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MINIREVIEWS

Review on renal recovery after anatrophic nephrolithotomy: Are we really healing our patients?

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Abstract

The main goals for urinary stone treatment are to preserve renal function, reduce or avoid complications related to calculi, and to render the patient free of calculi as soon as possible. Anatrophic nephrolithotomy (ANL) is a valid and useful alternative for conventional staghorn calculi excision. Although excellent stone free rates can be achieved with ANL there are some drawbacks that may be of concern. Morbidity related to intraoperative and postoperative complications is one of them. Another, great concern is the possibility of reduction on renal function related to the procedure itself. This may be related to nephron injury during nephrotomy and parenchymal closure or to ischemic injury. In this review we assess functional results after anatrophic nephrolithotomy.

Key words: Anatrophic nephrolithotomy; Kidney lithiasis; Kidney stone disease; Percutaneous nephrolithotripsy; Staghorn calculus

Core tip: Anatrophic nephrolithotomy (ANL) is a valid and useful alternative for conventional staghorn calculi excision. Although excellent stone free rates can be achieved with ANL there are some drawbacks that may be of concern. Morbidity related to intraoperative and postoperative complications is one of them. Another, great concern is the possibility of reduction on renal function related to the procedure itself. In this review we assess functional results after anatrophic nephrolithotomy.

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INTRODUCTION

The main goals for urinary stone treatment are to preserve renal function, reduce or avoid complications related to calculi, and to render the patient free of calculi as soon as possible. Procedures with low morbidity and rapid recovery are also essential in current practice. Guidelines from American Urological Association and European Urology Association state that conventional excision of staghorn stones must be considered only in exceptional cases and that percutaneous nephrolithtomy (PNL) should be the preferred choice[1,2].

The definition of "staghorn calculus" is related to the calculation that fills at least one caliceal group and, mandatorily, the pelvis. If the calculus fills the renal pelvis but not all the caliceal groups, it is recognized as a "partial staghorn calculus". However, if this kidney stone occupies the renal pelvis and at least three quarters of the pyelocaliceal system, it is labeled as "complete staghorn stone". Computed Tomography based morphometric studies may help classify and predict outcomes for staghorn calculus treatment[3,4], nevertheless, it is implicit that the greater the stone more difficult it is to leave the patient without remaining calculi in the collecting system. Several authors showed the relation between stone size and stone clearance. In a recent study, el-Nahas *et al*[5] showed that the stone-free rate for percutaneous nephrolithotomy as monotherapy was 56% and complete staghorn calculus was an independent risk factor for residual stones[5].

Undoubtedly, the main reason for conventional surgery rates decrease is the improvement of techniques such as extracorporeal shockwave lithotripsy (SWL) and endourological procedures (ureteroscopy and PNL)[6-9]. Yet, even with such technological developments, some special conditions are still best handled with conventional surgery, such as complex collecting system anatomy, extremely large stones, extremely poor function of the affected renal unit, or excessive morbid obesity.

Anatrophic nephrolithotomy (ANL) is one of the most used option for conventional staghorn calculus removal. Smith *et al*[10] described the anatrophic nephrotomy and plastic calyrhaphy a procedure in which stone removal and correction of collecting system anomalies was possible. Although excellent stone free rates can be achieved with ANL there are some drawbacks that may be of concern. Morbidity related to intraoperative and postoperative complications is one of then. Another, great concern is the possibility of reduction on renal function related to the procedure itself. This may be related to nephron injury during nephrotomy and parenchymal closure or to ischemic injury. In this review we assess functional results after anatrophic nephrolithotomy.

