounted to 11 days (Table 4).

PCN-monotherapy ($N = 42$): Most of the partial staghorn calculi were treated by PCN (Table 1). In 12 cases (29%) a second session was necessary. Eight patients required a total of 10 auxiliary procedures postoperatively: double-J stent ($N = 4$), percutaneous sodium bicarbonate irrigation ($N = 2$), retrograde ureteroscopy ($N = 2$), nephrectomy ($N = 1$), and renal embolization ($N = 1$). Three patients (7%) had colic, whereas fever was observed in 15 (36%) of all patients following therapy. Blood transfusions were required in 4 instances (mean: 4 units/patient). Two cases of severe renal hemorrhage did not respond to conservative management: in 1 patient, an arteriovenous fistula could be occluded successfully by superselective embolization; in the other, nephrectomy had to be performed. One patient with a solitary kidney, complete staghorn calculus, compensated renal insufficiency (serum creatinine 5 mg/dl) and gross obesity died 5 days after the PCN session due to pulmonary embolism. The mean duration of hospital stay amounted to 13 days (Table 3).

Combination ($N = 78$): The majority of complete staghorn calculi were treated using the combined approach (Table 1). Of the 78 patients, 27 (35%) required 3 sessions, 14 (18%) more than 3 procedures. A total of 17 ancillary procedures were performed in 11 patients (14%), mainly due to persistent ureteral obstruction: retrograde ureteroscopy ($N = 7$), Zeiss-loop ($N = 4$), double-J stent ($N = 3$), hemiacidrin irrigation ($N = 1$), laparotomy ($N = 1$), renal embolization ($N = 1$). In all, 12 patients (15%) experienced colic or pain during passage of stone gravel, 29 patients (37%) had significant temperature elevation, and 13 patients (17%) required blood transfusion following PCN (mean: 2.3 units). One perirenal hematoma was observed after ESWL and a massive renal hemorrhage after PCN could be stopped by transfemoral superselective embolization. Furthermore, 1 case of ileal perforation occurred following unusual puncture of the kidney without ultrasound guidance. After resection of the perforated part of the ileum, further follow-up of the patient was uneventful. One case of septicemia responded to medical treatment. The mean duration of hospital stay was 20 days (range: 6–51).

Follow-up data

The follow-up results after a mean observation time of 18 months are listed in Table 5.

ESWL-monotherapy

At discharge, 6 patients (19%) were stone-free, whereas 21 patients (68%) still had remnants in the kidney, 4 (13%) in the ureter. In 16 patients, follow-up data were available: 8 patients (50%) were stone-free, the other 8 patients showed remnants on the plain film of the abdomen, but no recurrent stone formation was observed. Of the 8 stone-free patients, 3 (37.5%) had been discharged with remnants in the kidney. Only 3 of 16 patients (19%) showed significant bacteriuria during follow-up in contrast to 26% at hospitalization.

Table 5. Follow-up results after treatment of staghorn calculi

a) Status at discharge	ESWL-monotherapy ($N = 31$)	PCN-monotherapy ($N = 42$)	Combination (PCN + ESWL) ($N = 78$)
Stone-free	6 (19%)	29 (69%)	18 (23%)
Remnants			
– kidney	21 (68%)	13 (31%)	57 (73%)
– ureter	4 (13%)	–	3 (4%)
UTI (at hospitalization)	8 (26%)	16 (38%)	31 (40%)
b) 18-month follow-up	($N = 16$)	($N = 26$)	($N = 47$)
Stone-free	8 (50%)	20 (77%)	28 (60%)
Remnants	8 (50%)	5 (19%)	16 (34%)
Recurrence	–	1 (4%)	3 (6%)
UTI	3 (19%)	3 (12%)	13 (28%)

PCN-monotherapy

At discharge, 29 patients (69%) were stone-free. Follow-up data were available in 26 patients: 20 patients were stone-free (77%), 5 (19%) showed remnants on the plain film of the abdomen, and in 1 patient (4%), recurrent stone formation was observed. Only 1 of 20 patients (5%) who left the hospital with remnants became stone-free during follow-up. Three patients (12%) had urinary tract infection compared to 38% at hospitalization.

