# Factors affecting complications according to the modified Clavien classification in complete supine percutaneous nephrolithotomy

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## Abstract

**Introduction:** An increase in percutaneous nephrolithotomy (PCNL) has been accompanied by an increase in complications. We identified the parameters affecting the severity of complications using the modified Clavien classification (MCC).
**Methods:** From 2008 to 2013, 330 patients underwent complete supine PCNL using subcostal access, one-shot dilation, rigid nephroscopy, and pneumatic lithotripsy. We assessed the impact of the following factors on complication severity based on the MCC: age, gender, body mass index, hypertension, diabetes, previous stone surgery and extracorporeal shock wave lithotripsy, preoperative hemoglobin, renal dysfunction (creatinine >1.4 mg/dL), preoperative urinary tract infection, anatomic upper urinary tract abnormality (AUUTA), significant (moderate–severe) hydronephrosis, stone-related parameters (opacity, number, burden, location, staghorn, complex stones), anesthesia type, kidney side, imaging and calyx for access, tract number, tubeless approach, operative time, postoperative hemoglobin, and hemoglobin drop and stone-free results.
**Results:** The complication rate was 19.7% (MCC: 0=80.3%, I=6.4%, II=11.2%, ≥III=2.1%). On univariate analyses, only the following factors affected MCC: gender, preoperative hemoglobin, AUUTA, significant hydronephrosis, imaging for access, calyx for access, tract number, postoperative hemoglobin, hemoglobin drop and stone-free result. Renal dysfunction was accompanied by higher complications, yet the results were not statistically significant. Multivariate logistic regression analysis demonstrated renal dysfunction, absence of significant hydronephrosis, AUUTA, multiple tracts, lower postoperative hemoglobin, and higher postoperative hemoglobin drop as the significant parameters which affected MCC and predicted higher grades. The paper's limitations include a low number of cases in the higher Clavien grades and some subgroups of variables, and not applying some techniques due to surgeon preference.
**Interpretation:** Many of the complete supine PCNL complications were in the lower Clavien grades and major complications were uncommon. Renal dysfunction, AUUTA, significant hydronephrosis, tract number, postoperative hemoglobin, and hemoglobin drop were the only factors affecting MCC.

## Introduction

Presently, percutaneous nephrolithotomy (PCNL) is preferred as a safe and effective way to remove large or multiple upper urinary tract calculi.[1-7] An increase in PCNL has been accompanied by variations in positions, techniques, and instruments, and these may have led to increased complications.[1,2,4,5] Following PCNL, 79.5% of patients may experience an uncomplicated postoperative period,[5,8] although there are reports of an early complication rate of 50.8%.[4] PCNL complications may occur during puncturing, access, or stone removal.[4] A standardized classification allow us to compare complications among different instruments, techniques, and centres.[3,4,7,9] In 2004, the modified Clavien system (MCC) was introduced and allowed us to classify complications based on life-threatening conditions, interventions required, and disability.[9] In recent years, this classification has been used to report PCNL complications instead of using simply "minor" and "major" distinctions.[3-8,10-12] In this study, we reported on the PCNL complications according to the MCC and identified the parameters affecting the severity of complications based on this classification.

## Methods

In a prospective analytical cross-sectional study, 330 patients with upper urinary tract stones underwent PCNL by 1 experienced surgeon from January 2008 to September 2013. We included patients with upper caliceal, middle caliceal and renal pelvic stones with stone burden ≥2 cm, lower caliceal stones ≥1.5 cm, upper ureteral stones ≥1 cm, extracorporeal