ANATROPHIC NEPHROLITHOTOMY PROCEDURE

Smith *et al*[10] identified some factors that may contribute for perpetuating renal inflammatory process after stone surgery: poor drainage, renal parenchymal damage, failure to control infection and inadequate removal of calculi. In order to control those issues and to preserve the maximal number of functional nephrons they described the anatrophic nephrotomy and calyrhaphy. The main steps in this procedure are: control of the main renal artery and obstruction of the posterior segment of renal artery, endovenous infusion of methylene blue to highlight the Brödel's white line, obstruction of the renal artery common trunk and creation of the condition of hypothermic ischemia, nephrotomy along the anterior border of the posterior calyces (approximately 0.5 to 1 cm posterior to Brödel's white line), calculus extraction, reconstruction of the pyelocaliceal system, and closure of the renal capsule[10]. The first 100 consecutive cases using this technique were published by Boyce *et al*[11] and showed 95% stone-free rate. Serum urea nitrogen obtained to assess renal function and serum creatinine has improved or remained stable in all but 2 patients. Other authors also published their results regarding renal function. Thomas *et al*[12] used 131 I hippuran scanning to assess renal function of thirteen patients operated on with classic ANL with a mean follow up of 13.6 mo. Thirteen percent decrease in renal function of the kidneys undergoing ANL surgery was reported. Nonetheless, total renal function assessed by effective renal plasma flow level remained normal in the postoperative stage. Compensatory hypertrophy may explain the unchanged total renal function as a 13% increase in the contralateral kidney was reported.

Studies in patients with solitary kidney may help to understand changes in renal function without the compensatory effect of the contralateral kidney. With a mean follow-up of 6 years, patients with solitary kidneys operated on with classic ANL were evaluated by Stubbs *et al*[13] and associates. No changes in pre- and post-operative serum creatinine was observed. However, creatinine clearance showed a small increase from 52 to 55 mL/min, but it was not statistically significant.

MODIFIED ANATROPHIC NEPHROLITHOTOMY

Several modifications of the classical approach have been described usually without defining the intersegmental plane[14-19]. Kijvkai *et al*[18] compared standard ANL and modified ANL and concluded that the standard procedure preserved more renal function than the modified[18]. Table 1 describes results of modified ANL in regard to renal function assed by scintigraphy.

In 2003, Kaouk *et al*[20] studied laparoscopic ANL for the management of staghorn renal stone in pigs[20]. After injecting polyurethane in the pyelocaliceal system to create a staghorn calculus model the animals were submitted laparoscopic nephrolithotomy. Glomerular filtration rate (GFR) was assessed before and four to five weeks later with diethylene triamine pentaacetic acid (DTPA) renal scans. The mean total GFR rised from 26.4 mL/min to 54.8 mL/min. A case series was first reported by Simforoosh and associates in 2008[21]

Table 1 Renal function after modified anatrophic nephrolithotomy

Ref.	*n*	Parameter	Renal function improvement/stabilization	Renal function decrease	Percent reduction
Belis *et al*[15]	13	131-iodine hippuran	100%	0%	-
Morey *et al*[16]	16	DMSA	18.8%	81.2%	4%
Melissourgos *et al*[17]	24	DMSA	62.5%	37.5%	4%
Kijvikai *et al*[18]	15 (7 St/8 Mod)	DTPA	0%	100%	9% St/27, 2% Mod
Ramakrishnan *et al*[19]	26	DMSA	87%	13%	-

DMSA: Dimercaptosuccinic acid; DTPA: 99mTc-diethylenetriaminepentaacetic acid; St: Standard; Mod: Modified.

with an update in 2013[22]. Stone-free rate was 88%. Mean pre-operative serum creatinine level rised from 1.20 mg/dL to 1.31 mg/dL in the postoperative period, but without statistically significant difference. Researcher described a stone-free rate of 63% in eight patients evaluated. Tree patients were submitted to preoperative 99mTc-DTPA renography to asses renal function 3 mo after surgery. Renal function decreased 4%, 12%, and 4% on the operated kidney of each patient.

