Urological Science xxx (2016) 1–4

Contents lists available at ScienceDirect

Urological Science

journal homepage: www.urol-sci.com

Original article

A practical formula to predict the stone-free rate of patients undergoing extracorporeal shock wave lithotripsy

Po-Cheng Chen [a], Yu-Ting Liu [b], Jui-Hsiang Hsieh [b], Chung-Cheng Wang [a, b, *]

[a] Department of Urology, En Chu Kong Hospital, College of Medicine, National Taiwan University, Taipei, Taiwan
[b] Department of Biomedical Engineering, Chung Yuan Christian University, Chung-Li, Taiwan

ARTICLE INFO

Article history:
Received 14 April 2016
Received in revised form
2 May 2016
Accepted 10 May 2016
Available online xxx

Keywords:
urolithiasis
shock wave lithotripsy
predictive formula

ABSTRACT

Objectives: We studied patients who underwent extracorporeal shock wave lithotripsy (SWL) to investigate the factors influencing the outcome, and built a logistic regression model to estimate the stone-free rate (SFR) after SWL.
Material and methods: From January 2013 to December 2013, we retrospectively reviewed the clinical status of 641 patients with a solitary urinary calculus who underwent SWL in our hospital. Univariate logistic regression was used to identify the factors leading to a high SFR, and significant factors were further analyzed by multivariate logistic regression. After the optimal model had been developed, we placed it on the website so others could calculate the SFR at their institutions.
Results: The overall SFR for all patients, patients with ureteral stones, and patients with renal stones were 54.8%, 67.8%, and 46.7%, respectively. Multivariate logistic regression showed that body mass index (BMI), stone length, stone width, and stone location were the independent factors that affected the overall successful rate. Stone length was the only significant factor to predict SFR for ureteral stones. BMI, stone length, and stone width were significant SFR predictors for renal stones. A logistic regression model was designed to estimate SFR, which has a sensitivity of 77.8% and specificity of 75.5%.
Conclusion: BMI, stone length, stone width, and kidney and ureteral stones were all prognostic factors influencing the outcome of SWL. We built a logistic regression formula to predict the SFR, which helps urologists to select patients for SWL.

1. Introduction

Urolithiasis is one of the most prevalent diseases in patients who visit the urology department. Extracorporeal shock wave lithotripsy (SWL) is a relatively noninvasive procedure used to manage symptomatic urinary stone disease.[1] However, treatment failure sometimes occurs, and further treatment such as ureteroscopic lithotripsy (URSL), or percutaneous nephrolithotomy is required. Identifying the stones that are less likely to respond well to SWL is important so that we may prevent wasting resources. We can prevent unnecessary procedures and provide better choices for stone management as well by assessing whether the patient is suitable for SWL.

Several studies have reported various factors to predict stone-free rate (SFR) after SWL.[2–5] The important factors previously mentioned are stone size, stone location, stone composition, and patient habits.[1] However, an easy formula to predict SFR after SWL for Taiwanese patients is not available. Thus, we investigated patients with a solitary ureteral or kidney stone who underwent SWL in our hospital. We analyzed the prognostic factors that influenced SFR and built a logistic regression model to predict the possibility of treatment success.

2. Material and methods

The Institutional Review Board and Ethics Committee approved this study (Identifier ECKIRB1051006) and waived the informed consent requirement. From January 2013 to December 2013, we enrolled 778 consecutive patients who underwent SWL for urolithiasis. All patients were treated with the same lithotripter (Dornier; DoLiS, Munich, Germany). The energy levels started with 10% intensity and gradually increased to a maximal 70% intensity

* Corresponding author. Department of Urology, En Chu Kong Hospital, 399, Fuxing Road, Sanxia District, New Taipei City 23702, Taiwan.
E-mail address: ericwcc@ms27.hinet.net (C.-C. Wang).

http://dx.doi.org/10.1016/j.urols.2016.05.004

with 60 pulses/min. The number of shockwave for kidney and ureter was about 3000–3200 and 3000–3500, respectively. The inclusion criterion was a solitary kidney stone or a solitary ureteral stone. We excluded patients who failed to receive adequate follow up and who had a history of congenital genitourinary tract anomaly, nonfunctioning kidney, ureteral stricture disease, or previous open ureteral surgery. A nonfunctioning kidney was defined as one having paper-thin parenchyma on urinary ultrasound or computed tomography. In addition, we excluded the radiolucent stones from this study. It was our routine procedure to perform ureteroscopic lithotripsy for radiolucent stones. Finally, 641 patients were included in the analysis. We retrospectively reviewed the medical records of these patients and evaluated the possible prognostic factors affecting the SFR after SWL. These factors included age, sex, weight, height, body mass index (BMI), diabetes mellitus, hypertension, gout, creatinine level, stone size, stone position, and pre-SWL double J ureter stenting.

The features of the treated stone were interpreted from plain abdominal radiography performed prior to SWL for all patients. Each radiograph was reviewed by at least one urologist and one radiologist. The follow-up evaluation routinely included a plain abdominal radiograph and kidney ultrasound at 2–4 weeks after SWL. A stone-free result was defined as residual stone fragments of less than 4 mm in length in the vertical axis and width in the horizontal axis or the absence of any stone fragments on the follow-up plain abdominal radiograph. Patients receiving second-time SWL or URSL were classified to the failure group.