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shock wave lithotripsy-resistant stones ≥1 cm, multiple location stones with stone burden ≥2 cm, and staghorn stones. We excluded patients with uncontrolled bleeding diathesis, untreated preoperative urinary tract infection (UTI), immunosuppression, and pregnant patients. Our ethics committee approved this study. Before surgery, we evaluated patients using blood cell count, coagulation tests, serum creatinine, urinalysis, urine culture, kidneys-ureters-bladder radiography, intravenous urography, ultrasonography, and computed tomography scan (in select cases). We considered preoperative serum creatinine >1.4 mg/dL as renal dysfunction. Also staghorn and multiple locations stones, and moderate and severe hydronephrosis were considered as complex stones and significant hydronephrosis, respectively. If patients were taking antiplatelet drugs, these drugs were discontinued for 10 to 14 days before surgery. Patients with UTI were treated by appropriate antibiotic therapy before the PCNL. Also appropriate prophylactic antibiotics were administered for all patients before and after the operation. All PCNLs were performed with patients in the complete supine position[13] due to the surgeon's experience. Compared with the prone PCNL, the complete supine PCNL is a safe and effective procedure; patients do not need to be repositioned after intubation and catheterization. The complete supine position also allows us to control the airway appropriately during anesthesia and to sit during surgery.[13] The procedure was initiated by cystoscopy and retrograde insertion of the ureteral stent and followed by puncturing the collecting system with an 18-gauge needle and inserting a 0.035-inch J-tip guidewire using the posterior subcostal access. A one-shot dilation technique (9-Fr dilator, 28-Fr Amplatz dilator), insertion of a 30-Fr Amplatz sheath (by possible and easy slipping and manipulating it over the 28-Fr Amplatz dilator into the collecting system),[13,14] rigid nephroscopy, and pneumatic lithotripsy were performed. Multiple tracts and nephrostomy tube were used according to surgeon preference. After PCNL, the ureteral stent and Foley catheter were removed within 24 and 48 hours, unless patients had serious complications (i.e., significant blood loss or hematuria and leakage) necessitating irrigation or prolonged drainage. A blood transfusion was performed in patients with hemodynamic changes following blood loss or bleeding, especially in patients with postoperative hemoglobin less than 10 mg/dL.

All patients were followed up to 3 months after surgery. We defined stone-free as the absence of stone fragments in intra-operative fluoroscopy or ultrasonography (and nephrostography in radiolucent stones) and in postoperative kidneys-ureters-bladder radiography and ultrasonography. We graded the complications according to severity using the MCC in 4 grades (0, I, II, ≥III) (Table 1).[9] Grade 0 included patients without complications. All patients with the grades of IIIa-V were classified as the grade ≥III (major complications).

We assessed the impact of the following factors on complication severity based on the MCC: age, gender, body mass index (BMI), preoperative hemoglobin, renal dysfunction, preoperative UTI, hypertension, diabetes mellitus (DM), ischemic heart disease (IHD), previous stone surgery and extracorporeal shockwave lithotripsy (ESWL), anatomic upper urinary tract abnormality (AUUTA), significant hydronephrosis, stone-related parameters (number, burden, opacity, location, staghorn and complex stones), type of anesthesia, kidney side, imaging for access, calyx for access, tract number, tubeless approach, operative time, postoperative hemoglobin, postoperative hemoglobin drop, and stone-free result.

The SPSS version 16.0 software was used for data statistical analysis. The univariate analyses (Spearman test for quantitative variables, Mann-Whitney test for categorical variables, and Kruskal-Wallis test for qualitative variables with >2 categories) were used to evaluate the association between the above parameters and MCC. Also multivariate analysis using ordinal logistic regression was used to predict the factors affecting MCC and severity of complications (with control and adjustment of other variables). All *p* values were two-tailed and <0.05 was considered statistically significant.

**Table 1. Modified Clavien classification of surgical complications**

| Grade | Definition |
|---|---|
| Grade I | Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions. Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. This grade also includes wound infection opened at the bedsides. |
| Grade II | Requiring pharmacological treatment with other than such allowed for grade I complications. Blood transfusion and total parenteral nutrition are also included. |
| Grade III | Requiring surgical, endoscopic or radiological intervention |
| Grade IIIa | Intervention not under general anesthesia |
| Grade IIIb | Intervention under general anesthesia |
| Grade IV | Life-threatening complication (including CNS complications)* requiring IC/ICU management |
| Grade IVa | Single organ dysfunction (including dialysis) |
| Grade IVb | Multiorgan dysfunction |
| Grade V | Death of a patient |
| Suffix "d" | If the patient suffers from a complication at the time of discharge, the suffix "d" (for "disability") is added to the respective grade of complication. This label indicated the need for a follow-up to fully evaluate the complication. |

Adapted from Dindo et al.[9] *Brain hemorrhage, ischemic stroke, subarachnoidal bleeding, but excluding transient ischemic attacks. CNS: central nervous system; IC: intermediate care; ICU: intensive care unit.

## Results

The mean patient age was 49.38 ± 12.63. The mean stone burden was 35.11 ± 17.09 mm. The complication rate was 19.7% (n = 65). The most common complications were blood transfusion and transient low-grade fever. Significant life-threatening bleeding, including gross hematuria, hematoma formation and hemoperitoneum, occurred in 15 patients (4.5%), who were treated conservatively (2.4%) or with interventions (2.1%). The rates of the Clavien grades of 0, I, II, III, IV and V were 80.3%, 6.4%, 11.2%, 1.5%, 0.3% and 0.3%, respectively. Grade ≥III included 7 patients (2.1%) (Table 2). We also detailed patient complications, grading, and management (Table 3).

