REVIEW

Percutaneous nephrolithotomy monotherapy for staghorn: paradigm shift for 'staghorn morphometry' based clinical classification

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Purpose of review

The term staghorn is plagued by an unclear morphology There is a need for clinical definition of staghorn that could classify patients in either of the two ends of the treatment spectrum for percutaneous nephrolithotomy (PCNL) monotherapy.

Recent findings

Staghorn morphometry was identified as a prognostic tool to predict tract(s) and stage(s) for PCNL monotherapy for staghorn. Staghorn morphometry requires a three-dimensional computed tomography urography assessment by volume rendering software. As per the detailed stone morphometric analysis, a clinically important definition of staghorn calculi based on the high odds probability of multiple tract(s) and stage(s) is proposed. Type 1 staghorn has a total stone volume of less than 5000 mm^3 with less than 5% unfavorable calyx stone percentile volume, whereas type 3 staghorn has a total stone volume of more than 20,000 mm^3 with greater than 10% unfavorable calyx stone percentile volume. Type 2 staghorn is in-between type 1 and 2. Based on the prediction model for achieving clearance by PCNL monotherapy, type 1 staghorn would require single tract and stage, type 2 single tract–single/multiple stages or multiple tract-single stage and type 3 multiple tract and stage.

Summary

Staghorn morphometry based clinical classification of staghorn is an exciting concept for PCNL monotherapy. Further prospective studies are required to validate the staghorn morphometry based clinical variate of staghorns. The prospective studies should take into account clinical presentations, operative complications, tract and stage required, postoperative complications, hospital stay, operative cost and stone-free status.

Keywords

computed tomography urography, percutaneous nephrolithotomy monotherapy, stage, staghorn, staghorn morphometry, tract

INTRODUCTION

Percutaneous nephrolithotomy (PCNL), shock wave lithotripsy (SWL) monotherapy and open surgery are the potential treatment alternatives for patients with staghorn stones. SWL monotherapy should not be used for most patients and may be considered only in patients with small volume staghorn stones with normal collecting system. Improved PCNL techniques with use of flexible nephroscopy and multiple tract allow PCNL to have highest achievable stone-free rates [1,2].

The term staghorn is plagued by an unclear morphology [1]. Consequently, the term 'staghorn' is often used to define any branched stone occupying more than one portion of the collecting system. Furthermore, the designation of 'partial' or 'complete' staghorn calculus also does not imply to any specific criteria of volume [1].

PERCUTANEOUS NEPHROLITHOTOMY ERA: CLINICAL CLASSIFICATION REQUIRED

There is a need for clinical definition of staghorn that could classify patients in either of the two ends

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KEY POINTS

- Staghorn morphometry adds to a new dimension to clinically define the staghorn into a more operatively relevant classification important for planning percutaneous nephrolithotomy monotherapy.
- Type 1 staghorn would require single tract and stage; type 2 single tract–single/multiple stages or multiple tract-single stage and type 3 multiple tract and stage.
- Further prospective studies are required to validate the staghorn morphometry based clinical variate of staghorns.
- This will ensure critical comparison between the groups across continents and will usher a new treatment paradigm shift in managing staghorns.

of the treatment spectrum for PCNL monotherapy. At the one end, is the so-called easy staghorn that could clear in a single tract and stage, whereas at the other end, the difficult staghorn requiring multiple tract and stage. As one ascends the treatment spectrum, the complications, recurrence and patient costs increase and at the same time the stone-free and hospital turnover rates decrease (Fig. 1) . It is also anticipated that insurance cover may vary at different scales of the treatment spectrum. From the surgeon's perspective, to know on what scale of the treatment spectrum does the patient lie, is also important. The 'best' treatment option for a particular condition in terms of healthcare economics is the one that achieves the desired outcome at the lowest cost [3]. There should be an optimum balance between monetary cost and treatment efficiency.

