Brazilian Journal of Urology
Official Journal of the Brazilian Society of Urology
Vol. 26 (5): 463-478, September - October, 2000

MANAGEMENT OF STAGHORN CALCULI: CRITICAL ANALYSIS AFTER 250 CASES

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ABSTRACT

Objectives: Based on long-term experience with over 250 patients and the review of the literature we want to focus on the state of the art management of complicated nephrolithiasis. This includes the application of extracorporeal shock wave lithotripsy (ESWL) and endourology as well as the remaining indications for open surgery.

Material and Methods: A total of 197 patients were treated with the new technologies in a five year period and compared to 83 patients who underwent open surgery for complicated nephrolithiasis prior to the introduction of ESWL and endourology. Two-hundred and forty-seven patients (186 respectively 61) could be followed over a period of up to 42 months to analyze the pattern of stone-clearance by passage of fragments, recurrent stone formation and urinary tract infection.

Results: Stone distribution (borderline vs. staghorn stones) was similar in both groups with a higher percentage of complete staghorn stones in the open surgery-group. Blood transfusion rate (37% vs. 10%) was significantly higher after open surgery, whereas the rate of minor side effects did not differ in both groups. Also major complications were observed at a similar rate (7 vs. 8%) as well as hospital stay (17.2 vs. 15.4 days). Stone-free rate at discharge after open surgery is significantly higher than after ESWL and endourology (80 vs. 31%). In contrast to this, the stone-free rate after 42 respectively 36 months does not differ significantly (72 vs. 60%). The majority of the remants after the modern techniques were asymptomatic (CIRF), whereas the recurrence rate after surgery is significantly higher (20% vs. 7%). Additionally, the reduction of urinary tract infection (UTI) rate is better after the modern approach (0.51 vs. 0.32 = UTI after/UTI before).

Conclusions: The introduction of minimally invasive techniques has completely changed the management of complex stones. Open surgery is only preferable in case of giant staghorns requiring numerous percutaneous procedures along with ESWL, after failure of the modern techniques or in cases necessitating additional surgical reconstruction. However, the multimodal minimally invasive therapy of complex renal stones requires an individual treatment plan for each patient depending on stone burden and distribution, anatomy of the collecting system, and the composition of the calculus.

Key words: kidney, kidney calculi, lithotripsy, percutaneous nephrolithotomy, surgery
Braz J Urol, 26: 463-478, 2000

INTRODUCTION

More than 20 years after the clinical introduction of extracorporeal shock wave lithotripsy (ESWL) and endourological techniques, such as ureteroscopy (URS) and percutaneous nephrolithotripsy (PCNL) (1-3), the treatment of urolithiasis has changed completely. Whereas in the seventies and the beginning of the eighties of the last century, the majority of renal and ureteral stones have been removed by open surgery (4-7), in the new millenium the latter has become a very rare event at least in European, Japanese and Anglo-American centers. The widespread use of ESWL resulted in a significant decrease of patients suffering from renal stones and consecutively an increase of ureteral stones from 10-20% to

30-40% in our treated stone population (8,9). Additionally, we do not see as many complicated renal stones as we have been treated with the new multimodal minimally invasive techniques in the eighties and early nineties (Table-1). We have therefore observed an increase in ureteroscopy but a decrease in percutaneous stone surgery.

Table 1 *– Change of indications: personal experience at three stone centers (Stuttgart, Mannheim, Heilbronn).*

	1984	1990	1999
Localization			
Caliceal stones	35%	43%	46%
Pelvic stones	42%	20%	13%
Staghorn stones	8%	3%	1%
Ureteral stones	15%	34%	40%
Treatment Modality			
ESWL	64%	79%	78%
PCNL	20%	5%	2%
URS	11%	15%	20%
Open surgery	9%	1%	0.1%

There are several reasons to explain this situation: 1)- the minimal morbidity associated with the new treatment modalities has significantly improved the compliance of the patients to undergo early therapy of their stone disease; 2)- the wide-spread use of diagnostic ultrasound has increased the early detection rate of urinary calculi; 3)- the new generation antibiotics (i.e. gyrase inhibitors) allow more effective treatment of urinary tract infections, particularly with respect to urease-splitting bacteria (i.e. proteus), and 4)- the possibility of multiple treatments in case of recurrent stone formation (i.e. by ESWL) without a significantly enhanced risk of deterioration of renal function or increasing technical difficulties, like in the era of open surgery, has improved the prognosis of our stone patients.

Nevertheless, even today we still see complex renal stones requiring more than a simple extracorporeal shock wave lithotripsy or an ureteroscopic stone removal. In the following, based on our own experience and the review of the literature we want to focus on the state of the art management of complicated nephrolithiasis, emphasizing all existing minimally invasive techniques. However, in addition the remaining indications for open surgery in the new millenium will be presented.

DEFINITION OF COMPLEX RENAL STONES

Complicated nephrolithiasis consists of a variety of stone-bearing situations depending on: 1)- the stone burden and distribution; 2)- the anatomy of the collecting system; 3)- the stone composition; 4)- the renal function; 5)- associated urinary tract infection.

The majority of complex renal stones are staghorn calculi, but also multiple stones behind infundibular stenosis or in a caliceal diverticulum may be complicated. Moreover, stones in renal abnormalities, such as horseshoe-kidney, medullary sponge kidneys, are most frequently difficult to manage (9). Finally, reduced renal function and/or infection of the renal collecting system always represents a challenge for the treating urologist. However, in the following we want to focus on the management of staghorn stones.