On univariate analysis, the following factors has no significant effect on MCC: age, BMI, preoperative UTI, hypertension, DM, IHD, previous stone surgery and ESWL, stone-related parameters, anesthesia type, kidney side, tubeless approach, and operative time. Although the group with renal dysfunction (grade 0: 66.7%; grade I: 18.5%; grade II: 14.8%; grade ≥III: 0.0%) had higher complications compared with group without renal dysfunction (grade 0: 81.5%; grade I: 5.3%; grade II: 10.9%; grade ≥III: 2.3%), this difference was not significant ($p = 0.111$) in univariate analysis due to a lack of control or adjustment of other variables. The following all affected the MCC: gender ($p = 0.040$), upper tract abnormality ($p = 0.002$), significant hydronephrosis ($p < 0.0001$), imaging for access ($p = 0.054$), calyx for access ($p = 0.019$), tract number ($p = 0.004$), and stone-free result ($p = 0.032$). The groups with significant hydronephrosis, ultrasonography, and stone-free also had lower complications. The groups with upper tract abnormality, multiple calices, and multiple tracts accesses had significantly lower rates of grade 0 complications and higher rates of other grades compared with the groups without abnormality, single calyx, and single tract accesses. Each MCC grade had significantly different mean preoperative hemoglobin ($p = 0.015$), postoperative hemoglobin ($p < 0.0001$), and postoperative hemoglobin drop ($p < 0.0001$) (Table 4).

In multivariate ordinal logistic regression analysis, anatomic upper tract abnormality (odds ratio [OR] 0.05), renal dysfunction (OR 0.32), the absence of significant hydronephrosis (OR 2.32), multiple tracts (OR 0.37), lower postoperative hemoglobin (OR 0.64), and higher postoperative hemoglobin drop (OR 1.57) were the significant parameters affecting MCC and predicting higher grades. We found that renal dysfunction, anatomic upper urinary tract abnormality, number of tract and postoperative hemoglobin protected this effect and prediction. A postoperative hemoglobin drop and significant hydronephrosis promoted the PCNL complication to a higher Clavien grade (Table 5).

## Discussion

In PCNL, many complications are minor and their precise reporting is necessary, although major complications or death may occur.[1-8,10,12] Compared with others studies, we had comparative results about complete supine PCNL complications according to the MCC.[3-8,10,12,15-17] The types of complications, their management, and outcomes affect this classification.[9,12] Therefore the MCC can be used to evaluate the severity of complications, yet it has its limitations. The MCC cannot predict the occurrence of a specific complication and cannot reveal its reason. Also due to different surgical managements, the subclassification of the higher Clavien grades has low reliability. If a single standardized manner is used for reporting and managing complications, the MCC can be applied to assess and compare PCNL complications at different centers or with techniques.[12,18,19] Improvement in the management of complications and detection of the factors affecting MCC can influence the severity of complications. Age, gender, BMI, hypertension, DM, cardiovascular disease, previous kidney or stone treatment and surgery, prior ESWL, preoperative hematocrit and kidney side had no significant effect on the mean Clavien score, risk of grade ≥IIIa, major complications or complication rate.[6,8,15,16,20-25] Some studies reported positive preoperative urine culture or pre-existent UTI as a significant parameter predicting complications.[15,16,20] However, in other studies, positive urine culture had no significant effect on the mean Clavien score, grade ≥IIIa or complications in multivariate analysis.[3,8,21] In our experience, age, gender, BMI, hypertension, DM, IHD, previous stone surgery and ESWL, preoperative hemoglobin, preoperative UTI and kidney side did not affect MCC. Positive preoperative urine culture does not predict urosepsis and systemic inflammatory response syndrome in PCNL.[26,27] Although antibiotic prophylaxis can decrease infectious complications,[28] the use of renal pelvic urine and stone cultures, and treatment of preoperative UTI should not be forgotten especially in patients with renal anomalies, hydronephrosis, large or staghorn stones and multiple tracts.[26,27]

One study reported no difference in the complication rates between groups with normal and impaired renal function.[29] However, another study reported that chronic kidney disease stages had significantly different complication rates and Clavien scores, and decreased kidney function came with an increase in complication rates.[30] In our study, renal dysfunction predicted complications and higher Clavien grades. Preoperative renal function may indeed predict PCNL complications and their severity.

