Increasing stone complexity does not affect fluoroscopy time in percutaneous nephrolithotomy

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Abstract

Background: The aim of this work was to assess whether stone complexity with the Guy's stone score (GSS) is associated with increased intraoperative fluoroscopy time.
Methods: We retrospectively reviewed records of 261 consecutive patients undergoing percutaneous nephrolithotomy between 2007 and 2015. Of these, 203 had both preoperative computed tomography for accurate staging and full intraoperative fluoroscopy and radiation dosimetry data were available. Stone complexity was assessed using GSS. A correlation between fluoroscopy time (FT) and GSS was assessed in a univariate and multivariate fashion, including parameters such as age, sex, body mass index (BMI), and number of accesses.
Results: The overall mean FT was 3.69 min [standard deviation (SD) 2.77]. The overall mean Guy's score was 2.5 (SD 1). There was a statistically significant correlation between operative time and FT ($r = 0.34$, $p < 0.0001$). There was a trend towards increasing operative time with increasing GSS ($r = 0.12$, $p = 0.08$), but there was no statistically significant correlation. There was no correlation between FT and GSS ($r = 0.04$, $p = 0.55$). On multivariable regression, accounting for sex, BMI, age, and singular *versus* multiple accesses, there was no significant correlation between stone complexity and FT ($p = 0.893$).
Conclusions: In the setting of conscious efforts to reduce intraoperative radiation exposure, increasing stone complexity, as classified by GSS, did not correlate with FT on univariate or multivariate analysis. Thus, treatment of more complex stones may be undertaken without concern that there is an inevitable need for significantly increased fluoroscopy exposure to the patient or operating room staff.

Keywords: percutaneous nephrolithotomy, stone complexity, Guy's stone score, radiation, fluoroscopy

Introduction

Percutaneous nephrolithotomy (PCNL) is considered the standard first-line treatment for large (>20 mm) renal stones.[1] The use of PCNL has been increasing in the United States (US) over the last decade, and this trend is likely to continue.[2]

The Guy's stone score (GSS) system is one internally and externally validated system for quantifying renal stone burden complexity.[3,4] As originally described by Thomas and colleagues in 2011, this system involves four grades and is based on caliceal location of stones, the presence of single or multiple stones, renal anatomy and whether the patient suffers from a spinal injury or abnormality.[4] The GSS system allows the urologist to assess the potential intraoperative and postoperative parameters, such as a stone-free state, operative time, length of stay, and postoperative complications based on the Clavien grade.[4,5]

Fluoroscopy is a commonly used technique for gaining antegrade access to the collecting system during PCNL. Using this technique, the intrarenal

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Table 1. Definitions of Guy's stone score.

Guy's score	Description
Grade 1	solitary renal stone in the mid or lower pole or in the renal pelvis in a kidney with normal anatomy
Grade 2	solitary renal stone in the upper pole or multiple stones in a patient with simple kidney anatomy; a solitary stone in a patient with abnormal anatomy, such as an abnormal collecting system, or in a patient with an ileal conduit
Grade 3	multiple renal stones in a patient with abnormal anatomy or stones in a calyceal diverticulum or a partial staghorn stone, defined as a stone involving the renal pelvis and at least two calyces
Grade 4	complete staghorn calculus (defined as all calices and the pelvis occupied by stones) or any stone in patient with spina bifida or a spinal injury

collecting system anatomy is well delineated. Fluoroscopy is also used throughout the procedure to monitor the various phases of the operation. Several epidemiological studies have shown an increase risk of malignancy with increasing radiation exposure.[6,7]

As with other radiographic technologies, the ALARA principle is utilized throughout the procedure. As defined by the US Nuclear Regulatory Commission, ALARA is an acronym for 'as low as (is) reasonably achievable,' described as:

making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.[8]

The three principles of ALARA are:

1. Minimizing time of radiation exposure.
2. Increase the distance from the radiation source.
3. Proper shielding with absorber materials to decrease the amount of absorbed radiation.

The time of radiation exposure can be variable from patient to patient and from surgeon to surgeon. In this regard, the surgeon performing the PCNL procedure can adhere to the ALARA principle by limiting the use of the continuous fluoroscopy in favor of pulse-dose and always using the low-dose over the high-dose exposure.

The purpose of this study was to examine further the relationship between the GSS and fluoroscopy time (FT).