STAGHORN CALCULI

Definition

Principally, staghorn calculi are defined as branched stones in the renal collecting system. However, as mentioned before, there are several different constellations, within this entity. This has been taken into consideration by the more complex definition of Rocco et al. (10) or the PICA-classification of Griffith et al. (11). For the modern management of such stones three factors are of major importance to decide the optimal treatment: 1)- the overall stone burden; 2)- the localization of the stone burden (i.e. which and how many calyces are involved); 3)- the anatomy of the collecting system (i.e. a dilated collecting system).

Based on this, several authors have introduced a relatively simple definition (Table-2) distinguishing between borderline stones, partial and complete staghorn calculi (12). Of course, the stone bur-

Table 2 *– Classification of staghorn stones.*

Stone Classification	**Description**	**Rocco** (10)	**Griffith** (11)
Borderline	filling the pelvis and one calyx	C2,C3	P1 IC1
Partial staghorn	filling the pelvis and two or more calyces	C4	P1 IC2
Complete staghorn	filling of the entire renal collecting system (> 80%)	C5	P1 IC3

den can be calculated more exactly using the area on the kidney-ureter-bladder (KUB) x-ray plan film, as proposed by Lam et al. (13). This was extremely useful in the evaluation of different therapeutic approaches, however in the daily routine the above mention classification proved to be sufficient.

Treatment Options

Whereas in former times, only the modification of the open renal surgery, i.e. anatrophic versus radial nephrolithotomy (4,7), was discussed and even conservative management was optioned (14), nowadays a multimodal approach has been developed to minimize morbidity of the treatment and aiming at optimal long-term results. This may include: 1)- extracorporeal shock wave lithotripsy with or without indwelling stent; 2)-percutaneous nephrolithotomy using different devices for stone disintegration; 3)- the combination of both techniques as a planned procedure; 4)- retrograde ureteroscopic stone disintegration using a holmium laser; 5)- open surgery (i.e. anatrophic or radial nephrolithotomy, sinusoidal pyelolithotomy).

Staghorn stones are unquestionably an indication for interventional therapy, since all reports following conservative treatment showed a substantially increased rate of nephrectomy (up to 50%) and an increase in associated morbidity (i.e. dialysis); in many cases (up to 28%) the disease resulted in death (5,14). Of course, the choice among the listed treatment modalities mainly depends on the specific finding of the staghorn stone (i.e. stone classification) (15). On the other hand, further factors such the age of the patient or the function of the stone-bearing kidney may be important (Table-3). Finally, it has to be emphasized that these criteria do not allow exact discrimination in every case.

Criteria of Success

The goal of any of these procedures is to carry the patient stone-free. However, with the introduction of ESWL particularly in case of larger calculi or stones in the lower caliceal group, even more than 40% of persisting fragments have been accepted (16,17), because in the majority of cases (90%) these asymptomatic fragments proved to be clinically insignificant (CIRF). This means, that these fragments did not induce early stone recurrence, which was different to the presence of residual stones in the era of open surgery, particularly in case of infected calculi. This may be attributed to the improved generations of antibiotics, but also to the fact, that the fragmented calculi are better treatable resulting in some residual sterile fragments after ESWL (16,17). Nevertheless, any patient with a treated staghorn stone requires a short a consequent follow-up (18).

Table 3 *– Criteria for choice of treatment for staghorn calculi.*

Criteria	**ESWL-Monotherapy**	**PCNL-Monotherapy**	**Combination (ESWL & PCNL)**
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	-	-

Figure 1 *– Staghorn stones - Indications for the different procedures: A) ESWL-monotherapy: partial staghorn stone (calcium-oxalate-dihydrate) in the right kidney involving the pelvis and lower caliceal group together with filling of the middle and upper caliceal group; B) PCNL-monotherapy: borderline stone (calcium oxalate-monohydrate) filling one lower pole calyx with an dilated collecting system (right side), easy removable by one-stage PCNL via a single percutaneous tract; C) Combination: complete staghorn stone (struvite) on the right side with a dilated collecting system. Percutaneous debulking of the lower pole calyces and pelvis is followed by ESWL for fragmentation of the upper pole part; D) Open surgery: complete giant staghorn stone (calcium oxalate monohydrate) multiple stones in all calyces. Stone removal requires an extended pyelotomy plus multiple radial nephrolithotomies. Additionally there was an UPJ-stenosis requiring pyeloplasty.*

Indications for ESWL-Monotherapy

Extracorporeal shock wave lithotripsy should be performed in case of minor stone burden, peripheral stone load (i.e. multiple stone-filled calyces) and a narrow renal collecting system. Moreover, patients with enhanced risk (i.e. cardiosclerosis, respirators problems) or other difficulties related to percutaneous surgery (i.e. children, urinary diversion) have to undergo ESWL alone (Figure-1A; Figure-2).