Combination

At discharge, 18 patients (23%) were stone-free. The follow-up group included 47 patients: 28 patients (60%) were stone-free on the plain film of the abdomen and ultrasound scan, 16 (34%) showed persistent stone gravel in the kidney, and 3 (6%) had stone recurrence. In 10 of 28 patients (36%) discharged with remnants, all debris had passed after 18 months. Of the follow-up group, 13 patients (28%), had significant urinary tract infection compared to 40% prior to treatment. We observed 1 delayed bleeding due to an arteriovenous fistula which could be occluded successfully by superselective renal embolization. Another patient developed perinephric abscess formation 6 months after discharge which could be drained successfully.

Discussion

In contrast to the era of open renal surgery, several important criteria now determine the choice of treatment of staghorn calculi (Table 2): (1) stone burden, (2) distribution of stone load, (3) anatomy of the kidney and renal collecting system, (4) radiodensity and (5) stone composition.

The major limitation to noninvasive ESWL-monotherapy is stone burden. For complete disintegration of large calculi, more than one session is usually required due to the limited number of shock waves per treatment (about 2500–3000 at our department) and the restricted transportation capacity of the ureter for stone gravel. It should be mentioned that the upper limit of impulses for Food and Drug Administration (FDA) approval in the USA at that time was 2000 impulses per session. Despite the use of low shock wave energy (15–16 kV), which results in better focussing and finer fragmentation [17], there is still a considerable risk of leaving larger fragments behind that may obstruct the ureter. Moreover, the passage of such a large number of fragments frequently results in the formation of a *Steinstrasse* with subsequent hydronephrosis. Since the majority of staghorn calculi are composed of stuvite, there is an increased risk of complications necessitating auxiliary measures and leading to a prolonged hospital stay [10, 16, 20].

Recently, prophylactic insertion of a double-J stent proved effective in lowering the rate of side effects related to stone passage [12]. However, there is the risk of clinically asymptomatic occlusion of the ureteral catheter with subsequent loss of renal function. Furthermore, the total time of passage of fragments remained unchanged after the use of a double-J stent. Despite the fact that ESWL can be performed under i.v.-analgesia (i.e., 100 mg tramadol) as a result of modifications of the generator and focussing system of the Dornier HM-3 [17], or without any anesthesia with piezoceramically induced shock waves [17, 22], we are of the opinion that ESWL-monotherapy should be used only in selected cases of partial and complete staghorn calculi: in cases of minor stone burden with a more peripheral distribution of the stone load (i.e., multiple calyceal calculi) and a narrow renal collecting system. Such calculi are difficult for percutaneous treatment requiring more than one percutaneous track and there is a risk of injuring the renal collecting system during percutaneous manipulations. Moreover, in cases of peripheral distribution of the stone load, a multistep-ESWL procedure is possible without the risk of leaving larger fragments behind. In such cases treatment should be started at the upper calyx to prevent gravel from falling into the lower calyx, which may prolong spontaneous passage. Staghorn calculi following urinary diversion (i.e., ileum conduit) may represent a special indication for ESWL-monotherapy. Since such patients pass the gravel much more rapidly than patients with an intact ureterovesical junction (Fig. 1).

PCN-monotherapy has been found to be advantageous in the treatment of partial staghorn calculi occupying the renal pelvis and only one lower and/or middle calyx, i.e. calculi with a central stone load. Such calculi can usually be removed in a one-stage procedure through one percutaneous access. Moreover, large, slightly or nonopaque stones should be retrieved percutaneously since roentgenologic localization for ESWL treatment is poor and follow-up (i.e., evaluation of ureteral obstruction) may be difficult. In the case of cystine stones, success of ESWL decreases with increasing stone burden. Such calculi are often resistant to extracorporeal shock wave lithotripsy, particularly if they are round, for they then present only a minimal surface for shock wave ex-

posure [16, 19]. For larger cystine calculi, PCN may be preferable (Fig. 2).

The major advantage of percutaneous nephrolithotomy is that the majority of patients (69%) are stone-free at the time of discharge, whereas after ESWL-monotherapy, about 80% of the patients leave the hospital with stone debris in the kidney or ureter involving the potential risk of complications. With respect to hospital stay, we could not observe any significant difference between the two methods (Table 5).

The majority of partial and complete staghorn calculi present with a major stone burden and a central and peripheral stone load. For such calculi the combination of PCN and ESWL proved to be effective in our series. In October 1983, this combined approach was initiated, compensating for specific drawbacks of the two monotherapy procedures [14]. Like other authors we begin with debulking PCN. A lower posterior calyx is usually punctured, providing straight access to the renal pelvis and thus maximal removal of stone burden by ultrasonic lithotripsy.

