นิพนธ์ต้นฉบับ

การทำนายผลสำเร็จของการสลายนิ่วชนิดก้อนเดี่ยวในระบบปัสสาวะส่วนบน โดยใช้ Aluminium step wedge

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บทคัดย่อ

วัตถุประสงค์: อธิบายวิธีประเมินความเข้มของนิ่วไต เพื่อเลือกผู้ป่วยที่เหมาะสมต่อการสลายนิ่ว

ผู้ป่วยและวิธีการศึกษา: ศึกษาในผู้ป่วย 55 ราย ที่มีนิ่วเดี่ยวขนาด 0.5-2 เซนติเมตรในกรวยไต หรือท่อไตส่วนบน โดยผู้ป่วยทุกรายได้รับการตรวจทางรังสีด้วยฟิล์มดิจิตอล KUB โดย Fuji computed radiography และใช้ aluminum step wedge เพื่อการเปรียบเทียบความเข้มของนิ่วกับ aluminium step wedge ซึ่งจำแนกเป็น[11] ระดับความเข้ม (mm aluminum equivalent)

ผลการศึกษา: ความเข้มของนิ่วจากฟิล์ม KUB มีค่า 3-26.7 mm aluminum equivalent โดยผู้ป่วย 16 รายที่สลายนิ่วไม่สำเร็จพบว่ามีความเข้มของนิ่วสูงกว่าผู้ป่วยที่สลายนิ่วสำเร็จ (mean ± SD, 16.69 ± 5.46 และ 10.65 ± 5.28 mm aluminum equivalent, p-value < 0.001) การศึกษานี้พบว่ามี positive correlation ของความเข้มนิ่วกับ mm aluminum equivalent

สรุป: การใช้ aluminum step wedge สามารถใช้เป็นค่าเปรียบเทียบที่เชื่อถือได้สำหรับการประเมินความเข้มของนิ่วไต หรือนิ่วท่อไตส่วนบน

คำสำคัญ: สลายนิ่ว นิ่วไต นิ่วท่อไต นิ่วระบบปัสสาวะ

Original article

Aluminium step wedge as a measurement to predict the ESWL success rate for solitary upper urinary tract stone.

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Abstract

Objective: To describe an objective method for evaluating kidney stone radiopacity for use in the selection of cases suitable for extracorporeal shock wave lithotripsy (ESWL).

Materials and Methods: We recruited 55 adult patients with a solitary 0.5-2 cm renal pelvic stone or proximal ureteral stone. All patients underwent routine plain KUB, and an aluminum step wedge was adapted before x-ray exposure. This plain KUB was digitized using Fuji computed radiography. Fuji computed radiography can evaluate the gray level of the stone and each of the 11 steps of the Al step wedge. This allows radiographic stone density to be expressed in mm aluminum equivalent (mm Al Eq).

Results: Stone density on plain KUB was 3 to 26.7 mm aluminum equivalent. The 16 patients in whom ESWL failed were found to have stones of a significantly higher density than the stones found in patients with complete stone fragmentation (mean ± SD 16.69 ± 5.46 vs 10.65 ± 5.28 mm aluminum equivalent, p-value<0.001). There was also a positive correlation between stone radiopacity in mm aluminum equivalent.

Conclusion: The aluminum step wedge with plain KUB provides a good reference for objectively assessing the radiopacity of renal calculi or proximal ureteral calculi.

Key Words: lithotripsy, kidney calculi, ureteral calculi, and urolithiasis

Introduction

There are many treatment options for urinary tract calculi; some can clear more stone with less invasive procedures. The most common procedure is extracorporeal shock wave, called ESWL, which can be used in many locations for treating urinary tract stones, especially renal calculi, but there are still some limitations about size, composition and burden of the stone[1-3]. There have many criteria using to select the patient who success in ESWL treatment include body mass index (BMI), renal function, stone characteristics and stone density[4-6,9,10]. However, no parameter is accurately to predict the ESWL success rate. A computed tomography (CT) scan is used to evaluate a stone density in order to choose the most appropriate stone treated by ESWL[11].

