Correlation of the S.T.O.N.E. Score with surgical outcomes of Percutaneous Nephrolithotomy in an academic hospital

Correlação da Pontuação S.T.O.N.E. com os resultados cirúrgicos da Nefrolitotomia Percutânea num hospital universitário

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ABSTRACT

Introduction: Percutaneous nephrolithotomy (PCNL) is the best option for the treatment of patients with large kidney stones. The S.T.O.N.E score system takes measurements of objective parameters from preoperative tomography into account, and aims to provide the surgical team with a preliminary assessment of the complexity of each case, allowing the surgeon to more accurately predict the final results of PCNL. However, adequate studies that confirm its results and effectiveness are so far lacking. Hence, our objective was to correlate the S.T.O.N.E. nephrolithometry scoring system to the actual surgical outcomes achieved in a cohort of patients undergoing PCNL, in an academic hospital. Patients and Methods: We retrospectively reviewed the charts of 277 consecutive patients who underwent percutaneous nephrolithotomy from 2014 to 2019 in our academic hospital. Only those patients with all radiological images available for review were included in this cohort. The S.T.O.N.E nephrolithotomy score was calculated based on the preoperative computed tomography (CT) scans and then correlated with stone-free rate (SFR), postoperative complications (PC) in accordance with the Clavien-Dindo system, length of hospital stay (LHS) and operative time (OT). Results: A total of 193 PCNLs were included. Mean age was 50.7 years (25-82); 56% of patients were female, and the right side was slightly more affected (51.8%). The mean S.T.O.N.E. score for the entire cohort was 8.45, but for patients with residual stone after PCNL, this figure was actually higher, at 9.4 (p <0.01). The overall SFR after an initial procedure was 51.8%, with logistic regression analysis showing that the number of involved calyces and stone size were significantly correlated with stone-free status (p<0.001). Mean LHS (3.47 days) and OT (117.9 mins) also significantly correlated with S.T.O.N.E. score (p<0.001). The overall complication rate after the primary procedure was 16.6% (of which 68.8% were grade I or II), and there were no complications Grades IVb or V. There was no significant correlation between complications-and the S.T.O.N.E. score (p=0.37). Conclusion: The S.T.O.N.E nephrolithometry score was significantly associated with stone free status, operative time and length of hospital stay, although not with occurrence of complications.
Keywords: S.T.O.N.E, Percutaneous Nephrolithotomy, complications, lithiasis.

RESUMO
Introdução: A nefrolitotomia percutânea (NLPC) é a melhor opção para o tratamento de pacientes com cálculos renais volumosos. O sistema de pontuação S.T.O.N.E. tem em conta as medições de parâmetros objectivos da tomografia pré-operatória e visa fornecer à equipa cirúrgica uma avaliação preliminar da complexidade de cada caso, permitindo ao cirurgião prever com maior precisão os resultados finais da NLPC. No entanto, até ao momento, não existem estudos adequados que confirmem os seus resultados e eficácia. Assim, o nosso objetivo foi correlacionar o sistema de pontuação de nefrolitometria S.T.O.N.E. com os resultados cirúrgicos reais obtidos numa coorte de doentes submetidos a NLPC, num hospital académico. Pacientes e Métodos: Revisamos retrospectivamente os prontuários de 277 pacientes consecutivos que foram submetidos à nefrolitotomia percutânea de 2014 a 2019 em nosso hospital académico. Apenas os pacientes com todas as imagens radiológicas disponíveis para revisão foram incluídos nesta coorte. O escore de nefrolitotomia S.T.O.N.E foi calculado com base nas tomografias computadorizadas (TC) pré-operatórias e depois correlacionado com a taxa livre de cálculos (SFR), complicações pós-operatórias (CP) de acordo com o sistema Clavien-Dindo, tempo de internação hospitalar (LHS) e tempo operatório (OT). Resultados: Foram incluídos 193 PCNLs. A idade média foi de 50,7 anos (25-82), 56% dos doentes eram do sexo feminino e o lado direito foi ligeiramente mais afetado (51,8%). A pontuação média do S.T.O.N.E. para toda a coorte foi de 8,45, mas para os pacientes com cálculos residuais após a PCNL, este valor foi efetivamente mais elevado, 9,4 (p <0,01). A SFR global após um procedimento inicial foi de 51,8%, com a análise de regressão logística a mostrar que o número de cálculos envolvidos e o tamanho do cálculo estavam significativamente correlacionados com o estado livre de cálculos (p<0,001). A média de LHS (3,47 dias) e OT (117,9 minutos) também se correlacionaram significativamente com a pontuação S.T.O.N.E. (p<0,001). A taxa global de complicações após o procedimento primário foi de 16,6% (das quais 68,8% foram de grau I ou II), não tendo havido complicações de grau IVb ou V. Não houve correlação significativa entre as complicações e o score S.T.O.N.E. (p=0,37). Conclusão: O score nefrolitométrico S.T.O.N.E. associou-se significativamente ao stone free status, tempo operatório e tempo de internamento, mas não à ocorrência de complicações.