Robot-assisted laparoscopic ANL (RANL) has also been described. Ghani *et al*[23] tried to replicate the conventional technique with ice-slush hypothermia. Follow-up at 1 mo demonstrated no change in renal function as estimated by creatinine clearance. King *et al*[24] evaluated seven consecutive patients submitted to RANL. Renal function was estimated by the Modification of Diet in Renal Disease study equation. In five of six patients estimated GFR was unchanged and improved in one patient (19 mL/min per 1.73 m^2 preoperative *vs* 25 mL/min per 1.73 m^2 postoperative).

PERCUTANEOUS NEPHROLITHOTOMY *VS* ANATROPHIC NEPHROLITHOTOMY

Several studies have assessed the impact of PNL on renal function[25-32]. Usually there is an immediate decrease on renal function after surgery with return to baseline on long term. Improvement or stabilization of renal function may occur because of better drainage, infection and inflammation resolution after surgery. On the contrary, renal function may decrease because of several injury mechanisms. Patient comorbidities, direct injury by kidney puncture and tract dilation, ischemia, inflammation and fibrosis are some of the possible mechanisms implicated on renal function deterioration.

Wilson *et al*[33] tried to quantify the level of parenchymal injury after stone treatment in an animal study. Percutaneous nephrolithotomy accounted for the largest amount of microscopic lesions, although, it was less than 2% of total renal volume and did not affected total renal function. Moskovitz *et al*[26] evaluated renal units separately and identified a remarkable reduction in the functional volume of the pole that underwent PNL, nevertheless, regional uptake and total renal function remained unchanged[26].

In cases where the amount of calculi is remarkable multiple access tracts may be required during the PNL procedure. It could be expected that the number of access tracts and ancillary procedures used for complete stone clearance could negatively impact on renal function. In regard to multiple tracts, there are few studies that support this hypothesis. El-Tabey *et al*[34] found that multiple punctures were an independent risk factor for renal function deterioration in a cohort of patients with solitary kidney. Hegarty *et al*[35] and Fayad *et al*[36] also noted that multiple tracts carries a risk of adversely affect renal function. Handa *et al*[37], on the other hand, showed that multiple access tracts does not lead to a more severe reduction in renal function[37].

Ancillary procedures such as extracorporeal shock wave lithotripsy (ESWL) and retrograde intrarenal surgery (RIRS) are frequently required for complete clearance of staghorn stones. The number of ancillary procedures to render the patient stone-free may range from 2.1 in partial to 3.7 in complete staghorn stones[1]. Most of the studies addressing PNL and ESWL do not show decrease in renal function[38-41]. Also, combined PNL and RIRS does not seem to adversely impact renal functio[42,43]. Zeng *et al*[43] reported that only 2.7% of patients had renal function deterioration after combined treatment. Nevertheless, the potential deleterious effect of ESWL on kidney structures is well established[44,45] and the combination of PNL may have a greater impact on renal function. In regard to RIRS parenchymal injury is not so evident, even so, more studies with longer follow-up are needed.

Most of the studies shows that renal function is not greatly compromised after PNL (Table 2). Nonetheless, there are no prospective randomized studies specifically comparing PNL and ANL. A well-designed study comparing PNL and open surgery was published by Al-Kohlany *et al*[46]. Eighty-eight renal units were assed, 43 submitted to PNL and 45 to conventional surgery. Modified ANL, extended pyelolithotomy, and combined pyelolithotomy/nephrolithotomy were included. Renal function was assessed with 99mTc-mercaptoacetyltriglycine (MAG3) scans and no significant decline in the operated renal unit was observed, although, results were not segregated by technique. Shen *et al*[47] also compared PNL and open surgery in a prospective randomized study. Renal function was assessed with serum and urinary b2-microglobulin and they found no difference between groups. As in Al-Kohlany *et al*[46]