There are many criteria used to select patients for ESWL treatment, including body mass index (BMI), renal function, stone characteristics and stone density[4-6,9,10]. However, no parameter can accurately predict ESWL success rate. A CT scan is used to evaluate stone density in order to choose the most appropriate stones to be treated by ESWL[11].

The CT scan is not popular because of its high cost[13,14]. Thus, we conducted this research, which assesses stone density, by using the aluminium step wedge instead of the CT scan. We believe this technique can be applied to predict ESWL success rates in our patients[7].

Material and Methods

This research is a prospective study performed at Siriraj Hospital between March 2011 and November 2012. We enrolled 55 patients, with no contraindications for ESWL treatment, who had radio-opaque solitary calculi located in either the renal pelvis or proximal ureter, with a size between 0.5 and 2 centimeters at its greatest diameter. We excluded all the patients who had severe hydronephrosis, percutaneous nephrostomy tube, or double J stent.

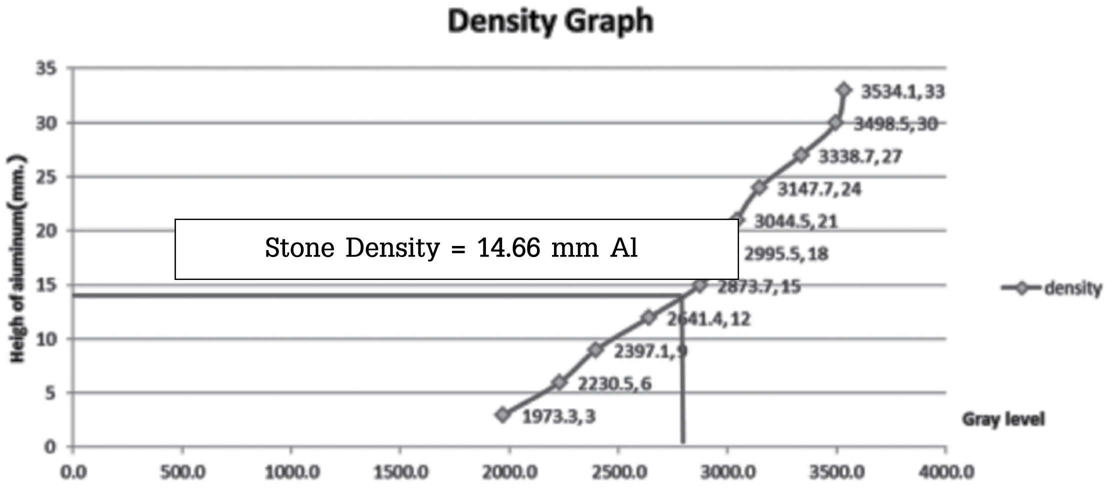
Plain KUB was performed on all patients, in which the aluminium step wedge was placed and the images were taken together on the same film. The x-ray machine was Fuji computed radiography, so the films could be calculated in a gray level of stone compared with the aluminium step wedge in eleven levels. Thus, we were also able to calculate the stone density in millimeter aluminium equivalent units (mm Al equivalent) (Figure 1-3).

The aluminium step wedge is composed of eleven pieces, each of which is 3 millimeters in width. We measured stone density three times as the density of the aluminium step wedge and the mean was calculated.

The gray level and thickness of the aluminum step wedge was used to plot the graph; X-axis is thickness of the aluminum step wedge and the Y- axis is the gray level of the aluminium step wedge. The gray level of the step is plotted on the graph for calculating the equivalence of the stone radiopacity to a particular thickness of the aluminum.