1 INTRODUCTION
Urinary lithiasis (UL) is one of the most frequent urological diseases, resulting in significant cost to the public health system, and compromising affected individuals’ quality of life¹. Its global prevalence has increased over the years between 2 to 20%, depending on the geographic region. In the United States, nearly 7% of women and 10.3% of men are affected by UL², with annual cost amounting to billions of dollars³.

Although most small-diameter stones are eliminated spontaneously or are amenable to treatment with extracorporeal shock wave lithotripsy (ESWL),
approximately 10% to 20% of patients with UL will require some sort of surgical intervention\textsuperscript{4}. In these cases, preoperative imaging is essential, not only to establish the diagnosis, but also to determine the best technique and adequate surgical planning. Non-contrast computed tomography (CT) is considered gold standard for nephrolithiasis \textsuperscript{5}, since it can clearly determine the complexity of the stone, its size, density, and distribution within the collecting system. Furthermore, it is able to outline the anatomy of the pelvicalyceal system and its internal ramifications within the kidneys, as well as their topographic relations with adjacent organs\textsuperscript{6,7}. Nowadays, it is unthinkable of surgically approaching a case of UL without a previous abdominal CT.

Ureteroscopy and percutaneous nephrolithotomy (PCNL) are the most used modalities in the treatment of UL, where beforehand knowing the characteristics of the stone (such as size, constitution, extent of calyceal involvement, pelvic anatomy, patient characteristics, etc.), will help in choosing the best access route, with significant impact on the final results\textsuperscript{8,9,10}. Despite the relatively widespread use of PCNL for the treatment of kidney stones, it is still considered a highly complex procedure, and can lead to several complications, some of them quite serious.

In the last decade, several attempts were made aiming the development of an objective system that could simply and accurately classify the diverse and oftentimes complex distribution of stones in the upper urinary tract. This tool would standardize the classification and predict the outcome of PCNL, its complications, and stone-free rates\textsuperscript{11,12}. As such, several authors have proposed the use of different scores to try to predict the outcome of PCNL based on data obtained from imaging or other preoperative parameters\textsuperscript{13,14,14,15,16}. Among these, the S.T.O.N.E score stands out as one of the most popular and promising. This tool is based on a literature review that aimed to identify reproducible, clinically relevant variables that could impact outcomes after PCNL\textsuperscript{15}. Briefly, the evaluated parameters in this score take into account the size of the calculus, pathway length during NLPC, presence of obstruction, number of calyces affected and stone density. All these parameters can be easily obtained from the preoperative CT.

However, a limitation of the S.T.O.N.E score is that it has only been validated in a small cohort. This fact may restrict its applicability to a broader patient population. In addition, the low incidence of treatment failure in the initial cohort may have presented an element of bias for the development and validation of this tool, making it necessary to carry out a larger study to confirm its results. Furthermore, according to some authors, its
reliability would benefit from a greater refinement of the methods used to score each of the involved factors, by taking into account their individual predictive power\textsuperscript{17}.

In view of these facts, the need for further studies that contribute to the consolidation of this important preoperative tool is evident. The application of the S.T.O.N.E score in our population, in addition to validating this tool in our hospital, allows for a better characterization of cases treated at a reference center. Its use can facilitate the hospital planning and proper patient guidance and counseling, predicting with relative safety stone-free rates and success of the treatment.

