Staghorn classification: Platform for morphometry assessment

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ABSTRACT

Introduction: The majority of staghorn classifications do not incorporate volumetric stone burden assessment. Accurate volumetric data can easily be acquired with the ever-increasingly available computerized tomography (CT) scan. This manuscript reviews the available staghorn stone classifications and rationalizes the morphometry-based classification.
Materials and Methods: A Pubmed search was performed for articles concerning staghorn classification and morphometry. Twenty abstracts were shortlisted from a total of 43 published abstracts. In view of the paucity of manuscripts on staghorn morphometry (4), older staghorn classifications were analyzed with the aim to determine the most optimum one having relevance to the percutaneous nephrolithotomy (PCNL) monotherapy outcome.
Results: All available staghorn classifications are limited with non-widespread applicability. The traditional partial and complete staghorn are limited due to non-descript stone volumetric data and considerable overlap of the intermediate ones in either group. A lack of standardized definition limits intergroup comparison as well. Staghorn morphometry is a recent addition to the clinical classification profiling of a staghorn calculus. It comprises extensive CT volumetric stone distribution assessment of a staghorn in a given pelvi–calyceal anatomy. It allowsmeaningful clinical classification of staghorn stones from a contemporary PCNL monotherapy perspective.
Conclusions: Morphometry-based classification affords clinically relevant nomenclature in predicting the outcome of PCNL for staghorn stones. Further research is required to reduce the complexity associated with measuring the volumetric stone distribution in a given calyceal system.

Key words: Percutaneous nephrolithotomy, staghorn stones, staghorn morphometry, staghorn classification, stone classification

INTRODUCTION

Staghorn is classically described as a branched renal calculus. The extension of a renal staghorn stone could be into a few calyces or it may involve all the calyces. The standard of care for renal staghorn stones is percutaneous nephrolithotomy (PCNL) monotherapy.[1] The distribution of staghorn stone burden in the pelvi–calyceal system (PCS) is an important determinant of the complexity of PCNL. In the era of PCNL monotherapy, there is a need for standardized nomenclature to quantitate differences in the staghorn complexity. This demands a detailed description of stone volume or surface area, distribution of the stone in the PCS and also the PCS anatomy. The historical literature is deficient in terms of detailed description of the staghorn stone and, therefore, series across the world are not comparable. Various authors have proposed a uniform objective stone volume or surface area data that would make the assessment in a given scenario more objective. There is also a need for such an objective data with respect to PCNL monotherapy as a standard of care for managing staghorn stones. PCNL monotherapy is varied with respect to different approaches for renal staghorn stones in terms of patient position, access, number of tracts, size of the tracts and intracorporeal energy sources utilized. In the context of surgical recommendations, the treatment pattern is mostly affected by the anatomical attribute of the staghorn calculus. A staghorn stone that one clinician deems inappropriately complex due to its branching pattern or calyceal anatomy, may be standard for another clinician. Morphometry-based classification is a natural evolution and attempt to objectively define the clinical complexity of renal staghorn stones.

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MATERIALS AND METHODS

This article reviews the current status of morphometry-based staghorn stone classification. A Medline search was performed using the key words 'staghorn stone classification' and 'staghorn morphometry'. There were a total of 43 abstracts, of which 19 were chosen for review. A total of four publications are present in the contemporary literature regarding staghorn morphometry. In view of the paucity of adequate data, other classifications of staghorn were also included. An attempt was made to rationalize the importance of morphometry-based classification in the contemporary management of staghorn calculus.

Morphological classification

Several groups have proposed classification schemes to better define staghorn calculi taking into account size, morphology and composition. Most of the initial classification schemes have involved morphological and composition based classification. From a contemporary clinician's perspective stone composition is important because a soft stone would break easily during intracorporeal lithotripsy. Struvite staghorn stones have a higher content of organic matrix, rendering these stones fragile.[1] They fragment easily with lithotripters and are easy to clear. Bacteremia is more commonly associated during lithotripsy. These stones are also more prone to recurrence if residual fragments remain. Whewellite stones and uric acid stones are hard and smooth.[2] Their fragmentation occurs in large pieces that need to be removed. Cystine, although rare, is the hardest.[3] Secondary staghorn stones are seen in Cushing's syndrome, hyperparathyroidism and renal tubular acidosis.[2] They are usually calcium phosphate and hydroxyapatite stones.[2] There is no specific method of treating a particular staghorn in a given renal unit. Traditional open approaches have been replaced with percutaneous renal procedures. Most staghorn stones break easily with the available intracorporeal lithotripters.