Osther and colleagues reported similar complications and mean Clavien scores between groups with and without renal malformation.[31] In children, renal anomalies and solitary

| Table 2. Patient-, stone- and operation-related data and PCNL outcomes | | | |
|---|---|---|---|
| Mean age (SE, range), year | | 49.38 ± 12.63 (0.70, 16–78) | |
| Age groups | 15–44 years, n (%) | 114 (34.6%) | |
| | 45–59 years, n (%) | 139 (42.1%) | |
| | ≥ 60 years, n (%) | 77 (23.3%) | |
| Male/female ratio, n (%) | | 184 (55.8%)/146 (44.2%) | |
| Mean BMI (SE, range), kg/m$^2$ | | 28.03 ± 4.79 (0.27, 15.88–46.71) | |
| BMI groups | | | |
| | <25 kg/m$^2$, n (%) | 94 (28.5%) | |
| | 25–29.9 kg/m$^2$, n (%) | 128 (38.8%) | |
| | ≥30 kg/m$^2$, n (%) | 108 (32.7%) | |
| Mean preoperative hemoglobin (SE, range), g/dL | | 13.39 ± 1.63 (0.09, 9.1–19.1) | |
| Mean preoperative serum creatinine (SE, range), mg/dL | | 1.14 ± 0.62 (0.03, 0.50–8.80) | |
| Hypertension, n (%) | | 111 (33.6%) | |
| Diabetes mellitus, n (%) | | 64 (19.4%) | |
| Ischemic heart disease, n (%) | | 25 (7.6%) | |
| Previous stone surgery (open, PCNL) at the same side, n (%) | | 89 (27.0%) | |
| Previous ESWL at the same side, n (%) | | 139 (42.1%) | |
| Renal dysfunction (preoperative serum creatinine >1.4 mg/dl), n (%) | | 27 (8.2%) | |
| Anatomic upper urinary tract abnormality, n (%) | | | |
| | Duplication of collecting system, n (%) | | 3 (0.9%) |
| | Single kidney, n (%) | | 1 (0.3%) |
| | Polycystic kidney, n (%) | 8 (2.4%) | 1 (0.3%) |
| | Medullary sponge kidney, n (%) | | 1 (0.3%) |
| | Malrotation of kidney, n (%) | | 1 (0.3%) |
| | Lower calyx diverticulum, n (%) | | 1 (0.3%) |
| Pre-operative urinary tract infection, n (%) | | 99 (30%) | |
| Significant (moderate-severe) hydronephrosis, n (%) | | 194 (58.8%) | |
| Mean stone burden (SE, range), millimeter | | 35.11 ± 17.09 (0.95, 10–200) | |
| Stone number (single/multiple), n (%) | | 87 (26.4%)/243 (73.6%) | |
| Stone opacity (radio-opaque/radiolucent), n (%) | | 285 (86.4%)/45 (13.6%) | |

SE: standard error of the mean; MCC: modified Clavien classification; PCNL: percutaneous nephrolithotomy; BMI: body mass index; ESWL: extracorporeal shock wave lithotripsy

kidney had no significant effects on complication rates.[21] In our study, anatomic upper urinary tract abnormalities significantly affected MCC and came with higher complications. The following factors may affect surgical techniques regarding access to the collecting system, manipulation and removal of stone and increase the complication rate: alteration in position and axis of the kidney, renal morphology, vasculature and mobility of the kidney, morphology of calices, pelvis and upper ureter.[31,32] Laparoscopy, computed tomography or simultaneous use of fluoroscopy and ultrasonography might provide safe and easier access and manipulation in these cases.[31-33] Also case volume, surgeon experience, and type of anomaly can affect the PCNL outcomes.[3,15,31,32]

Pre-existent hydronephrosis did not predict major complications in the Olbert study.[20] Renal morphology (including hydronephrosis) had no significant effect on complications in staghorn stones.[15] In our study, significant hydronephrosis predicted lower complications in MCC. An appropriate anatomic space facilitates calyx puncturing, access to the collecting system and stone manipulation, and reduces renal and pelvi-calyceal trauma and complications.[32]

Stone-related parameters (opacity, number, burden, location, staghorn and complex stones) did not affect MCC in our experience. In multiple studies, stone burden had no significant effect on the mean Clavien score, risk of grade ≥IIIa, major complications, or complication rate.[8,15,16,20,21] In other studies, stone surface area or stone size significantly affected complications and mean Clavien score.[3,17] Moreover, stone location, staghorn and complex stones had a significant influence on mean Clavien score, Clavien grades, or complications in some studies.[3,10,16,21,34] In other studies, stone distribution and staghorn stone had no significant effect on complications or grade ≥IIIa.[6,17] Puncturing, access and stone removal largely affect PCNL complications.[4] Stone characteristics may have eligible effects on the occurrence and severity of PCNL complications.