2 PATIENTS AND METHODS

This is a retrospective, cross-sectional, observational study that analyzed data from 277 consecutive patients who underwent percutaneous nephrolithotomy (PCNL) from 2014 to 2019 in Hospital das Clinicas da Faculdade de Medicina - UNESP. All procedures were performed in the same hospital by a urologist with experience in endourology and a urology resident in-training. Patients strictly followed all clinical, ethical and surgical protocols of this Institution. This study was approved by the local Research Ethics Committee (CAAE: 49313321.0.0000.5411; protocol number: 4.898.390).

We excluded patients who had not been preoperatively assessed with computed tomography (CT), were less than 18 years old, had prior history of surgery on the ipsilateral kidney, and patients with incomplete data, as well as lack of postoperative control imaging to assess residual lithiasis status.

The S.T.O.N.E score was calculated based on the preoperative CT scans, according to Okhunov et al\textsuperscript{15}, and subsequently correlated with stone-free status; postoperative complications by Clavien-Dindo system\textsuperscript{18}; length of hospital stays (LOS) and operative time (OT).

All statistical analyses were done using R, version 2.12.2 (R Foundation for Statistical Computing, Vienna, Austria) and performed using a linear Model ANOVA, Pearson’s Chi-squared test, Kruskal-Wallis rank sum test, and linear regression analysis. In all tests, p < 0.05 was considered to indicate significant differences.
3 RESULTS

From 2014 to 2019, 277 patients underwent PCNL for the treatment of kidney stones at our hospital, of whom 193 met the inclusion criteria and were considered in the final analysis.

Mean age at the time of surgery was 50.7 years (SD=12.18 years). Women (56%) and the right kidney were the most affected (51.8%), p< 0.05.

Demographic data and stone characteristics assessed by the S.T.O.N.E score were compared between patients with and without residual stones (stone free) and are shown in Table 1.

The stone-free rate (SFR), i.e, the percentage of patients without residual stones or smaller than 4 millimeters, was 51.8% (100 patients). Mean S.T.O.N.E score was 9.4 for these cases, versus 8.45 for the entire cohort (p<0.001). Figure 1 shows the number of cases for each S.T.O.N.E score and correlates with SFR, demonstrating that more complex cases (with higher scores) had lower SFR.

Considering the parameters evaluated in the preoperative CT, our analysis showed that the number of calyxes involved and stone size correlated significantly with stone-free rate (p<0.001). Likewise, length of stay (mean 3.47 days) and operative time (mean 117.9 minutes) also significantly correlated with stone-free status (p<0.001).

In our cohort, moderate/severe hydronephrosis was observed in 51% of patients deemed stone-free, and in 61.3% of patients with residual stone; however, this difference was not statistically significant (p=0.15). Furthermore, skin-stone distance and stone density were not significantly associated with presence of residual stones (p=0.225 and 0.874, respectively).

The overall rate of complications after the primary procedure was 16.6%, being observed in 32 patients. According to the Clavien-Dindo classification\textsuperscript{18}, postoperative events included grade I complications (10 cases, 31.3%); Grade II (12 cases, 37.5%); Grade IIIa (5 cases, 15.6%); Grade IIIb (4 cases, 12.5%) and Grade IVa (1 case, 3.1%). No Grade IVb or V complications were observed. The low number of individuals with complications precluded a detailed analysis of specific types of complications. Statistical analysis showed that there was no significant correlation between complications (Clavien-Dindo system) and the score obtained by S.T.O.N.E (p = 0.37).
4 DISCUSSION

Large kidney stones represent a relevant problem in most countries and, when not properly treated, can lead to significant morbidity\textsuperscript{19}. Since the first PCNL was performed in 1976, this minimally invasive method has been replacing open surgery for the treatment of complex renal lithiasis. In general, PCNL is indicated in stones greater than two centimeters and/or staghorn calculi, cystine calculi, patients with kidneys presenting stenoses and/or diverticula, or failure after extracorporeal lithotripsy. Uncorrected coagulopathy represents a contraindication to percutaneous renal access\textsuperscript{20}.