Anatomical classification

The traditional anatomical definition of staghorn calculus is a renal pelvic stone with extension into the renal calyces.[1] Rocco *et al.*[4] in 1984 suggested renal calculus classification according to topography and morphology. They used the acronym CERPUwher the letter "C" described the morphology, size and topography of the stone. The letter "E" described the excretory tract, with symbols "+" and "–" being used for the presence or absence of dilatation and "e" and "I" for extra- and intrarenal position of the pelvis. The letter "R" referred to clinical recurrences. Finally, the letter "P" denoted functional status of the parenchyma. Griffith *et al.* subsequently suggested another classification based on complexity, burden and distribution of stone in the pelvi–calyceal system.[5] Burden was defined as the sum of the longest axial diameter of all stones. A scoring diagram was used to notify the complexity and burden of stone in the pelvi–calyceal system. The stone burden was defined as the sum of the longest axial diameter of all stones. The kidney is divided into pelvis, branches or infundibula and calices. The use of such a scoring diagram allowed a concise description of the complexity and burden of stone in each renal system and facilitated computerized stratification of the upper tract stones. Rassweiler *et al.*[6] and Di Silverio[7]classified staghorn stones into: borderline, when stones cover the renal pelvis and one calyx; partial, when beside the pelvis, two calices are occupied; complete, when stones are in the whole collecting system or 80% of it; and gigantic, when the whole collecting system has stones and a dilation of the system occurs. All these classification systems were complex with limited clinical application. They could not gain widespread acceptance.

Historically, staghorn calculi were classified as partial or complete.[1] Partial staghorn calculi were defined as renal pelvic calculi extending into two calyceal groups and complete staghorn stones were defined as renal pelvic calculi extending into all major calyceal groups, filling at least 80% of the collecting system. But, this type of classification does not put any light on the management planning of staghorn stones and is also not based on any specific volume criteria.[1] There is a considerable overlap of stone burden between partial and complete staghorn calculus.[8] Guy's stone score was developed through a combination of expert opinion and published data review to test the association of stone with stone-free rates achievable.[9] It comprised four grades: Grade I, solitary stone in mid/lower pole or solitary stone in the pelvis with simple anatomy; grade II, solitary stone in upper pole or multiple stones in a patient with simple anatomy or a solitary stone in a patient with abnormal anatomy; grade III, multiple stones in a patient with abnormal anatomy or stones in a calyceal diverticulum or partial staghorn calculus; and grade IV, staghorn calculus or any stone in a patient with spina bifida or spinal injury. It was found to be reproducible, with good inter-rater agreement. Guy's stone score was the only factor that significantly and independently predicted the stone-free rate. The system was a generalized one and was not exclusively formulated for staghorn stones.

Stone burden classification

With the advent of widespread CT scan, stone area and volume could be measured easily using software. Stone volume is an important predictor of stone-free rates following shock wave lithotripsy.[10] Lingeman *et al.*[11] advocated the use of stone surface area by 3D CT for more accurate reporting of treatment results. The difficulty in accurately assessing stone burden explains the wide range of reported stone-free rates for shock wave lithotripsy (SWL) monotherapy from 22% to 85%.[1] Lam and Lingeman *et al.*[12] suggested that stone surface area correlates well with stone volume, whereas maximal stone length does not. Stone surface area determination enables more accurate reporting of treatment results, and thus recommendation based on stone burden.

The European Association of Urology recommends stone volume measurement by using maximum diameter, and using it on a scalene ellipsoid formula.[13] Finch *et al.*[14] studied the correlation of 3D-reconstructed stone volume with respect to the accuracy of scalene, oblate and prolate ellipsoid volume equations. They concluded that the average shape of renal stones changes with diameter. As the stone diameter increases, the accuracy of determining stone volume decreases. Therefore, staghorn stones having a hallmark of large stone volume are less accurately measured with CT diameter. As the maximum diameter increases, the calculated stone volume becomes less accurate, suggesting that larger stones have more asymmetric shapes. The best way to measure stone volume, therefore, is from 3D-reconstructed stone volumes. Construction of a 3D model of renal stones can also potentially minimize the risks of percutaneous procedures and achieve higher one-stage stone-free rates. It is essential for comprehensive PCNL planning in a patient with complex renal stone. 3D reconstruction of the renal stones by many types of software can establish a virtual safe and reliable percutaneous renal access route on the 3D model of renal stones. Li *et al.*[15] performed PCNL with the assistance of the 3D model and found it to be feasible and highly effective in achieving a single-stage clearance rate of 93.3%.