ESWL Technique

All patients received pre-treatment analgesic drugs before the ESWL session. All patients used the same machine. Intensity was set at level 4 to 5, and the rate was set at 90 times per minute. The ESWL session was stopped when either the stone was broken into fragments, or 4,000 times were completed. At 4 weeks after ESWL, the patient was followed up with plain KUB and the stone fragment was defined as a non-responder using the following criteria: the stone was not fragmented, or the ssize was more than 5 mm after 3 sessions of ESWL.



level	1	2	3	4	5	6	7	8	9	10	11
heigh of aluminum	3	6	9	12	15	18	21	24	27	30	33
gray level	1973.3	2230.5	2397.1	2641.4	2873.7	2995.5	3044.5	3147.7	3338.7	3498.5	3534.1

Figure 1. Density Graph

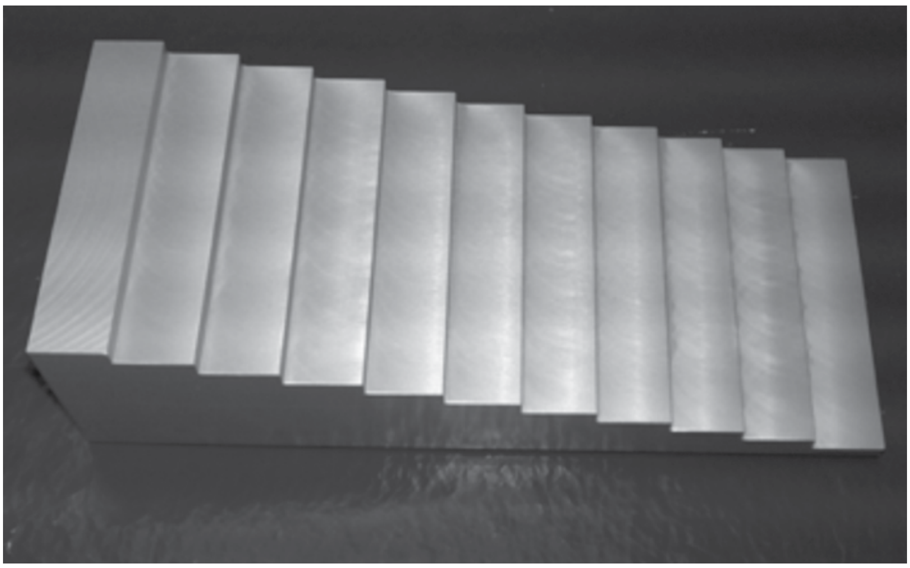


Figure 2. Aluminium Step Wedge

Figure 3. Plain KUB

After we divided the patients into two groups, we compared their parameters, including stone density and the number of ESWL sessions.

Statistical Analysis

The Pearson correlation test was used to find the correlation between stone density and the number of ESWL sessions, as well as the Independent T - test. Fisher's exact test and the chi-square test were also used to evaluate the significant difference (p-value < 0.05). Lastly, cut off point was calculated by ROC curve.

Result

Stone density was between 3 and 26.7 mm Al equivalent and its mean was 12.40 ± 5.96 mm Al equivalent. Stone size was between 5 and 18 mm and its mean was 9.32 ± 3.47 mm. Patient demographic details and characteristics are summarized in Table 1. The overall stone clearance rate was 70.91% after 3 sessions of ESWL were completed by the patient. All of the patients could be categorized into two groups. The non-responder group had sixteen patients, who had significantly higher stone densities than the patients in the other group (p-value < 0.001).(Table 2) Mean stone density in the non-responder and responder group were 16.69 ± 5.46 mm Al equivalent and 10.65 ± 5.28 mm Al equivalent, respectively. As shown in Table 2, lower pole calyceal stones had a success rate of 0%, thus patients with a lower pole calyceal stone were not candidates for ESWL.