Puncturing of a stone-filled calyx did not represent a major problem in the majority of cases. One reason for this may be the use of a ureteral balloon catheter placed at the ureteropelvic junction as described by Korth [11]: This allows permanent filling and dilation of the renal collecting system by contrast dye, so that, in almost all cases, a guide-wire could be passed beside the calculus into the renal pelvis. We therefore do not see any advantage in disintegrating the lower part of a staghorn calculi to facilitate insertion of a guide wire for percutaneous nephrolithotripsy [10]. A second percutaneous track is established only in special situations, i.e., if major stone burden is left that cannot be retrieved via the first track, or in case of an additional calculus behind an isolated calyceal neck stenosis when the success of ESWL is unlikely. These strict guidelines for percutaneous surgery resulted in a significant decrease of operative time (mean: 75 min) compared to other series (cf. Brannen et al.: 159 min [4]). It has to be emphasized that in our series only partial or complete staghorn calculi were treated. With respect to the low rate of severe complications (8%), we believe that a differentiated approach according to the above-mentioned criteria (Table 2) is able to minimize the morbidity associated with treatment.

The combination of PCN and ESWL resulted in a prolongation of hospital stay (20 days vs 15 after open surgery), due to the fact that an average of 2.6 sessions (PCN and/or ESWL) were required. An interval of at least 4 days between PCN and ESWL is advisable to enhance healing of the uroepithelium. Initially, we observed three cases of intraparenchymal spreading of stone fragments after ESWL treatment when performed only 2 days after PCN. The interval between each ESWL session depends on the passage of stone debris and should be at least 3 days. With respect to the prolonged hospital stay after the combined procedure, it has to be noted that recovery time after discharge was very short in contrast to patients who underwent open renal surgery.

Follow-up results, differed from an earlier series of ours in which we had a 82% stone-free rate after 3 months [16], compared to the 63% stone-free rate after 18 months in the current series. The main reasons for this difference are:

- the earlier follow-up group consisted of a significantly higher rate of patients who were stone-free at discharge,
- the earlier series included 10 patients treated by open surgery, all of whom were stone-free,
- borderline calculi were included, and
- all questionable findings, like dust or superimposing intestinal gas, were rated "stone-free".

In the present series, however, the very stringent criteria for a "stone-free" diagnosis described by Palfrey et al. [15] was imposed.

It is obvious that after PCN-monotherapy most of the patients are stone-free at discharge, whereas after ESWL-monotherapy or the combination, the stone-free rate increases progressively by 30%–40% over a follow-up period of 18 months.

It has to be emphasized that the 3 groups cannot be compared, since different calculi were treated. For example, the combination group includes all patients who could not be made stone-free by one PCN. Moreover, the majority of remnants following ESWL or the combination (ca. 70%; Fig. 3) represent minor stone gravel in the lower calyceal group, and 2/3 of the patients with residual fragments did not have symptoms of fever, colic or urinary tract infection. Moreover, the rate of urinary tract infection has decreased from 36% to 21% after treatment. One reason for this may be that disintegration of the calculus releases bacteria which are then better reached by the antibiotic drugs excreted into the urine. The same mechanism may be responsible for the relatively low recurrence rate of 5% after 18 months despite the relatively high rate of remnants in the kidney. Another reason for the low recurrence rate may be the fact that patients maintain a high fluid intake during the time of stone passage. Nevertheless, our observation period is still too short for definitive statements regarding recurrent stone formation after PCN and ESWL.

One major advantage of percutaneous nephrolithotomy plus extracorporeal shock wave lithotripsy is that these techniques may be used repeatedly without increasing technical difficulties and/or the loss of renal function [10, 16]. In view of this, the higher rate of residuals may not play an important role. If remnants or recurrent calculi become symptomatic, they can be treated again by ESWL or, if necessary, percutaneously.

Particularly regarding the fact that it is now possible to perform extracorporeal shock wave lithotripsy without the need of anesthesia or only under i.v. analgesia, thus allowing treatment of symptomatic remnants or early recurrences [17, 22], we feel that our concept of minimal invasiveness and minimal morbidity using multimodal treatment (extracorporeal shock wave lithotripsy and per-

cutaneous nephrolithotomy) for staghorn calculi has been confirmed by our follow-up data.

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