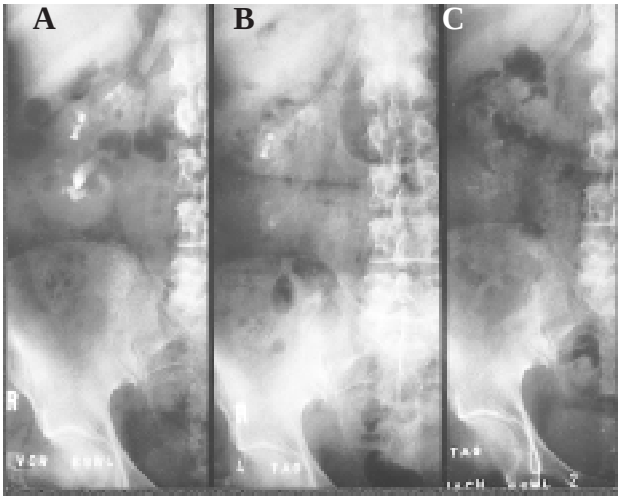

Figure 2 *– ESWL-monotherapy for partial staghorn stone: A) KUB prior to ESWL; B) KUB 4 days after the first ESWL-session treating the pelvic part and lower caliceal group; C) KUB after the second session treating the upper caliceal group. Only some stone dust is left in the upper and lower calyx.*

Indicatios for PCNL-Monotherapy

The percutaneous nephrolithotomy in single session can be successfully applied for cases of major stone burden with central (= pelvic) stone load in an enlarged (= dilated) collecting system (i.e. borderline, and partial staghorn calculi) (Figure-1B). Furthermore, slightly opaque or shock wave resistant calculi (i.e. cystine) are candidates for PCNL alone (Figure-3).

Indications for the Combination

The combination of ESWL and PCNL, principally started by the percutaneous approach, is applied for all cases of major stone burden (i.e. partial and complete staghorn stones) (Figure-1C) with central and peripheral stone load. The rationale for the combination therapy is to reduce the morbidity of the PCNL, which is carried out in the majority of cases via one lower pole tract, and the use of ESWL selectively for disintegration of those calculi (parts of the staghorn stone) that cannot be reached with the nephroscope (Figure-4).

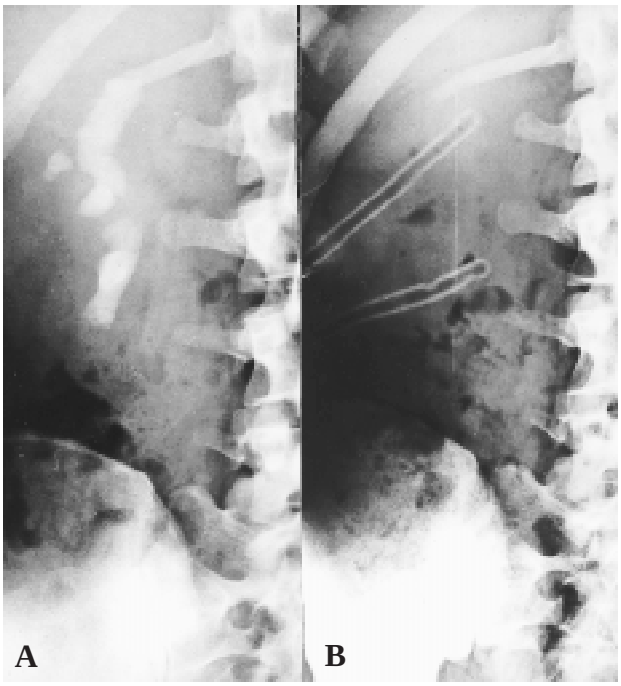

Figure 3 *– PCNL-monotherapy for a partial staghorn stone: A) KUB prior to PCNL shows filling of the upper and lower calyces with a cystine stone; B) Complete stone removal via two percutaneous tracts.*

Indications for Open Surgery

Surgery is a potential treatment option for any staghorn for several reasons. The stone can be removed by a single procedure with comparable stone-free rates. Therefore, some authors still advocate open surgical removal in case of complete staghorn stones (19-22). However, there is the problem of loss of renal function after such extensive surgical interventions like anatrophic intersegmental pyelolithotomy, which has been reported in the range of 30-50% (23). Overall, the residual stone rate after open renal surgery is about 15%, with a 30% stone recurrence rate over 6 years and a 40% risk of urinary tract infections (16,19-25).