Table 1. Demographic Data

Character	Value
Mean ± SD age (range)	52.51 ± 12.89 (18-77)
No. sex:	
Male	35
Female	20
Mean ± SD mm stone size (range)	9.32 ± 3.47 (5-18)
Mean ± SD mm Al Eq stone density (range)	12.40 ± 5.96 (3-26.70)
Position of stone	
Non lower pole calyx	35
Lower pole calyx	5
Proximal ureter	15

Table 2. ESWL Results in 55 patients

Characteristic	Completed fragmentation	Failure	p-Value
No. Pts (%)	39 (70.9)	16 (29.10)	
Mean ± SD stone density (mm Al Eq)	10.65 ± 5.28	16.69 ± 5.46	< 0.001
Position of stone			Success rate
Non lower pole calyx	25	10	71%
Lower pole calyx	0	5	0%
Proximal ureter	14	1	93%
No. of sessions			
1	14	-	
2	16	-	
3	9	-	
> 3	-	16	

Our study suggests that there is a significant correlation between the number of ESWL sessions and stone density in millimeter aluminium equivalent units (R2 = 0.253, p-value < 0.001) (figure 4).

We used ROC curve= 0.819 (95%CI=0.706-0.932, p-value<0.001) and found the density of stones in mm Al Eq. suitable for treatment with ESWL. The cut off point is 12.135 mm Al Eq(sensitivity 79.49%, specificity 81.25%). (Table 3, Figure 5)

In this research, we determined that success rate is dependent on the position of the stone. Proximal ureteral stones, non lower calyceal stones, and lower calyceal stones had success rates of 93%, 71% and 0%, respectively. Lower calyceal stones had a low success rate because success rate depends on anatomy of kidney. Ureteral stones had a success rate higher than renal stones due to fact they are smaller. In this study, none of the stones underwent analysis

Discussion

Stone density is the key factor used to evaluate the success rate of ESWL; however, it cannot be estimated accurately. There have been many methods used to measure stone density, such as comparing it with spine density, or the 12th rib on the same film, but these are not standard measurements, because bone density depends directly upon bone mineralization[1,16]. Moreover, there are many factors that affect radio-opacity, such as body habitat, x-ray exposure and film processing[15].

We have determined that assessing renal stone and proximal ureteral stone radiopacity on plain KUB is an accurate and objective method for predicting the outcome of ESWL. We used the aluminum step wedge as a reference for this assessment. We used computer software for the comparison in order to avoid false subjective data, and thus present the results in a better quantitative manner. Also, we compared the gray levels of the different steps of the aluminum step wedge to the stone's gray levels, instead of using the absolute gray level of the stone as the only indicator of its density; therefore, we eliminated the previously mentioned external factors that could affect stone radiopacity and subsequently its gray level.

