Communication

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A Smart Computer Program to Assist Healthcare Providers in Selecting the Best Treatment for Patients with Urinary Stones

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Abstract: Urinary tract stones can obstruct the urinary tract, resulting in severe lower back pain, blood in the urine, vomiting, and painful urination. While small stones can pass naturally through the urine stream, larger ones necessitate fragmentation with shock wave lithotripsy (SWL) or laser ureteroscopy (URS) to prevent urinary tract blockage. A smart computer program was developed to predict treatment efficacy for removing a stone and potential complications for individual patients based on factors such as age, health conditions, stone details, and treatment instruments, ultimately recommending the most suitable option. Here, I present three case studies and their predicted outcomes. The program is available at: http://peteranoble.com/webapps.html

Keywords: urinary stones; shockwave lithotripsy; laser ureteroscopy; stone fragmentation; AI predictions

Introduction

Stones in the urinary tract are becoming more common worldwide, likely due to shifts in dietary habits and climate change[1]. These stones form when certain substances in the urine, such as calcium, oxalate, and/or uric acid, become highly concentrated and clump together in the urinary tract. While small stones, typically around 4 millimeters or less, can pass out of the body through the urine stream, larger ones may become lodged in the urinary system, causing symptoms like severe lower back pain, blood in the urine, vomiting, and painful urination. It is estimated that approximately 11% of people in the United States will experience a urinary tract stone at some point in their lives[2].

Physicians use shock wave lithotripsy (SWL) or laser ureteroscopy (URS) to fragment stones, facilitating their passage out of the body while minimizing treatment complications for patients, such as pain and bleeding. SWL delivers strong shock waves to the stone from outside the body, without causing harm to internal organs[3]. In contrast, URS is a more invasive procedure[4], involving the insertion of a small, flexible tube with a camera into the urinary tract to locate the stone. Subsequently, a laser beam inside the tube fragments the stone into small pieces[5].

The effectiveness of SWL and URS treatments varies depending on factors such as the patient's health, age, body size, and the size, type, and location of the urinary stone[6-10]. For example, URS may entail more treatment complications and higher costs, sometimes requiring extended hospital stays compared to SWL[11-12]. Most patients tend to prefer SWL[13]. While a recent review by the National Institute of Health suggests that URS marginally outperforms SWL, SWL is generally considered more effective and cost-efficient[14]. Selecting the 'optimal' treatment for a patient is therefore not straightforward; an approach that helps physicians with these decisions is highly desired.

Using anonymous data accessible from the Kidney Stone Registry (http://kidneystoneregistry.com.s3-website-us-west-2.amazonaws.com/), I analyzed the treatment outcomes from 17,242 patients who have undergone SWL or URS treatments at multiple sites across the United States. The anonymous dataset lacks identifiable information, ensuring no possible linkage to personal data. Details of the approach and quality assessment of the AI models used to build the smart program can be found here: Refs. 15 and 16.

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Results

A smart computer program[15] predicted the efficacy of stone fragmentation treatments and assessed potential post-treatment health issues. The program considered various factors, including age, sex, weight, presence of health conditions like diabetes, prior medication use, and details about the stone such as size and location. Additionally, it took into account the type of machines used for SWL and URS treatments.

The computer program produced four predictions: the likelihood of fragmenting the stone to 4 millimeters or less for SWL and URS, as well as the probability of treatment-related health issues for each method. The output for each prediction consisted of the average and standard deviation from 10 independently trained Artificial Intelligence (AI) models.

Additionally, the program recommended the most suitable treatment for an individual patient based on the average and standard deviation of the models, as specified in the original study[16]. Three examples are shown below.

Case Presentations

Case 1

Patient: A 29-year-old woman with BMI of 24 kg/m^2 and no health problems.
Stone: In her left kidney, 14mm long and 8mm wide.
Medications: She has not taken any blood thinners.
Machines: Dornier Compact Sigma (SWL) and Lumenis Versapulse 100 watt (URS).
Web interface for input data of this patient (Figure 1)[15].
The program output (Figure 2):
- SWL: 69.4% chance of breaking up the stone, 11.2% chance of problems.
- URS: 61.1% chance of breaking up the stone, 5.5% chance of problems.
- Recommendation: URS is better, with fewer expected problems.

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Stone Decision Engine

Information

Kidney stones can cause intense pain by obstructing the urinary tract. Shockwave lithotripsy (SWL) and laser ureteroscopy (URS) are two treatment interventions employed to fragment stones into small pieces (<=4mm), facilitating their natural passage out of the body. This Decision Engine program recommends the optimal treatment option for patients by analyzing their characteristics relative to 17,242 patient treatments [pdf]. An example of a filled out form and the subsequent results is shown here [pdf]. Predictions are for informational purposes and not a substitute for professional medical advice.