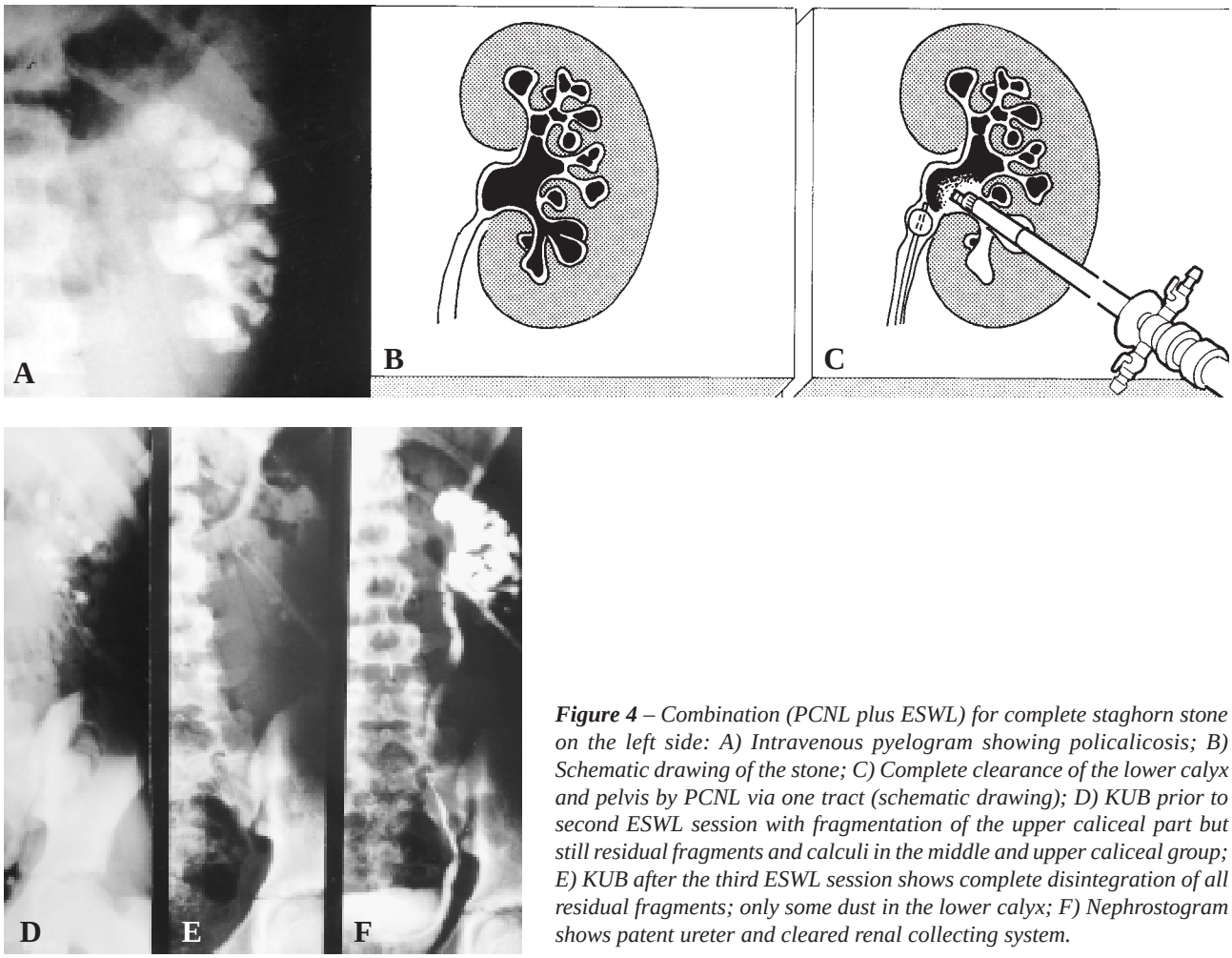

Figure 4 *– Combination (PCNL plus ESWL) for complete staghorn stone on the left side: A) Intravenous pyelogram showing policalicosis; B) Schematic drawing of the stone; C) Complete clearance of the lower calyx and pelvis by PCNL via one tract (schematic drawing); D) KUB prior to second ESWL session with fragmentation of the upper caliceal part but still residual fragments and calculi in the middle and upper caliceal group; E) KUB after the third ESWL session shows complete disintegration of all residual fragments; only some dust in the lower calyx; F) Nephrostogram shows patent ureter and cleared renal collecting system.*

We have therefore restricted the indications for open surgery to those cases with giant stone burden that cannot be reached endoscopically nor by a considerable number of ESWL-treatments or if additional reconstructive surgery (i.e. calicoureterostomy, pyeloplasty) is required, Figure-1D (25). Nephrectomy of non-functioning kidneys can be performed laparoscopically (26-27).

Therapeutic Approach

Independently to the following procedure, every patient with a staghorn stone requires antibiotic prophylaxis (i.e. gyrase inhibitors) at least 2 days prior to the intervention. In our series 38% of the patients presented with urinary tract infections prior to the treatment (25), 51% of whom were Proteus mirabilis.

ESWL-Monotherapy

The techniques of extracorporeal shock wave lithotripsy have been described in detail previously (28-31). In case of a larger stone (> 2 cm) we recommend the insertion of a double J-stent prior the procedure. This avoids obstruction of the ureter by formation of a steinstrasse, but does not inhibit the passage of fragments along the stent (13). Staghorn stones should be first treated at the pelvic part to enable passage of fragments, thereafter the upper and middle calyces are focussed leaving the lower pole untreated to avoid that fragments fall into the lower calyces from where further passage may be prolonged (Figure-3). Depending on the energy setting of the machine, the number per session should not exceed 4000 impulses. The interval between each treatment should be at least 2 days.

PCNL-Monotherapy

This is performed as a one-stage procedure with the patient under general anesthesia using a retrograde balloon occlusion catheter placed at the uretero-pelvic junction (12,25). Access is usually through the lower pole posterior calyx with removal of the lower caliceal and pelvic stone burden. In case of major stone burden, we always place an Amplatz sheath down the percutaneous tract. This allows removal of larger stone fragments and reduces the risk of pelviocaliceal influx. Only in selective cases (i.e. stones less suitable for ESWL, i.e. cystine), we recommend the puncture of an additional calyx to achieve complete stone clearance in a single PCNL-session (Figure-3). Another option to access stone burden in upper and middle calyces may be the use of a flexible cystoscope together with a holmium or dye laser introduced via the Amplatz sheath.

Combination

In the combined approach, we principally recommend to start with a debulking PCNL via the lower pole posterior calyx. The puncture of the kidney is performed under combined sonographic and fluoroscopic control. On occasion, multiple tracts (maximum 3) can be made, in case of massive stone burden (i.e. in the upper dilated calyx).

Open Surgery

Whereas in our earlier experience the technique of clamping and cooling was used (32,33), we have recently preferred the technique of radial nephrotomies with intraoperative color-duplex-sonography (7). Other options include extended pyelolithotomy, anatrophic nephrolithotomy or posterior lower nephrolithotomy. Nowadays, we would not put the same emphasis to achieve complete stone clearance, because minor residual stones can be treated effectively with ESWL.