ROLE OF COMPUTED TOMOGRAPHY UROGRAPHY

Stone-free rates following PCNL monotherapy or sandwich therapy have been found to be highly dependent on the stone burden [4]. Several groups have proposed classification schemes to better define staghorn calculi taking into account size, morphology and composition of the stones. More recently, the use of a computed tomography (CT) imaging with three-dimensional reconstruction or of a coronal reconstruction of axial CT images was reported to obtain an accurate stone volume calculation. The difficulty in accurately assessing stone burden explains the wide range of reported stone-free rates for SWL monotherapy from 22 to 85% [5]. Mishra *et al.* [6••] recently hypothesized that the most important parameter affecting surgical success was the term 'staghorn morphomerty'. This hypothesis was based on the assumption that some partial staghorn required multiple tracts, whereas some complete staghorn required single tract. They opined that a collecting system with favorable anatomy might permit single tract easy nephroscopy navigation into each calyx [7]. On the

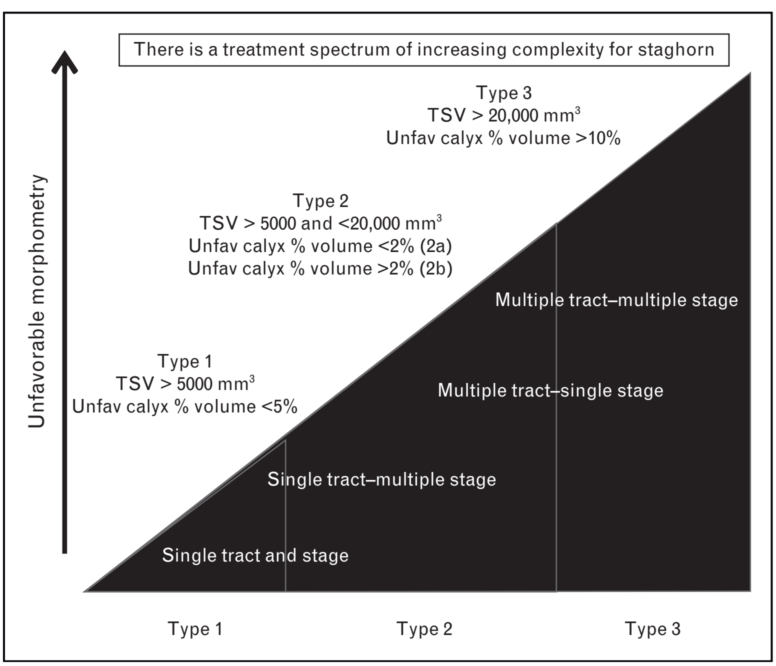


FIGURE 1. Proposed clinical classification of staghorn in percutaneous nephrolithotomy (PCNL) monotherapy era. Type 1 staghorn would require single tract and stage; type 2 single tract-single/multiple stages or multiple tract-single stage and type 3 multiple tract and stage.

contrary, a compact collecting system with narrow infundibuli may not permit easy nephroscopy through a single tract. A friendly collecting system with a large stone volume and a corresponding large stone volume in an unfavorable calyx requires a separate tract for clearing the unfavorable calyceal stone bulk. Staghorn morphometry was defined as the staghorn stone volumetric burden distribution in the collecting system assessed by CT urography (CTU) and its three-dimensional volume rendering. This adds to a new dimension to clinically define the staghorn into a more operatively relevant classification important for planning PCNL monotherapy.

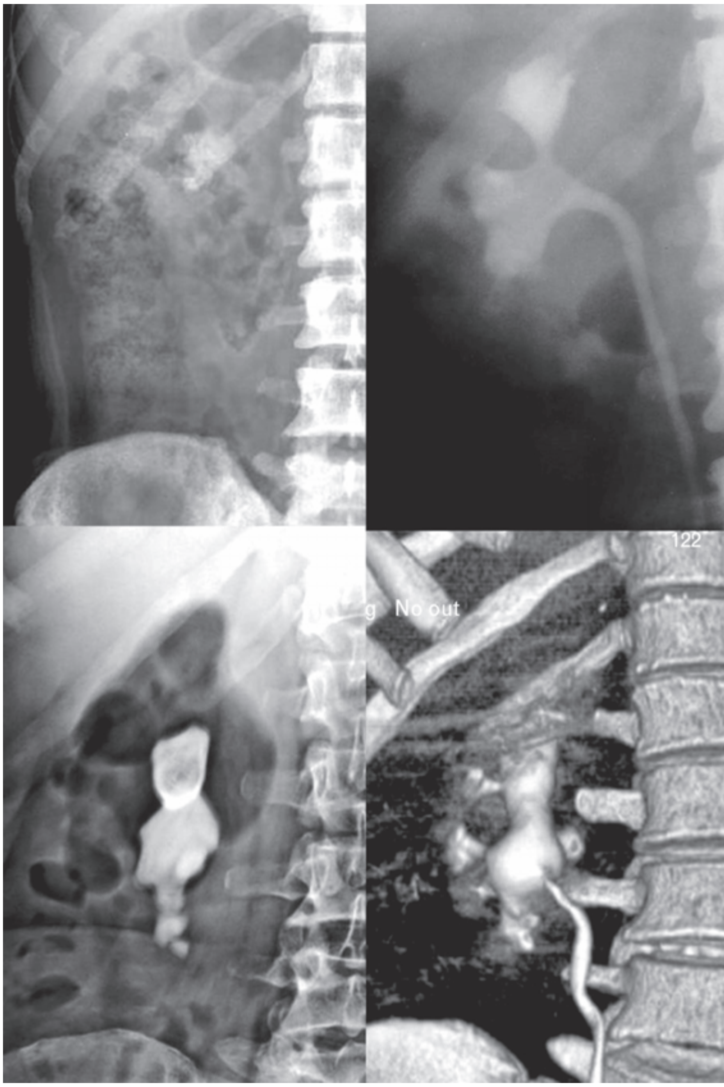
CLINICAL RELEVANCE OF TRACT(S) AND STAGE(S)