Materials and methods
After obtaining approval of our Institutional Review Board, we retrospectively reviewed the records of 261 patients between June 2009 and September 2015 at one academic medical center. Our data collection began in 2009 and does not represent a change in PCNL technique. Of these 261 patients, 203 patients had preoperative abdominopelvic computed tomography (CT) images available for review in addition to recorded intraoperative FT and radiation dose. The CT images were reviewed by two investigators and scored according to the GSS. Conflicts in assigning GSS was resolved by a third investigator. Table 1 defines each GSS.

The patients' age, sex, body mass index (BMI), number of accesses, operating time, and FT and radiation dose were recorded.

PCNL technique
Percutaneous renal access was obtained intraoperatively for all patients by a single experienced endourologist using a fluoroscopic-guided multiplanar bulls eye technique. Balloon dilation and a 30 French access sheath were utilized to create the tract, and stones were fragmented with a combination of ultrasonic or pneumatic lithotripsy. For the all cases, a nephrostomy tube, re-entry Pollack catheter and double J ureteral stent were placed at completion. A double J stent was never omitted due to surgeon preference to help promote ureteral healing and postoperative drainage.

Table 2. Overall patient demographics.

Parameter	Mean ± standard deviation	Range
Patient age (years)	56.2 ± 13.7	15–89
Sex (male/female)	124 (61%)/79 (39%)	N/A
BMI (kg/m^2)	32.4 ± 9.5	18.2–69.1
Number of accesses	1.2 ± 0.5	1–3
OR time (hours)	2.9	0.33–6.8
Fluoroscopy time (seconds)	221.45 ± 166.28	11.2–939.5
Radiation exposure (mGy)	108.28 ± 355.10	4.54–5024

BMI, body mass index; mGy, milligray; N/A, not available; OR, operative room.

We recorded operative time as starting when the prone cystoscopy (our preferred technique for retrograde access) began and ending after the nephrostomy tube was sutured into place. At our institution, an antegrade flexible ureteroscopy is routinely performed to address any fragments that may have migrated into the ureter. Additionally, a mapping pyelogram is performed with a flexible nephroscope, instilling contrast to opacify the collecting system and then fluoroscopically and endoscopically confirming that each calyx has been inspected and is stone-free prior to the conclusion of the operation.

While a radiology technician was present in call cases, the fluoroscopy pedal was controlled by the surgeon. At all times low-dose fluoroscopy was used in the pulsed mode at a rate of eight pulses per second, as opposed to the continuous mode. FT was recorded by the radiology technician, measured in seconds.

Data analysis
Correlation between FT and GSS was assessed in a univariate and multivariable fashion, adjusting for parameters such as age, sex, BMI, and number of accesses. Pearson's correlation coefficient was used to assess for correlation. A *p* value <0.05 was considered statistically significant. Statistical analysis was performed using STATA, version 13.1.

Results
A total of 203 patients were included, of which 124 were men (61%) and 79 were women (39%).

Table 3. Fluoroscopy time by Guy's stone score.

Guy's stone score	Number of patients	Mean fluoroscopy time (min)
1	35	3.29
2	81	3.85
3	45	3.49
4	42	3.91

The average age of patients was 65 years old. The mean operating time was 2.9 h. The overall mean FT was 3.69 min [standard deviation (SD) 2.77; Tables 2 and 3].

For our primary question, there was no correlation between FT and GSS ($r = 0.04$, $p = 0.55$). On multivariable regression, accounting for sex, BMI, age, and singular *versus* multiple accesses, and stone type, there was still no significant correlation between stone complexity and FT ($p = 0.893$, 95% CI −0.40–0.46).

There was a statistically significant correlation between operative time and FT ($r = 0.34$, $p < 0.0001$). While there was a trend towards increasing operative time with increasing GSS, there was no statistically significant correlation ($r = 0.12$, $p = 0.08$).