Own Experience

Patients

Some of our personal experience with the multimodal minimally invasive management of staghorn calculi has been published previously (12,25,33). In this paper, we want to focus on long-term results in comparison to those obtained by open surgery. A total of 197 patients were treated with the new technologies in a 5-year period and compared to 83 patients who underwent open surgery for complicated nephrolithiasis prior to the introduction of ESWL and endourology. Two hundred and forty-seven patients (186 respectively 61) could be followed over a period of 36 respectively 42 months to analyze the pattern of stone-clearance by passage of fragments, recurrent stone formation and urinary tract infection.

Distribution of Treatment

In correlation to the increasing stone burden and complexity of the cases, the percentage of ESWL-monotherapy decreases from 45% for borderline stones to 2% in case of a complete staghorn. PCNL is most frequently performed (28%) for management of partial staghorn calculi, whereas the combination is applied in 74% of all complete staghorns. For borderline stones only 6% of the patients required more than 3 sessions compared to 10% for partial and 21% for complete staghorn stones. Open surgery was performed in 7% for partial and in 11% for complete staghorn calculi. Overall, 53 patients were treated by ESWL-monotherapy, 56 by PCNL-monotherapy, and 77 had a combination of both techniques (Table-4).

Treatment Data

Thirty-seven percent of patients with “borderline” and 35% of patients with partial staghorn calculi presented with urinary tract infection prior to treatment, in contrast to 50% with complete staghorn stones. A detailed analysis of all relevant data is listed on Tables-4, 5 and 6. Three or more sessions were necessary in 24% of all patients, ranging from 0% (PCNL-monotherapy) to 54% (combination). This was because maximally two PCNL-sessions were performed for stone removal. Any further parts of the stone that could not be treated effectively received ESWL.

Blood transfusions were required in 10% of the patients, in no case after ESWL-monotherapy, but in 17% after the combination, mainly because of the increased technical difficulties of percutaneous nephrolithotomy.

Table 4 *– Clinical results in the modern management of complex renal stones.*

Criteria	ESWL (n = 53)	PCNL (n = 56)	PCNL & ESWL (n = 77)	All (N = 186)
Borderline stones	44 (83%)	25 (45%)	18 (23%)	87 (47%)
Partial staghorn	7 (13%)	26 (46%)	30 (39%)	63 (34%)
Complete staghorn	2 (4%)	5 (9%)	29 (38%)	35 (19%)
2nd session	13 (25%)	15 (28%)	77 (100%)	105 (56%)
3rd session	3 (6%)	–	27 (35%)	30 (16%)
> 3 sessions	1 (2%)	–	14 (18%)	15 (8%)
Blood transfusion	–	5 (9%)	13 (17%)	18 (10%)
Auxiliary measures	19 (36%)	9 (17%)	11 (14%)	39 (21%)
- Ureterorenoscopy	3 (6%)	1 (2%)	7 (9%)	11 (6%)
- Open surgery	2 (4%)	2 (4%)	1 (1%)	4 (2%)
Minor complications	23 (44%)	22 (39%)	41 (52%)	86 (45%)
- Colic	12 (23%)	4 (7%)	12 (15%)	28 (15%)
- Fever	11 (21%)	18 (32%)	29 (37%)	56 (30%)
Major complications	5 (10%)	4 (7%)	4 (4%)	13 (7%)
- Septicemia	3 (6%)	1 (2%)	1 (1%)	5 (3%)
- Bleeding	1 (2%)	2 (4%)	2 (2%)	5 (3%)
- Others	1 (2%)	1 (2%)	1 (1%)	3 (1%)
Mean hospital stay (d)	11.6	12.9	19.8	15.4

Table 5 *– Follow-up results after management of complex stones.*

Criteria	ESWL (n = 53)	PCNL (n = 56)	PCNL & ESWL (n = 77)	All (N = 186)
Stone-free at discharge	6 (11%)	35 (63%)	17 (22%)	58 (31%)
Remants in kidney	32 (60%)	21 (37%)	57 (74%)	110 (59%)
Remnants in ureter	15 (29%)	–	3 (4%)	18 (10%)
Stone-free after 36 m.	35 (66%)	40 (71%)	37 (48%)	112 (60%)
Asymptomatic remnants (CIRF)	11 (21%)	10 (18%)	25 (33%)	46 (25%)
Symptomatic remnants (SIRF)	3 (6%)	2 (4%)	10 (13%)	15 (8%)
Recurrence	4 (8%)	4 (7%)	5(6%)	13 (7%)
UTI (at hospitalization)	14 (26%)	20 (36%)	31(40%)	65 (35%)
UTI (after 36 m.)	6 (11%)	4 (7%)	11(14%)	21 (11%)

UTI = urinary tract infect; CIRF = clinically insignificant fragments; SIRF = significant residual fragments.

Auxiliary measures have to be performed in 21% of all patients, ranging from 14% after the combination to 36% after ESWL-monotherapy. Nowadays, this figure could be even higher, since we recommend the prophylactic insertion of a double-J stent prior to ESWL-monotherapy. However, only 8%

needed curative auxiliary measures (31), such as ureteroscopy or open surgery.

Forty-five percent of the patients experienced minor side effects like colic or fever. Whereas colics have been more frequently associated with ESWL-treatment, postoperative fever occurred increasingly after PCNL. In contrast to this, major complication have been observed only in 7% of all patients, including perirenal hematoma after ESWL, bleeding after PCNL, colon perforation after PCNL, and pulmonary embolism.

The mean hospital stay amounted to 15.4 days ranging from 11.6 to 19.8 days.