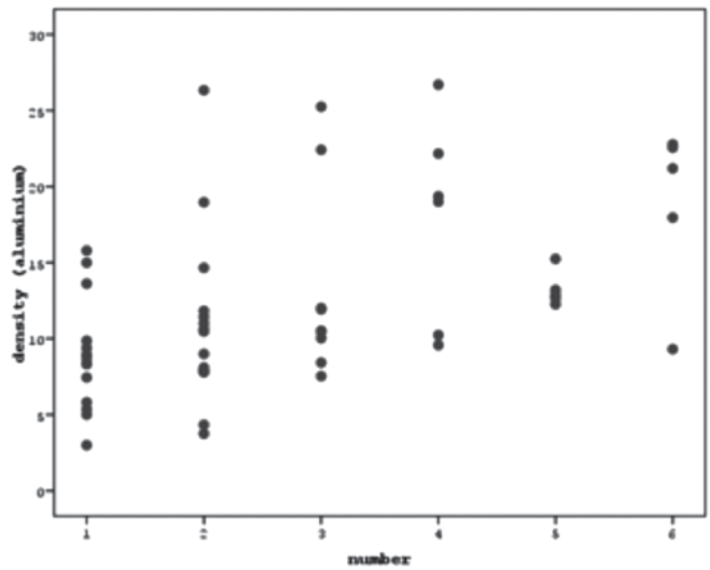


Figure 4. Correlation Graph

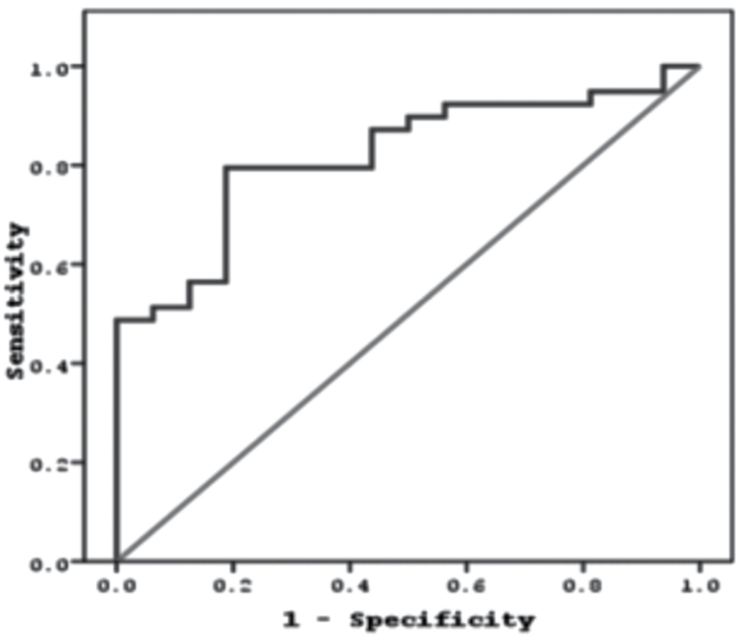


Figure 5. Cut off Point Graph

Table 3. Cut off Point

Stone Density (mm Al Eq)	Sensitivity (%)	Specificity (%)
11.875	74.36	81.25
11.965	76.92	81.25
12.135	79.49	81.25
12.455	79.49	75.00
12.755	79.49	68.75

We tried to find some method that could measure stone density accurately by introducing the aluminium step wedge as a stone density reference, and using the computer software calculation to decrease any error. By placing the aluminium step wedge in the same film, all factors were eliminated. The gray level of the aluminium step wedge was compared with the gray level of the stone directly, instead of using the gray level of the stone itself to predict the success rate of ESWL. Measuring the stone's HU value is the most common technique used to evaluate stone density. Meanwhile, a prospective study by Osama El-Gamal and Amr El-Badry found that a positive correlation between the HU value of the stone and its radiopacity in mm Al Eq[7].

We are not sure about the measurements of the gray levels on the aluminium step wedge in the different positions; we can only be certain on the same step. Therefore, we randomly measured 20 points per step and used the coefficient of variation statistical methods (Table 4). Gray levels were not different. Some steps showed high SD and CV because the bone and soft tissue of patients had an error in the measurement of the gray level.

Conclusion

The aluminum step wedge with plain KUB provides a good reference for objectively assessing the radiopacity of renal calculi and proximal ureteral calculi, with the advantages of a low cost and less radiation exposure. In addition, according to our results, it seems that high density stones (> 12.135 mm Al Eq.) may not be suitable for treatment with ESWL, or multiple sessions may be required for fragmentation. However, in this study it was difficult to determine a cut off value at which ESWL should be avoided, because a large number of subjects would be required to obtain an accurate value in this regard. More studies are needed to determine whether stone radiopacity on this scale can predict its chemical composition.

Table 4. Coefficient of Variation

Level	N	Minimum	Maximum	Mean	SD	Coefficient of Variation (CV)
1	20	1860	2088	1973.3	64.8	3.28%
2	20	1928	2899	2230.4	211.9	9.50%
3	20	2249	2545	2397.1	88.0	3.67%
4	20	2504	2789	2641.4	79.2	3.00%
5	20	2759	2976	2873.6	61.0	2.12%
6	20	2853	3087	2995.5	67.0	2.24%
7	20	2787	3222	3044.4	126.1	4.14%
8	20	2937	3386	3147.7	129.5	4.11%
9	20	3027	3510	3338.7	147.6	4.42%
10	20	3290	3592	3498.4	70.4	2.01%
11	20	3281	3654	3534.1	111.1	3.14%

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