Discussion
To date, this is the largest cohort of PCNL patients to be studied with regard to FT and GSS. Recently, Sfoungaristos and colleagues showed in a cohort of 108 PCNL patients, a positive

relationship between the amount of FT and stone burden, stone location, number of stones, higher GSS and STONE nephrolithometry score (stone size, tract length, obstruction, number of involved calices, and essence/stone density).[9] In our cohort of nearly double the size, we were unable to replicate this result of increased FT with increased GSS. Comparatively, a previous study of 103 PCNLs, Noureldin and colleagues demonstrated a significant correlation between FT with the number of punctures, estimated blood loss and operative time, but reported no relationship between STONE nephrolithometry score and FT.[10]

From a cohort of 185 patients reported by Noureldin and colleagues, a correlation was shown between GSS and post-PCNL stone-free status, estimated blood loss, operative time, and length of stay.[11] In a separate study of 185 PCNL cases, Noureldin and colleagues did show a positive correlation between GSS and post-PCNL stone-free status, estimated blood loss, operative time, and length of stay.[11] This study, however, did not report on the correlation between FT and GSS. Like our study, Kumsar and colleagues also showed in their cohort of 102 PCNLs that there was no significant relationship between GSS and stone-free status, as well as GSS and FT.[5]

In the setting of conscious efforts to reduce intraoperative radiation exposure, increasing stone complexity did not correlate with FT on univariate or multivariable analysis. As a single center study, these findings may simply reflect the outcomes of a single practice pattern. However, it does reinforce the utility of adherence to the ALARA principles and further illustrates that increasing stone complexity does not mandate significant increase in fluoroscopy utilization. When compared with the mean FT, this was 5.6 ± 1.4 min in Kumsar's cohort of 102 patients,[5] which is higher than our mean FT of 3.69 ± 2.77 min in 203 patients. There may also be differences in the technique used by for obtaining access (bulls eye technique *versus* triangulation) between investigators in the other studies, which may account for a difference in FT. Although a single surgeon series may theoretically limit generalizability, a subsequent strength is that it may decrease the differences accounted by variability in surgical technique.

We chose to characterize stone complexity based on the GSS, a previously well validated

instrument.[3,4] Other studies have used alternative preoperative nomograms, including the STONE nephrolithometry score, which was initially developed for predicting stone-free status following surgical intervention. This prognostic tool uses stone size, tract length, degree of hydronephrosis, number of calyces involved and stone density (HU).[12] As opposed to GSS, STONE nephrolithometry does not consider the complexity of the kidney anatomy or the potential confounding patient factors that could make PCNL more difficult, such as concomitant urinary diversion, spinal injury or spina bifida. Thus, we feel GSS is a more accurate tool to predict surgical complexity, and thus more likely to correlate with increased fluoroscopy time.

Given the lack of correlation between GSS and FT, it can be understood that complex stones may be treated without concern of significant additional radiation risks to the patient or operating room staff. This is important in the preoperative counseling of the patient, specifically in the surgical consent process. This is especially important for recurrent stone formers, who have likely received a significant amount of radiation in diagnosis and surveillance of their stone disease and will predictably have a disproportionate amount of lifetime radiation exposure. Of note, this is also of importance to the urologist and surgical team that may be tasked with addressing complex renal stones on a regular basis.

One explanation for the observed lack of correlation between stone complexity and FT could be our routine practice of meticulous mapping pyelography, antegrade flexible ureteroscopy, fluoroscopic-guided antegrade double J stent placement and a chest fluoroscopy, all of which likely cause similar amounts of radiation to each patient. These other uses of intraoperative fluoroscopy could potentially have diluted out the differences in radiation incurred by difficulty in obtaining access to a more complex system or removing more complex stones. Nevertheless, despite these 'fixed' additional fluoroscopy exposures, our total FT remains less than that of comparable and contemporary PCNL series.[5]

The major limitation of our study was its retrospective design. In addition, we acknowledge that in addition to FT, several other variables factor into actual exposure of radiation by the patient, including the amount of shielding, distance from the radiation souse and patient BMI. Due to the

complexity of calculating actual radiation exposure in mSv, we choose not to account for these elements and instead focused on FT only. Also, we acknowledge that the stone-fee rate is an important factor when discussing FT. While not factored into our analysis, in all cases the goal of the operation was to reach a stone-free state in one procedure, While the retrospective nature of our study poses the potential for unmeasured confounders and unrecognized biases, we feel that the relatively large cohort of patients reviewed as well as the standardized surgical technique strengthen our results.

In the setting of conscious efforts to reduce intra-operative radiation exposure, increasing stone complexity, as classified by GSS, did not correlate with FT on univariate or multivariate analysis. Thus, treatment of more complex stones may be undertaken without concern that there is an inevitable need for significantly increased fluoroscopy exposure to the patient or operating room staff.

Conflict of interest statement
The authors declare that there is no conflict of interest.

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