Although general guidelines exist for the treatment of large stones, the urological community remains without a standardized and widely accepted system for classifying upper urinary tract stones. To date, despite several previous attempts, none of the proposed systems have been universally adopted due to their limited clinical utility, complicated use, and lack of validation\textsuperscript{15}.

In 2013, the Smith Institute for Urology introduced a quantitative scoring system, the S.T.O.N.E. This score uses easy-to-calculate parameters derived from non-contrast CT images and does not require specific software for its calculation\textsuperscript{15}. Therefore, we chose to use it in our NLPC cases, in order to obtain a correlation between this score and the postoperative results in this population, given it had already been validated in other studies.

The average age was 50.7 years in our cohort, mostly women. Although the literature suggests a peak incidence of urolithiasis in young adults around 33 years old (30.2 for women and 35.4 for men), in our study the age considered for analysis was at the time of definitive treatment (PCNL) and not the initial manifestation of the symptoms, as considered by most authors\textsuperscript{21}. Traditionally, urolithiasis predominantly affected men, but the classic male:female (M:F) ratio of 3:1 has shown considerable decline in recent decades\textsuperscript{22}. Studies around the world, including the Brazilian population, have revealed a growing predominance of lithiasis in females with an M:F ratio of 0.8:1\textsuperscript{21,23}. Although our results show that stones were slightly more prevalent in the right kidney, there is no consensus on laterality. In the literature, it is not uncommon to find papers suggesting that the left side is more affected in men, while in women, the right side would be more frequently involved\textsuperscript{24}. Some authors even postulated that there would be an association between the laterality of the stone and the side on which the patient usually sleeps\textsuperscript{25}.

To deepen our investigation, we subdivided the studied population into two large groups: stone-free and those who still had residual lithiasis after PCNL. The general
characteristics of the two populations were comparable in age, sex and laterality. However, as expected, the incidence of residual lithiasis was higher among patients with larger stone burden. According to previous studies, SFR after PCNL monotherapy for kidney stones ranges from 49% to 78%. In our cohort, the SFR after one single surgical approach was 51.8%. Although within the limits in the literature, this number is well below the 80% described by Okhunov. It is noteworthy that our results may have been influenced by the large mean stone mass in our patients (1,171.02 ± 835.9 mm²) and by the inherent characteristics of a teaching hospital. As previously described, PCNLs at our center are performed by residents who have not yet reached their learning curve, albeit still being considered a highly complex surgery.

Considering the relationship between S.T.O.N.E score and SFR, Okhunov et al demonstrated that stone free patients had a significantly lower score than those with residual calculus (6.8 vs. 9.7, respectively); which is in line with our results (7.73 vs. 9.24, respectively).

In our study, logistic regression analysis showed that only two of the five variables in the S.T.O.N.E. nephrolithometry were significant predictors of stone-free state: number of calyces involved and stone size (p<0.001). Our results corroborate the findings of Okhunov, who observed that mean stone size in patients without stones and those with residual stones was 465 and 1.064 mm², respectively (p=0.01). According to the same authors, size of the stone and number of involved calyces were the most robust predictors of SFR, since the potential variables that were associated with a higher risk of residual lithiasis were the increasing number of calyces affected (p<0.0001) and renal pelvis involvement (p<0.007).

Our results showed that patients with higher SFRs had shorter hospital stays and less time in the operating room (with p<0.01 and p<0.001, respectively). These results are justified by the lower complexity of this group which, as previously discussed, had a lower stone burden and a smaller number of calyces involved. As noted by Okhunov et al, higher nephrolithometry scores were associated with greater blood loss and operative time, in addition to longer hospital stay.

In their multivariate regression analysis, Okhunov et al found that only stone size was predictive of the occurrence of postoperative complications. The relatively low incidence of complications (21%) and the sample size (117 cases) were the factors used by the authors to justify the lack of statistical power in detecting a correlation between the score and the complications of the PCNL. Very similarly, the overall rate of
postoperative complications found in our cohort was only 16.6% and no significant correlation was observed with the S.T.O.N.E. score. We believe that the explanations presented by Okhunov and collaborators are plausible and also justify the lack of correlation observed by us.