The concept of tract(s) and stage(s) is clinically relevant for planning PCNL monotherapy for staghorn calculus. Attention to accurately tract selection and placement as well as possession of the full array of endourologic equipment are essential to achieving an excellent outcome [8]. For staghorn calculus, single tract renders less than optimum access for clearing all the calyceal extensions [8–11]. Therefore, it may be advocated for small burden staghorn stones [12]. It has lesser morbidity but is limited by suboptimal stone-free rates [8]. Multiple tracts are often required for large burden staghorn [1–15]. The stone clearance rates have been demonstrated to be superior to single-tract access [9]. Although the amount of renal functional loss [16] is similar in multiple versus single tract, it is significantly associated with more hemorrhagic complications [11,14–17]. Staging the procedure reduces the short-term morbidity, specifically fluid absorption and blood loss [17,18]. The main advantage of staging is to increase the stone-free status by doing second-look nephroscopy [7,10,13,19,20]. The disadvantages of PCNL monotherapy done in multiple stages are an increased hospital stay, patient costs and decreased hospital turnover. Therefore, it is pertinent to reduce the tract(s) and stage(s) as and when required while maintaining highest achievable stone-free rate.

Staghorn morphometry was identified as a prognostic tool to predict tract(s) and stage(s) for PCNL monotherapy for staghorn. Considering the well supported accuracy and relative ease of use of noncontrast CT, it has become a logical choice for the urologist to use the technique as a diagnostic tool for stone disease. The future of imaging for intervention and surveillance of stone disease lies in the continued progress of CT [21]. Computer image analysis is accurate, rapid and easy to perform. Bandi *et al.* [22] studied the volumetric data of nonstaghorn simple renal stones and found that stone volume is an optimal predictor of stone-free status after SWL. Lam *et al.* [23] were the first to study stone burden and advocated the use of stone surface area by three-dimensional CT for more accurate reporting of treatment results.

CLINICAL CLASSIFICATION OF STAGHORNS

Staghorn morphometry requires a three-dimensional CTU. The voxel size of the three-dimensional image is provided to the software program. As per the detailed stone morphometric analysis, Mishra *et al.* [6■■] introduced a clinically important definition of staghorn calculi based on the high odds probability of multiple tract(s) and stage(s) (Fig. 1). Type 1 staghorn (Fig. 2, top) has a total stone volume (TSV) of less than 5000 mm^3 with less than 5% unfavorable calyx stone percentile volume, whereas type 3 (Fig. 3, bottom) staghorn has a TSV of more than 20 000 mm^3 with greater than 10% unfavorable calyx stone percentile volume. Type 2 (Fig. 2, bottom and Fig. 3, top) staghorn is in-between type 1 and 2. Based on the prediction model for achieving clearance by PCNL monotherapy, type 1 staghorn would require single tract and stage, type 2 single tract-single/multiple stages or multiple tract-single stage and type 3 multiple tract and stage. Most patients with type 1 are likely to have partial staghorn. Even with the higher unfavorable calyx stone locations, most would clear easily in single stage with or without the use of flexible nephroscopy. Type 2 staghorn PCNL monotherapy may be individualized as per the operating team philosophy. Flexible nephroscopy may aid in single tract clearance depending upon the unfavorable calyx stone volume. A smaller volume (<2%, type 2a; Fig. 2, bottom) may result in single stage while a larger volume (>2%, type 2b; Fig. 3, top) in multiple stages. If an aggressive multiple-tract approach is utilized to avoid flexible instrumentation, similar burden stone can still be cleared in single stage. Flexible nephroscopy for a large unfavorable calyx stone volume may prolong the PCNL monotherapy by increasing stage primarily by increasing the operative time. Type 3 staghorn would ultimately test the patience and the skill of the surgeon. Most would result in multiple tracts and stages. Flexible nephroscopy has a limited role in such a variety of staghorn. During counseling patients with type 3 category, the clinician and patient should be aware of the cost implications, hospital stay and marginally reduced stone-free state. These are also those patients in whom clearance may be suboptimal