Personal Information

Age: 29
Sex: ○ Male ◉ Female
Body Mass Index: 24
Serious Medical Condition (e.g., Diabetes)? ○ Yes ◉ No
Anticoagulants used 3 day prior to treatment? ○ Yes ◉ No

Stone Characteristics

Stone Length: 14
Stone Width: 8
Stone Location: ◉ Kidney ○ Ureters ○ Other
Stone Side: ◉ Left ○ Right

SWL Machine Type (select one)

○ Dornier Compact Delta II ○ Dornier Compact Delta III ◉ Dornier Compact Sigma ○ Storz F2 ○ Storz SLX-T

URS Machine Type (select one)

○ Dornier Medilas H20 ○ Dornier Medilas H30 ○ Dornier Medilas H35 ◉ Lumenis Versapulse 100 watt ○ Lumenis Versapulse 20 watt ○ Odyssey Convergent 30 watt

Submit

Figure 1. Screenshot of web interface displaying input data for Case 1 patient.

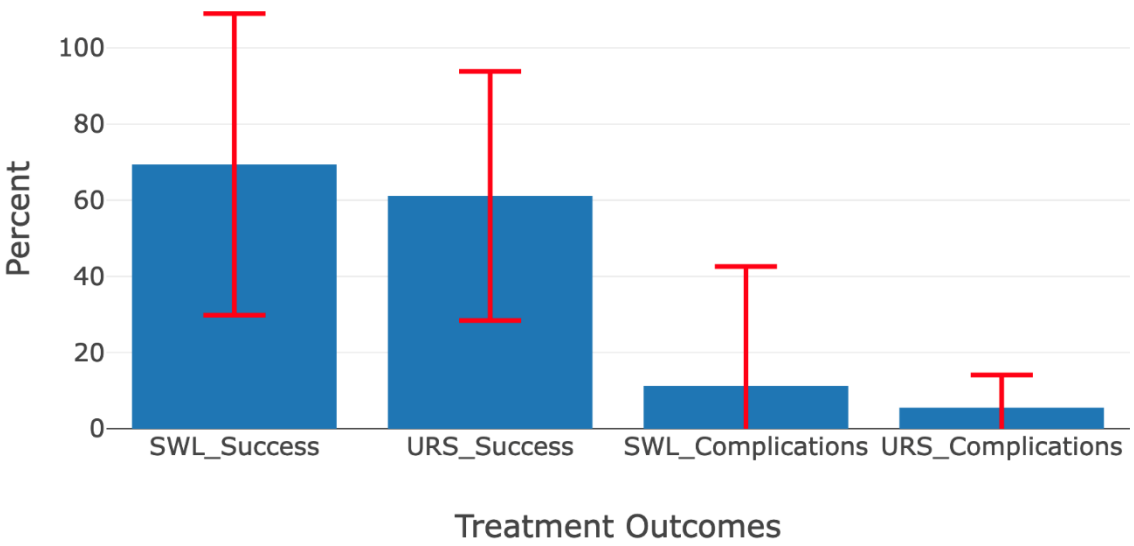

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Figure 2. Average and standard deviation of predictions for stone fragmentation success (<=4mm) and treatment complications based on output from ten AI models for each prediction. URS has fewer treatment complications than SWL and is the preferred option.

Case 2

Patient: A 45-year-old man with BMI of 28 kg/m² and no health problems.
Stone: In his right kidney, 10mm long and 10mm wide.
Medications: He has not taken any blood thinners.
Machines: Storz SLX-T (SWL) and Odyssey Convergent 30 watt (URS).
The program output (Figure 3):
- SWL: 94.7% chance of breaking up the stone, 2.4% chance of problems.
- URS: 100% chance of breaking up the stone, 0% chance of problems.
- Recommendation: Both SWL and URS are preferred options.