CT has been used for assessing renal staghorn by various researchers. The Arthur Smith institute formulated the S.T.O.N.E. nephrometry score[16] for predicting the outcome of PCNL, which varies from four to 11. This score is determined by five parameters by a pre-operative CT scan: Stone size (S), tract length (T), obstruction (O), number of involved calices (N) and essence or stone density (E). As the score increases, blood loss, complication and hospital stay increases and the clearance rate decreases. But, this classification is not specific to staghorn. This classification is based on subjective criteria of obstruction that can be measured as no, mild or severe hydronephrosis; therefore, this score may vary for the subjective interpretation of the degree of hydronephrosis.

The AUA Nephrolithiasis Guidelines Panel has demonstrated superior stone-free rates, improved complication rates and reduced need for secondary procedures in those patients treated with PCNL monotherapy for staghorn calculus.[1] Standardized reporting of renal staghorn is essential for consistent decision making and effective comparisons, particularly as data emerge suggesting a relation between staghorn stone burden and PCNL monotherapy outcomes. Therefore, a classification of staghorn based on actual stone burden and integrative with PCNL monotherapy is required.

Morphometry-based classification

Mishra *et al.*[17] attempted to classify staghorn based on volumetric burden distribution within the pelvi–calyceal system. Herein, the objective was to afford standardized communication regarding the anatomical features of the staghorn. In the preliminary retrospective study, they performed an extensive volumetric burden data assessment correlating with the tracts and stages required in PCNL monotherapy for staghorn stone.[17] The classification was made according to the total stone volume (TSV) and unfavorable calyx stone percentile volume (UCSPV).[17] TSV was defined as the stone volume calculated by reconstructing the entire stone image on the software. In order to quantitate the stone volume, CT urography was performed and stone volume was assessed using a CT scan volumetric assessment software (3D-DOCTOR™; Able Software Corporation, Lexington, MA, USA). The assessment of favorable and unfavorable calyx was performed on the image plane view of the software. A favorable calyx was defined as a calyx-containing stone that is at an obtuse angle to the entry calyx and has an infundibular width >8 mm. The stones were classified in the following groups: Type 1 staghorn <5000 mm^3 TSV and <5% UFCSPV; Type 2a 5000-20,000 mm^3 TSV and <5% UFCSPV; Type 2b <20,000 mm^3 TSV and >5% UFCSPV; and Type 3 >20,000 mm^3 and any UFCSPV. Multivariate analysis revealed that the tract depends on the UFCSPV while the stages required depend on the TSV in PCNL monotherapy. The combination of TSV and UCSPV predicted the complexity of staghorn. In the odds ratio calculation, [2] they found that the odds ratio increased adversely for multiple tracts as the UCSPV increased. Quantitating stone volume may be standardized universally if CT-assisted stone volumetric assessment is performed. Paul *et al.*[18] performed a retrospective study including a total of 170 renal units in 163 patients who underwent treatment for staghorn calculi. There was no significant difference in TSV when single or two tracts were compared, but there was a significant increase for more tracts. Pelvic, pelvic and entry caylx percentile volume were significantly lower in the multiple tract group. UFCSPV were significantly less in single and two tract (s) than in the multiple tracts group. The staghorn morphometry also correlated with stages of PCNL. Increasing stone volume resulted in increasing stages. The single-stage procedure had significantly lesser TSV and PSV. Unfavorable calyx stone volume and percentile stone volume was higher in multiple stage procedures.

What we need today is validation of the concept of staghorn morphometry. It appears complex on the basis of the initial work done. However, it has opened a pandora of future work to be done on classifying staghorn stones. What may seem complex today could become easy with the development of dedicated stone software.

There should also be a prospective study to account for the clinical benefit of classifying staghorn stones. We presume that the higher is the complexity of the staghorn morphometry, more is the hemoglobin drop, hospital stay, complications and treatment costs.

CONCLUSION

Prospective morphometric classification of staghorn stones should guide us in the eventual treatment outcome. The outcome parameters that are most relevant are stone clearance, complications, hospital stay and auxiliary procedures. As the staghorn stone morphometry increases, there is a possibility of a lower stone-free rate. In addition, type 3 staghorn stones are likely to be challenging to the treating urologist. It is also relevant from a prognostication perspective as well as insurance cost.

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