Continuous variables were expressed as means and standard deviations; categorical variables were expressed as counts and percentages. The independent *t* test was used for comparison of continuous variables. The Pearson chi-square test or Fisher exact test was applied to compare categorical variables. Univariate logistic regression was used to identify factors having an effect on SFR. Significant factors in the univariate logistic regression were further analyzed by multivariate logistic regression. In all tests, $p < 0.05$ was considered to indicate statistical significance. A logistic regression model was built by analyzing all possible factors. After the model was developed, a formula for predicting SFR was placed on the website (http://ppt.cc/bMLoC). This formula could be used by Taiwanese urologists to predict the SFR before patients undergo SWL. All statistical analyses were performed using SPSS for Windows (Version 20.0, Armonk, NY: IBM Corp.) and R Statistical Software (Version 3.2.1; Glmulti package, GNU project).

3. Results

We divided these 641 patients into two subgroups (ureteral stone and kidney stone). Table 1 shows the patient characteristics and stone features of the two groups. The stone size, length, and width in patients with ureteral stones were significantly smaller than those in patients with kidney stones. The SFRs for all patients, patients with ureteral stone, and patients with renal stone were 54.8%, 67.8%, and 46.7%, respectively.

Table 2 shows the comparison of patients with treatment failure and treatment success. Patients with successful results were significantly younger ($p = 0.004$), had lower BMI ($p = 0.005$), more ureteral stones ($p < 0.001$), more ureteral stents ($p = 0.001$), and shorter stone length ($p < 0.001$) and width ($p < 0.001$) compared with patients with failure of SWL treatment. However, other patient characteristics such as sex, height, serum creatinine level, history of diabetes mellitus, hypertension, or gout were comparable between the two groups.

Table 3 lists the significant factors predicting SFR after extracorporeal SWL, including age ($p = 0.004$), BMI ($p = 0.005$), pre-SWL double J ureteral stenting ($p = 0.002$), stone length ($p < 0.001$), stone width ($p < 0.001$), stone size ($p < 0.001$), and a kidney or ureteral stone ($p < 0.001$). Multivariate logistic regression showed that only BMI, stone length, stone width, and kidney or ureteral stone remained significant factors affecting overall SFR after SWL.

Table 4 shows the multivariate logistic regression for factors associated with SFR in SWL, categorized by ureter and kidney stones. Stone length was the only statistically significant factor to predict SFR after SWL for ureter stones. However, BMI, stone length, and stone width were significant predictors for SFR for renal stones.

In the construction of the model for evaluation, logistic regression was used to analyze the binary outcomes (success and failure) of all possible factors. Among them, we used the Akaike Information Criterion to obtain the final evaluation model (best model) of this search. The benefit threshold value (cutoff) was identified using propensity receiver operating characteristic (ROC) curve analysis. The propensity ROC curves assessed each potential threshold value to optimize the sensitivity and specificity. Finally, we used 10-fold cross-validation to analyze the final model. Then, we developed the formula to predict the SFR of SWL (Figure 1). We used the Youden index to determine the best cutoff point of possibility. If the calculated probability was >0.58, we predicted that the patient would be stone-free. If the calculated possibility was <0.58, we

Table 1
General characteristics of all patients who underwent SWL (comparison of patients with ureteral stone and kidney stone is shown; ureteral stone vs. kidney stone).

	Total	Ureteral stone	Kidney stone	*p*
Patient details				
No.	641	245	396	
Age (y), range, mean ± SD	20–86, 49.9 ± 12.5	20–86, 47.2 ± 12.0	20–85, 51.6 ± 12.5	0.10
Sex, no. of men, %	464, 72.4	188, 76.7	276, 69.7	0.05
DM, *n*, %	22, 3.4	7, 2.9	15, 3.8	0.66
Hypertension, *n*, %	28, 4.4	12, 4.9	16, 4.0	0.69
Gout history, *n*, %	54, 8.4	18, 7.3	36, 9.1	0.56
Weight (kg), range, mean ± SD	39–110, 71.1 ± 14.0	39–110, 72.2 ± 14.6	41–110, 70.3 ± 13.5	0.10
Height (m), range, mean ± SD	1.39–1.88, 1.64 ± 0.09	1.39–1.86, 1.65 ± 0.09	1.43–1.88, 1.63 ± 0.09	0.23
BMI, range, mean ± SD	17.2–42.4, 26.3 ± 4.1	17.2–39.9, 26.5 ± 4.2	17.2–42.4, 26.1 ± 4.1	0.26
Creatinine level, range, mean ± SD	0.1–11.4, 1.2 ± 0.9	0.6–6.5, 1.2 ± 0.5	0.1–11.4, 1.2 ± 1.0	0.67
Stone characteristics				
Left side, *n*, %	350, 54.6	137, 55.9	213, 53.8	0.60
Right side, *n*, %	291, 45.4	108, 44.1	183, 46.2	
Stone length (mm), range, mean ± SD	2–25, 9.4 ± 4.4	4–23, 8.4 ± 3.8	2–25, 10.0 ± 4.7	<0.05
Stone width (mm), range, mean ± SD	2–23, 6.3 ± 2.8	2–14, 5.6 ± 2.1	2–23, 6.7 ± 3.1	<0.05
Stone size (mm^2), range, mean ± SD	6.3–452, 53.4 ± 52.2	6.3–220, 41.8 ± 35.5	6.3–452, 60.7 ± 59.1	<0.05
Pre-SWL double J stent, *n*, %	79, 12.3	10, 4.1	69, 17.4	<0.001
Stone free rate, *n* (%)	351 (54.8)	166 (67.8)	185 (46.7)	<0.001

BMI = body mass index; DM = diabetes mellitus; SD = standard deviation; SWL = extracorporeal shock wave lithotripsy; stone size = π × stone length × stone width.