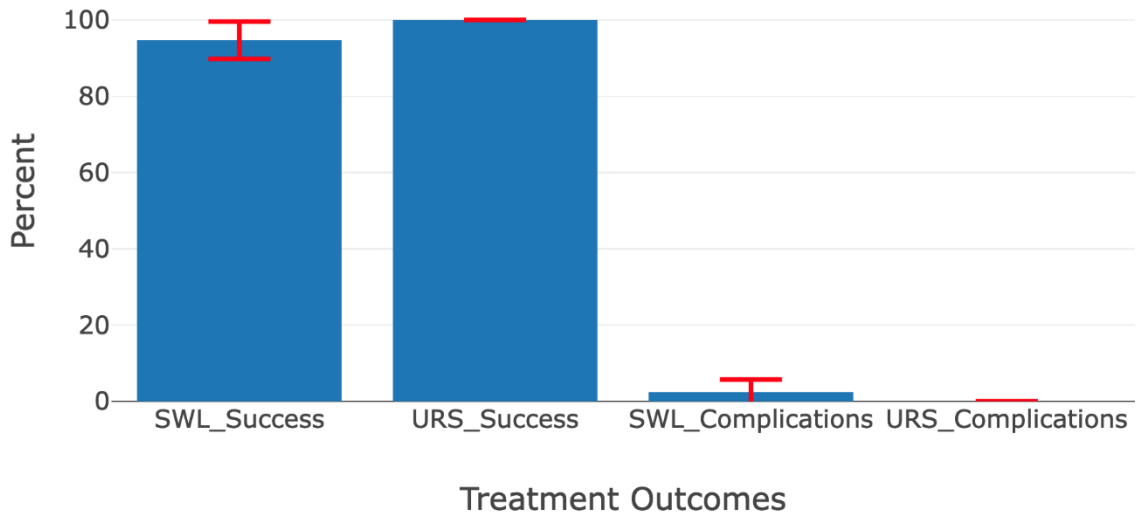

Figure 3. Average and standard deviation of predictions for stone fragmentation success (<=4mm) and treatment complications based on output from ten AI models for each prediction. Both SWL or URS are preferred options.

Case 3

Patient: A 75-year-old woman with BMI of 30 kg/m² and health problems.
Stone: In her left ureter, 9mm long and 9mm wide.
Medications: She has not taken any blood thinners.
Machines: Storz F2 (SWL) and Lumenis Versapulse 20 watt (URS).
The program output (Figure 4):
- SWL: 62% chance of breaking up the stone, 3.1% chance of problems.
- URS: 84.9% chance of breaking up the stone, 55.3% chance of problems.
- Recommendation: SWL is better, with fewer expected problems.

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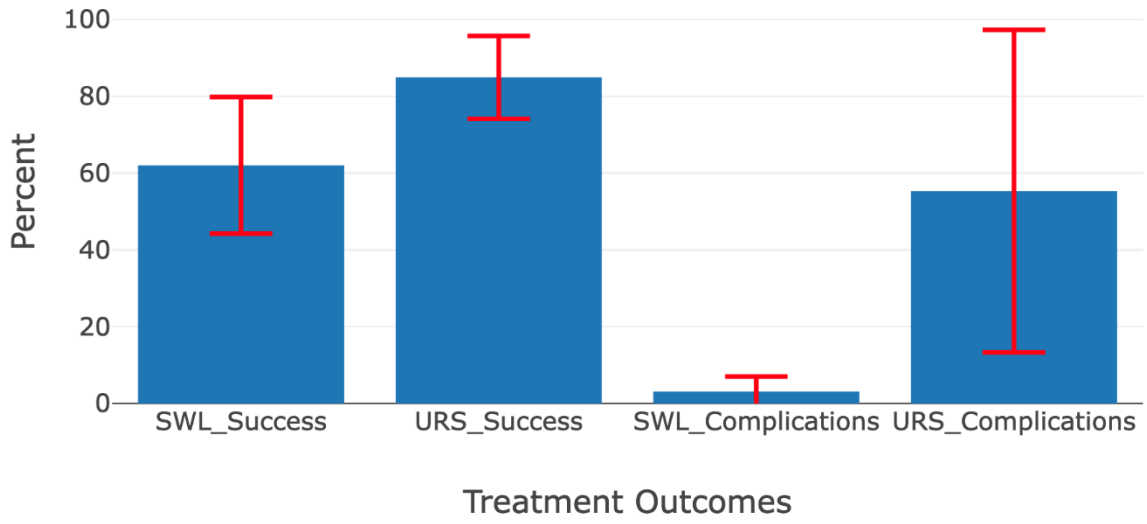

Figure 4. Average and standard deviation of predictions for stone fragmentation success (<=4mm) and treatment complications based on output from ten AI models for each prediction. Both SWL is the preferred option because it has a lower probability of treatment complications than URS. .

Discussion

The motivation of the study was to demonstrate the utility of a smart computer program that predicts SWL and URS outcomes, aiding healthcare professionals in patient care decisions. Our study is unique from other studies because the interventions took place at multiple institutions (n = 41+) by different medical professionals (n = 41+) using a variety of SWL and URS instruments. Hence, the results should be generalizable and not specific to a particular institution or healthcare professional. While there are specific guidelines for the management of urolithiasis set by the American Urological Association (AUA) and European Association of Urologists (EAU), our study provides recommendations based on past treatments that, in theory, should align with these guidelines.

The average prediction accuracies based on Confusion Matrices for SWL stone removal and treatment complications were 84.8% and 95.0%, respectively, while those for URS were 89.0% and 92.2%, respectively[16]. Taken together, the approach yielded moderate to high accurate predictions, regardless of treatment or outcome.

Conclusions

The smart computer program represents a groundbreaking advancement in predicting stone treatment outcomes for individual patients having a urinary stone. It leverages data from multiple institutions and diverse physicians, analyzing thousands of patients.

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Conflict of Interest: None.

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