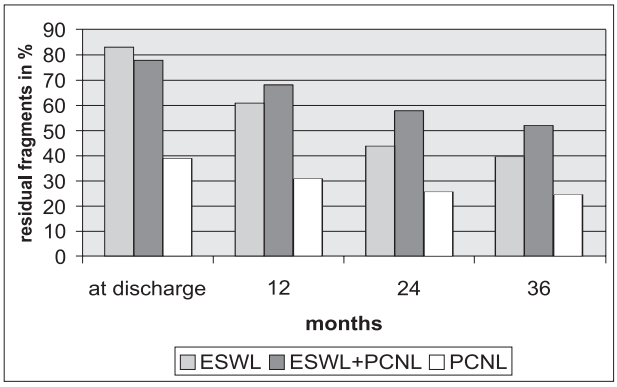

Figura 5

Follow-up Data

The mean follow-up of our study was 36 months. Thirty-one percent of all patients were stone-free at discharge ranging from 63% after PCNL-monotherapy to 11% after ESWL-monotherapy. However, after a 3 years period, 60% of the patients (48 to 71%) became stone-free, depending mainly on the complexity of the treated stone (Figure-5). Twenty-five percent (21 to 33%) of all patients had still clinically insignificant residual fragments (CIRF), and only 8% (4 to 13%) had symptomatic fragments mainly associated with UTI (Table-5). The overall recurrence rate amounted to 7% independent on the treatment group. Only 11 % suffered still from urinary tract infection compared to 35% at hospitalization (Table-5).

Comparison with Open Surgery

Our series of open surgery was performed prior to the introduction of ESWL and Endourology.

The stone distribution in terms of borderline vs. staghorn stones was similar in both groups, but

Table 6 *– Modern management of complex stones. Comparison of results with open surgery.*

Criteria	**Open Surgery (n = 83)**	**Modern Management (N = 186)**	
Borderline "stones"	40 (48%)	87 (47%)	
Partial staghorn	16 (19%)	63 (34%)	
Complete staghorn	27 (33%)	35 (19%)	
Blood transfusion	31 (37%)	18 (10%)	($p < 0.05$)
Nephrectomy rate *	12 (14%)	3 (2%)	
Minor complications	28 (39%)	86 (45%)	n.s.
- Colic	-	28 (15%)	
- Fever	27 (33%)	56 (30%)	
- Wound problems	5 (6%)	-	
Major complications	6 (8%)	13 (7%)	n.s.
- Septicemia	3 (4%)	5 (3%)	
- Bleeding	-	5 (3%)	
- Others	3 (4%)	3 (1%)	
Mean hospital stay (d)	17.2	15.4	n.s.

* *In 9 cases due to poor function, in 3 instances due to septicemia. n.s. = not statistically significant.*

the percentage of complete staghorn stones was higher in the open surgery group (Table-6). The blood transfusion rate (37% vs. 10%) was significantly higher after open surgery, whereas the rate of fever and other minor side effects did not differ in both groups. Also major complications were observed in a similar rate (7 vs. 8%) as well as hospital stay (17.2 vs. 15.4).

In the follow-up of both groups, there are further significant differences (Table-7): the stone-free rate at discharge after open surgery is significantly higher than after ESWL and endourology (80 vs. 31%). In contrast to this, the stone-free rate after 42 respectively 36 months does not differ significantly (72 vs. 60%) but is in favor of the open approach (Figure-6). It is to be noted, on the other hand, that the majority of the remants after the modern techniques represent CIRF, whereas the recurrence rate after surgery is significantly higher (20% vs. 7%). Additionally, the reduction of urinary tract infection rate is better after the modern approach (0.51 vs. 0.32 = UTI after/UTI before), Table-7.

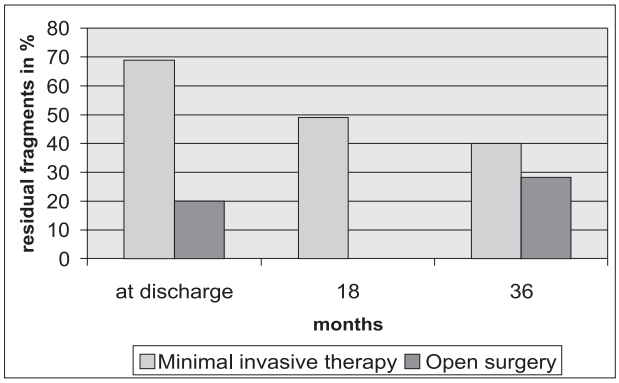

Figura 6

DISCUSSION

The surgical management of urinary stone disease has undergone dramatic changes and seen the implementation of technological innovations that are unsurpassed in the field of urological surgery over the past 20 years. Before these advancements, open surgery was the only surgical option for nephrolithiasis. In the current era, the first question in the management of any stone usually is whether the situation is amenable to ESWL. This should come

***Table 7** – Modern management of complex stones. Comparison of follow-up results (1984-1987) with open surgery (1981-1983).*

Criteria	**Open Surgery (n = 61)**	**Modern Management (N = 186)**	
Stone-free at discharge	49 (80 %)	58 (31%)	p < 0.05
Remants in kidney	12 (20 %)	110 (59%)	
Remnants in ureter	-	18 (10%)	
Mean follow-up (months)	42	36	
Stone-free	44 (72 %)	112 (60%)	n.s.
Asymptomatic remnants (CIRF)	2 (3%)	46 (25%)	p < 0.05
Symptomatic remnants (SIRF)	3 (5%)	15 (8%)	n.s.
Recurrence	12 (20%)	13 (7%)	p < 0.05
UTI (at hospitalization)	35 (57%)	65 (35%)	
UTI (after follow-up)	18 (30%)	21 (11%)	
UTI after/UTI before	0.51	0.32	p < 0.05

UTI = urinary tract infect; CIRF = clinically insignificant fragments;
SIRF = significant residual fragments.

as no surprise because of the ease of use and noninvasive nature of the procedure. The real issue is whether the excellent results obtainable with this technology in case of small stones translate into successful treatment when targets are complex stones such as staghorn calculi. The patient demand and the desire to avoid painful incisions and long recovery periods, and finally the pressure to provide cost-effective care with shorter hospitalizations after surgery have created a treatment philosophy that defines success as the ability to eradicate the stone with the least invasive modality.