Among the limitations present in our study, we highlight its retrospective nature and inclusion of data from a single center. Moreover, it was not possible to accurately calculate the blood loss during surgical procedures, as such data were not routinely reported. In addition, the S.T.O.N.E. score was calculated by a single reviewer and agreement between different raters was not performed.

In conclusion, the S.T.O.N.E score was significantly associated with stone-free rates after PCNL, operative time, and hospital stay, but it was not useful for predicting complications. As additional information, this study allowed knowing the characteristics of our center and its results. This data will be used to improve our results in order to offer excellent treatment to our users.
REFERENCES


ANNEX

Table 1. Clinical and demographic data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No stone free (N=93)</th>
<th>Stone Free (N=100)</th>
<th>Total (N=193)</th>
<th>P value</th>
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<tbody>
<tr>
<td>Age</td>
<td>49.75 (12.8)</td>
<td>51.64 (11.5)</td>
<td>50.73 (12.1)</td>
<td><strong>0.283</strong></td>
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<tr>
<td>Sex</td>
<td>0.990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex Female</td>
<td>52 (55.9)</td>
<td>56 (56)</td>
<td>108 (56)</td>
<td></td>
</tr>
<tr>
<td>Sex Male</td>
<td>41 (44.1)</td>
<td>44 (44)</td>
<td>85 (44)</td>
<td></td>
</tr>
<tr>
<td>Side Right</td>
<td>47 (50.5)</td>
<td>53 (53)</td>
<td>100 (51.8)</td>
<td></td>
</tr>
<tr>
<td>Side Left</td>
<td>46 (49.5)</td>
<td>47 (47)</td>
<td>93 (48.2)</td>
<td></td>
</tr>
<tr>
<td>Size (mm²)</td>
<td>1171.02 (835.96)</td>
<td>591.72 (461.45)</td>
<td>870.87 (727.24)</td>
<td>&lt; 0.001</td>
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<tr>
<td>Skin to stone distance (mm)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>&lt;100</td>
<td>50 (53.8)</td>
<td>45 (45)</td>
<td>95 (49.2)</td>
<td></td>
</tr>
<tr>
<td>&gt;100</td>
<td>43 (46.2)</td>
<td>55 (55)</td>
<td>98 (50.8)</td>
<td></td>
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<tr>
<td>Obstruction/ Hydronephrosis</td>
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<td></td>
<td></td>
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<tr>
<td>None/mild</td>
<td>36 (38.7)</td>
<td>49 (49)</td>
<td>85 (44)</td>
<td></td>
</tr>
<tr>
<td>Moderate/Severe</td>
<td>57 (61.3)</td>
<td>51 (51)</td>
<td>108 (56)</td>
<td></td>
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<tr>
<td>Number of calices</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>39 (41.9)</td>
<td>89 (89)</td>
<td>128 (66.3)</td>
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<tr>
<td>3</td>
<td>37 (39.8)</td>
<td>7 (7)</td>
<td>44 (22.8)</td>
<td></td>
</tr>
<tr>
<td>Staghorn</td>
<td>17 (18.3)</td>
<td>4 (4)</td>
<td>21 (10.9)</td>
<td></td>
</tr>
<tr>
<td>Density (UH)</td>
<td>0.874</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;950</td>
<td>27 (29)</td>
<td>28 (28)</td>
<td>55 (28.5)</td>
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</tr>
<tr>
<td>&gt;950</td>
<td>66 (71)</td>
<td>72 (72)</td>
<td>138 (71.5)</td>
<td></td>
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<tr>
<td>Length hospital stay</td>
<td>3.57 (1.58)</td>
<td>3.37 (1.75)</td>
<td>3.47 (1.67)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Operatory time</td>
<td>129.78 (49.44)</td>
<td>107.03 (35.78)</td>
<td>117.93 (44.25)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Source: Authors
Figure 1: Proportion of patients with and without residual calculus according to S.T.O.N.E score after NLPC.

Source: Authors