Total stone volume	2959
Entry calyx stone volume	428
Pelvic stone volume	2188
Favorable calyx stone volume	343
Unfavorable calyx stone volume	0
Pelvic stone percentile volume	73.94%
Pelvic and entry calyx stone percentile volume	85.53%
Favorable calyx stone percentile volume	14.47%
Unfavorable calyx stone percentile volume	0
Staghorn classification	1

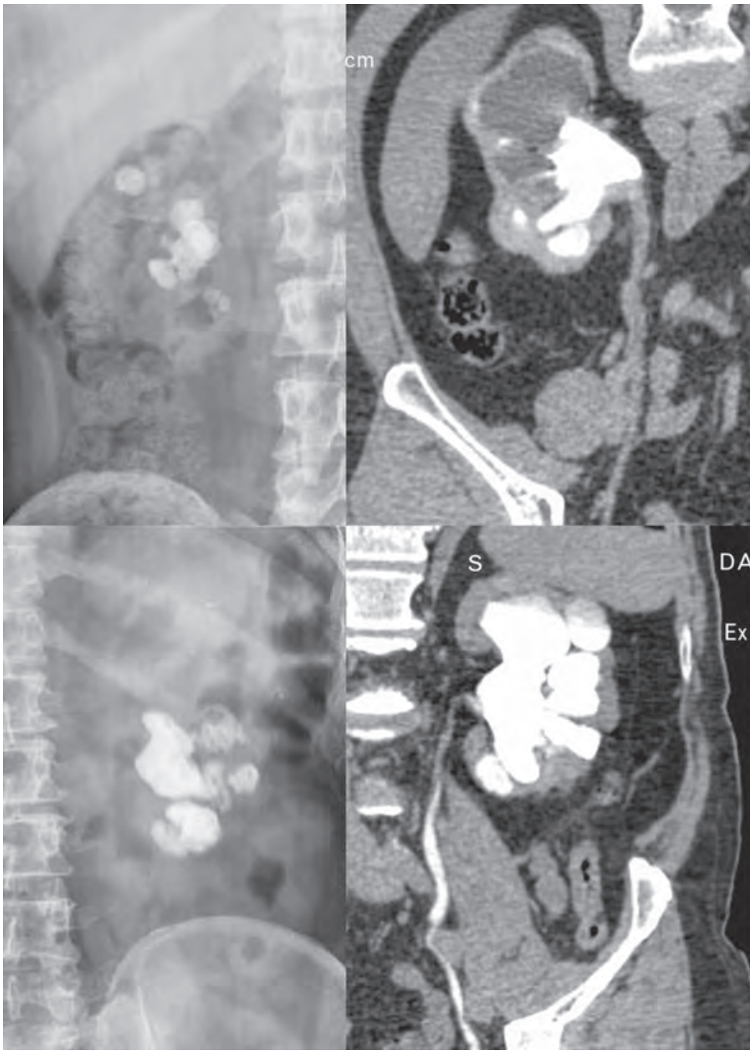
Total stone volume	18 439
Entry calyx stone volume	7737
Pelvic stone volume	9266
Favorable calyx stone volume	1436
Unfavorable calyx stone volume	0
Pelvic stone percentile volume	50.03%
Pelvic and entry calyx stone percentile volume	94.12%
Favorable calyx stone percentile volume	5.88%
Unfavorable calyx stone percentile volume	0
Staghorn classification	2A

FIGURE 2. Type 1 staghorn (top 3 figures) has a total stone volume (TSV) of less than 5000 mm^3 with less than 5% unfavorable calyx stone percentile volume. Type 2a staghorn: for stones more than 5000 mm^3 and less than 20 000 mm^3, an unfavorable calyx stone percentile volume of less than 2% (bottom 3 figures) could be cleared with single tract and stage.

leading to residual fragments causing recurrent stone formation.