Guidelines for the Treatment of Staghorn Calculi

In this situation, particularly in case of complex stones, urologists have to define the indications for selection of the best procedure for treat the individual stone. The Nephrolithiasis Clinical Guidelines Panel of the American Urological Association reviewed 110 articles concerned with staghorn calculi resulting to the following guidelines (18). The committee believed that a newly diagnosed staghorn was an indication for active treatment. Percutaneous stone removal, followed by ESWL or repeat PCNL, should be used for most patients with struvite staghorns. Neither ESWL-monotherapy nor open surgery should be used as first-line treatment for staghorns in most patients.

As options PCNL and ESWL are equally effective in treating small-volume staghorns when the renal anatomy is normal or near normal. Also as an option, open surgery is appropriate therapy when the staghorn cannot be managed by any reasonable number of PCNL and ESWL sessions, i.e. in case of a giant staghorn. Nephrectomy is a reasonable option for a poorly functioning stone-bearing kidney.

This summary is in accordance with our previously stated indications (Table-3). It reflects, however, the limitations of further clarifications mainly due to the lack of prospective randomized studies as well as an accepted way to describe staghorns in the literature. We therefore believe that it is important to focus further on the comparison of the different treatment strategies for staghorn stone in the literature. For this purpose, the changing treatment philosophy and consecutively the criteria of therapeutic success have to be addressed.

Treatment Philosophy

As stated before, the introduction of the new technologies resulted to the philosophy to treat the stone most effectively with minimal invasiveness and morbidity for the patient. This includes the amount and severity of complications associated with the applied procedures, length of hospitalization and disability, and initial stone-free rates. However, the ultimate goals of therapy in this specific group of patients should include the long-term stone-free rates, minimizing the rates of recurrent stones and infection, and the preservation of renal function (16,34).

Morbidity of the Treatment

The morbidity of open surgery have been reported extensively in the literature (4,6,21,22,35-40) including fever (26-29%), blood transfusions (14-70%), pneumothorax (5%), recurrent bleeding (4%), septicemia (1%), urinoma/fistula (1%), embolism (2%), flank abscess (2%), flank pain (16%), flank bulge (5%), incisional hernia (2%) and wound infections (4%) with a postoperative hospital stay ranging from 11 to 16 days.

Using the modern approach (3,12,13,15, 25,37-45), the morbidity mainly is associated to percutaneous surgery with the need of blood transfusions (5-53%), fever (12-64%), septicemia (2-4%), pneumothorax (2%), A-V malformation requiring superselective embolization (1%), flank abscess (1%), and colon perforation (1%). The hospital stay ranged between 9.5 and 18 days.

Our own experience with both methods (Tables-6 and 7) correlates with these data. There is no doubt, that due to the complexity of the disease both approaches are associated with significant side effects. On the other hand, there is sufficient evidence that the overall peri- and postoperative morbidity of ESWL and endourology is significantly less compared to the open approach. The fact that the modern techniques require multiple treatment sessions (2.8 vs. 1 session) (18) does not represent a disadvantage, be-

cause it has an impact neither on morbidity nor on the hospital stay.

The differences between both approaches are even more pronounced with respect to the long-term complications. Whereas the time to normal activity ranged between 44 to 54 days after open surgery, this was only 21 to 30 days after ESWL plus endourology (38-40). Complete loss of renal function was seen in 2-8% after open surgery associated with a nephrectomy rate of 7-14%. Based on these, earlier calculations considered an overall dialysis rate of 5% of all patients with urolithiasis (46,47). The nephrectomy rate in our series was only 2% using the modern approach, and in a follow-up period of 3 years there was no further need of renal ablation due to delayed loss of renal function (Tables-6 and 7). In our personal experience with almost 20 years of multimodal minimally invasive stone management there have been only casuistic cases of stone-related dialysis in the eighties, however, not a single remembered case in the last ten years. This underlines the possibilities of ESWL and endourology to treat and also retreat patients with complicated stone disease without a significant risk of loss of renal function.

Residual Fragments

When open surgery was the standard treatment for the management of renal calculi, the presence of residual fragments suggested a failed procedure, even those remaining fragments were small. Because residual calculi may act as a nidus for recurrent stone formation, complete stone removal was the principal goal of therapy. The introduction of extracorporeal shock wave lithotripsy, however, shed a new perspective on this century-old concept, minimizing the importance of postprocedural residual fragments.