Table 2 Renal function after percutaneous nephrolithotomy

Ref.	*n*	Follow up	Parameter	Renal function improvement/stabilization	Renal function decrease
Ekelund *et al*[25]	11	14 d	DTPA	73%	27%
Moskovitz *et al*[26]	88	1.5-24 mo	SPECT/DMSA	Total percent uptake unchanged	Decreased functional volume of the treated region
Tok *et al*[27]	711	12-24 h	eGFR	13% improvement in the geriatric group	2% decreased in the non-geriatric group
Kuzgunbay *et al*[28]	16	51.1 mo	Serum creatinine	75%	25%
El-Nahas *et al*[29]	122	12 mo	Tc99m MAG3	91.5%	8.5%
Nouralizadeh *et al*[30]	94	48 h	eGFR	0%	100%
Akman *et al*[31]	272	37.3 mo	eGFR	79.6%	20.4%
Ozden *et al*[32]	69	45.7 mo	eGFR	85%	15%

DTPA: 99mTc-diethylenetriaminepentaacetic acid; SPECT/DMSA: Single photon emission computed tomography; eGFR: Estimated glomerular filtration rate; Tc99m MAG3: Technichium99 metastable Mercaptoacetyltriglycine.

study, results were not segregated by technique.

DISCUSSION

Renal function improvement may occur after stone treatment. Possible mechanisms related to increase in renal function are the relieve in obstruction, resolution of infection and inflammatory process, and compensatory hypertrophy of the remaining tissue[12]. Nevertheless, the stone-extraction procedure may itself negatively compromise the functional condition of the surgically treated kidney. Decreased renal function after percutaneous nephrolithotomy may occur because of parenchymal damage during needle puncture and tract dilation. Ischemic injury may also arise if there is inadvertent injury to major vessels, although, it is not so common.

In regard to anatrophic nephrolithotomy decrease in renal function may occur because of direct injury to parenchymal tissue, leading to a permanent scar at the site of nephrotomy. Another possible mechanism is the ischemia-reperfusion injury related to occlusion of renal artery and vein. Protection measures as ice-slush hypothermia and mannitol have been used, as well as restriction of ischemia time to no longer than 30 min. However, the impact of those measures on renal function are not fully known.

It seems that the type of methodology used to assess renal damage influences the postoperative results. When functional markers are employed, kidney damage is temporary and usually mild. Examples of functional markers are renal plasma flow, GFR, serum creatinine, and estimated GFR. However when cellular damage and morphological assessment are considered, renal damage becomes more evident. In most surgeries postoperative renal function is preserved and even when renal dysfunction is observed, it is usually negligible. Nevertheless, information about long term follow-up is scarce, as well as the the cumulative impact of multiple procedures.

As previously addressed PNL is the standard treatment for staghorn stones. Nevertheless, there are some limitations with this approach. The Clinical Research Office of the Endourological Society (CROES) PNL Global Study and the British Association of Urological Surgeons Section of Endourology have reported the efficacy of PNL for treatment of patients with staghorn stones[48,49]. The CROES study group analyzed outcomes of 1466 patients with staghorn calculi compared with 3869 patients with nonstaghorn stones undergoing PNL. They found that patients with staghorn stones more frequently underwent multiple punctures (16.9% *vs* 5.0%) and had lower complete stone-free rates (56.9% *vs* 82.5%). The United Kingdom study group reported on 299 patients who underwent PNL for staghorn calculi demonstrating an intraoperative complete stone-free rate of 59% and 47% on formal postoperative imagin[49].

When the number of less invasive procedures exceeds what is considered reasonable, we must consider the conventional surgery[1,2]. With the advances in laparoscopic and robotic assisted methods replication of the open technique is possible with less morbidity. The main drawbacks of open surgery as bleeding, longer recovery and morbidity related to flank incision may be overcome with laparoscopic/robotic approach.

Although a definitive conclusion can not be drawn from the available literature in regard to which one is the best approach to treat complete staghorn stone, percutaneous nephrolithotomy still is the first option. Nevertheless, in carefully selected cases anatrophic nephrolithotomy may achieve optimal outcomes.

CONCLUSION

Although parenchymal damage after anatrophic nephrolithotomy is of concern renal dysfunction is usually clinically insignificant. Comparative studies of the available modalities are scarce as well as long term follow-up and the impact of multiple procedures.

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