HOW TO INCREASE APPLICABILITY?

Staghorn morphometry found two parameters of relevance in predicting tract and stage. These were TSV and unfavorable calyx stone percentile volume. To be applicable in other places, the calculation should be made easy unlike in the study by Mishra *et al.* [6▪▪], wherein the calculation was too exhaustive and was made by the researcher himself. TSV in mm^3 may not be difficult to be measured by the radiologist. There are many stone volumes rendering software that can calculate stone volume. The voxel image size has to be proper for the calculation to be accurate. The issue of unfavorable calyx is complex. The researcher decided the entry calyx for planning staghorn based on the main tract concept proposed by Ganpule *et al.* [9]. Specifically, it consisted of the optimum calyx chosen, keeping in view the relations of the ribs and adjoining viscera that could clear the maximum stone burden. The stone volume amenable for clearance through the entry calyx is the volume present in it, pelvis and any of the favorable calyces. The rest of the calyceal stone distribution is classified as being in either favorable calyx or unfavorable calyx. The assessment of favorable and unfavorable calyx is done on CT intravenous urography plates or maximum



Total stone volume	11138
Entry calyx stone volume	30
Pelvic stone volume	10039
Favorable calyx stone volume	0
Unfavorable calyx stone volume	1069
Pelvic stone percentile volume	90.13
Pelvic and entry calyx stone percentile volume	90.40
Favorable calyx stone percentile volume	0
Unfavorable calyx stone percentile volume	9.60
Staghorn classification	2B

Total stone volume	32704
Entry calyx stone volume	2529
Pelvic stone volume	10941
Favorable calyx stone volume	13927
Unfavorable calyx stone volume	5307
Pelvic stone percentile volume	33.45%
Pelvic and entry calyx stone percentile volume	41.18%
Favorable calyx stone percentile volume	40.25%
Unfavorable calyx stone percentile volume	16.22%
Staghorn classification	3

FIGURE 3. Type 2b staghorn: total stone volume (TSV) more than 5000 mm^3 and less than 20 000 mm^3, an unfavorable calyx stone percentile volume of more than 2% (top 3 figures) could be cleared with single/multiple tract. Clearing with singe tract may increase the stage in view of more operating time. The larger stone bulk could require multiple tract that may achieve clearance in a single stage. Type 3 staghorn (bottom 3 figures) has a TSV more than 20 000 mm^3 and unfavorable calyx stone percentile volume of more than 10%. It would require multiple tract and stage.

intensity projection images of noncontrast CT. A favorable calyx is defined as a calyx containing stone that is at obtuse angle to the entry calyx and has an infundibulum more than 8 mm. An unfavorable calyx, on the contrary, has an acute angle and infundibular width of less than 8 mm. The percentage of the stone in unfavorable calyx to the TSV is defined as unfavorable calyx stone percentile volume. This may be a grey area wherein different urologists may have a different perception of the calyces. In a broader perspective, there may be an overlap in the entry calyx, but still the unfavorable calyx can be calculated based on the entry calyx planned. The authors also agree to the fact that a deemed unfavorable calyx may change its configuration once the system is dilated filling with retrograde saline. The unique feature of this classification was that it was made with an objective to preoperatively define the staghorn. It would still be relevant, if a clinical variate of staghorn behaved accordingly in prospective studies. A radiologist cannot make the issue of finding out the percentile volume in unfavorable calyx. Therefore, it is left to the urologist to make an assessment. At the moment, in the absence of widespread volume calculating softwares, it is left to the discretion of the urologist, who can make a rough estimation as to the percentage of stone in the unfavorable calyx.

CONCLUSION

Staghorn morphometry based clinical classification of staghorn is an exciting concept for PCNL monotherapy. Further prospective studies are required to validate the staghorn morphometry based clinical variate of staghorns. The prospective studies should take into account clinical presentations, operative complications, tract and stage required, postoperative complications, hospital stay, operative cost and stone-free status. If found valid, a more rigorous attempt to define staghorn is required globally. This will ensure major comparison between the groups across continents and will usher a new treatment paradigm shift in managing staghorns.

Acknowledgements

None.

Conflicts of interest

K.P. and V. are the computer experts and were actively involved in exhaustive volumetric assessment for the parent study.

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

■ of special interest

■■ of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 165).

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