Nevertheless, in the last decade the main goal of PCNL and ESWL treatment was to achieve a complete stone-free status ignoring the fact that more and more patients benefit from successful stone disintegration but with minor asymptomatic residual fragments, the so called “clinically insignificant residual fragments” = CIRF (Table-5). Of course, the acceptance of this change of therapeutic endpoints would have a major impact on treatments strategies for all complex stones. Some authors do not accept the CIRF-theory in case of complex stones because the majority of calculi are associated with infection of the urinary tract and consist of struvite with a high risk of persisting infection and stone recurrence (19). This is true for open surgery: the stone free rates at discharge are significantly higher (80-93%) than after the modern techniques (19-37%). However, after 3 months these figures are rising up to 67-78%. Our long-term experience after three years revealed an overall stone-free rate of 60%, which was not statistically significant from the 72% stone-free rate after open surgery. Subsequently, the recurrence rate was significantly higher after open surgery (20% vs. 7%) (Table-7).

Infection

Moreover, about 3 quarters (46 of 61) of the residual fragments were asymptomatic (= CIRF) in our series, which has been found recently by other authors, too (42). In both series, more than 50% of stones consisted of struvite, however, the rate of urinary tract infection could be significantly reduced (i.e. from 35% to 11%). The ratio UTI after/UTI before was significantly higher after open surgery than when using ESWL and endourology (0.51 vs. 0.32) (Table-7). There may be several reasons to explain these finding: 1)- residual fragments are better reachable for antibiotic drugs than residual stones which still may contain bacteria; 2)- the quality of antibiotics (i.e. gyrase inhibitors) has improved; 3)- the operative trauma to the collecting system as well as to the renal parenchyma is significantly less after PCNL plus ESWL than after open surgery.

Anatomical criteria of the lower caliceal system (i.e. length of the caliceal neck, pelvic-caliceal angle) may help to predict the chance of complete stone clearance (48,49). Nevertheless, one has to accept the fact, that even in case of complex stone the majority of residual fragments after extracorporeal shock wave lithotripsy are or may become clinically insignificant (= CIRF) and only about 10-15% require further treatment (= SIRF). This has been in accordance to a recent review of the literature concerning more than 14,000 patients (50).

In contrast to this, persisting infection still remains one of the main problems after open surgery.

Even in a recent study Rocco et al. revealed a 21% UTI-rate in their follow-up (22).

Perspectives

In summary, the introduction of minimally invasive techniques has also completely changed the management of complex stones. Open surgery is only preferable in case of giant staghorns requiring numerous percutaneous procedures along with ESWL, after failure of the modern techniques or in cases necessitating additional surgical reconstruction. Even stone-bearing non-functioning kidneys can be removed laparoscopically in most situations. The majority of long-term studies show almost similar stone-free rates, but lower percentages of stone recurrence and urinary tract infections when using ESWL and endourology. In addition, the number of dialysis cases because of progressing nephrolithisis is trending towards zero. However, the multimodal minimally invasive therapy of complex renal stones requires an individual treatment plan for each patient depending on stone burden and distribution, anatomy of the collecting system, and the composition of the calculus (Table-3).

Recently ureterorenoscopic techniques have been introduced for the management of staghorn stones based on the holmium laser technology (51). However, at present, we feel that such techniques have only limited indications because of the problems with removal of stone burden, intrarenal influx in case of infected stones, as well as with respect to the prolonged operating time. On the other hand, there may be reasonable indications for flexible ureterorenoscopy, i.e. in the treatment of calculi behind caliceal neck stenosis (52).

Finally, as mentioned before, we have to face the upcoming problem of adequate training and education in the surgical management of complex renal stones. This affects both, the percutaneous and open surgical techniques. The frequency of staghorn stones has declined dramatically in our daily routine, which is in accordance with other centers in Europe and United States. None of the existing centers - except those in stone-belt areas - is currently able to reproduce the large series of the eighties. On the other hand, increasing reports of extensive use of the modern techniques are presented from countries, which previously had only limited access to ESWL and endourology, i.e. in Eastern Europe, India, (52). The main problem of training represents the difficulty and complexity of these procedures, albeit percutaneous or open surgery. This situation is similar to the training of laparoscopy and retroperitoneoscopy. Therefore, we feel that such complex stone cases should be concentrated to a few centers of expertise, which then could also provide adequate training for urologists with special interests in this field.

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Received: July 19, 2000
Accepted: August 20, 2000

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EDITORIAL COMMENT

The authors present their extensive experience in the contemporary management of staghorn calculi. Having been leaders in the minimally invasive management of staghorn calculi, including shock wave lithotripsy and percutaneous techniques, this manuscript provides an excellent overview of endoscopic and shock wave-related approaches to the management of complex renal stones.

Comparing almost 200 patients who had undergone contemporary minimally invasive management of symptomatic staghorn calculi to more than 80 patients who had undergone open nephrolithotomy, this study finds that minimally invasive techniques offer reliable, safe and efficacious options for the management of complex renal calculi. The results and suggestions offered in the current manuscript are comparable to the recommendations introduced in the American Urological Association's Nephrolithiasis Guidelines report on the management of staghorn calculi (1). In essence, small-volume staghorn calculi in a non-dilated collecting system can be managed in many cases with shock wave lithotripsy monotherapy. However, for large volume staghorn calculi, a percutaneous approach either as monotherapy or in conjunction with shock wave lithotripsy should provide stone-free rates comparable to that of open surgery. Moreover, these minimally invasive approaches offer the benefits of decreased blood loss, decreased growth of residual fragments as well as a more rapid return to normal activity.

The authors stress that the minimally invasive techniques of shock wave lithotripsy and percutaneous nephrolithotomy have replaced open stone surgery for the management of all but the most complex of staghorn calculi. Finally, the authors note the importance of adequate training in various endoscopic techniques, which will provide the Urologist the ability to manage complex renal and ureteral stone disease.

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