Multiple studies[35-37] demonstrated comparative complication rates and Clavien classification of complications for general and spinal anesthesia similar to our results, although Cicek

**Table 2. Patient-, stone- and operation-related data and PCNL outcomes (cont'd)**

| | | | | |
|---|---|---|---|---|
| Stone location | Only one calyx, n (%) | | 71 (21.5%) | |
| | Only pelvis, n (%) | | 55 (16.7%) | |
| | Only upper ureter, n (%) | | 8 (2.4%) | |
| | Multiple locations, n (%) | | 163 (49.4%) | |
| | Staghorn, n (%) | | 33 (10.0%) | |
| Complex stones, n (%) | | | 196 (59.4%) | |
| Type of anesthesia | General, n (%) | | 320 (97.0%) | |
| | Spinal, n (%) | | 10 (3.0%) | |
| Kidney side (right/left), n (%) | | | 170 (51.5%)/160 (48.5%) | |
| Imaging for access | Fluoroscopy, n (%) | | 301 (91.2%) | |
| | Ultrasonography, n (%) | | 29 (8.8%) | |
| Calyx for access | Upper calyx group, n (%) | | 21 (6.4%) | |
| | Middle calyx group, n (%) | | 77 (23.3%) | |
| | Lower calyx group, n (%) | | 219 (66.4%) | |
| | Multiple calices group, n (%) | | 13 (3.9%) | |
| Number of tract (single / multiple), n (%) | | | 300 (90.9%)/30 (9.1%) | |
| Tubeless approach (without nephrostomy tube insertion), n (%) | | | 307 (93.0%) | |
| Mean operative time (SE, range), minute | | | 57.16 ± 28.94 (1.65, 10–195) | |
| Mean postoperative hospital Stay (SE, range), day | | | 2.23 ± 1.18 (0.06, 1–9) | |
| Mean postoperative hemoglobin (SE, range), g/dL | | | 12.13 ± 1.88 (0.10, 7.0–16.5) | |
| Mean postoperative hemoglobin drop (SE, range), g/dL | | | 1.27 ± 1.33 (0.07, 0.0–7.5) | |
| Stone-free result | Stone-free, n (%) | | 254 (77.0%) | |
| | Residual fragments, n (%) | | 76 (23.0%) | |
| Success (stone-free or residual fragments <4 mm at one day after operation), n (%) | | | 279 (84.5%) | |
| Complication, n (%) | | | 65 (19.7%) | |
| Blood transfusion, n (%) | | | 42 (12.7%) | |
| Transient low-grade fever, n (%) | | | 25 (7.6%) | |
| Significant life-threatening bleeding (gross hematuria, hematoma, hemoperitoneum), n (%) | | | 15 (4.5%) | |
| MCC of complications | Grade 0, n (%) | | 265 (80.3%) | |
| | Grade I, n (%) | | 21 (6.4%) | |
| | Grade II, n (%) | | 37 (11.2%) | |
| | | Grade III, n (%) | | 5 (1.5%) |
| | Grade ≥ III, n (%) | Grade IV, n (%) | 7 (2.1%) | 1 (0.3%) |
| | | Grade V, n (%) | | 1 (0.3%) |

SE: standard error of the mean; MCC: modified Clavien classification; PCNL: percutaneous nephrolithotomy; BMI: body mass index; ESWL: extracorporeal shock wave lithotripsy

and colleagues reported higher minor complications (grades I-II), lower major complications (grades ≥IIIa), and lower rates of thce grades of II-IIIb and IVb for spinal anesthesia.[35]

We found that imaging for access did not affect MCC in multivariate analysis. Different studies demonstrated similar complications between ultrasonography and fluoroscopy, and imaging type had no significant effect on complication rates in children.[21,38,39] Ultrasonography can be an appropriate alternative for fluoroscopy due to suitable outcomes, minimum radiation exposure, proper anatomical identification despite longer access and operative times, and the need for adequate skills or experience.[32,33,38-40]

In children, mid-calyceal puncture had a significant effect on complications.[21] Shin and colleagues found that a punctured calyx did not predict grade ≥IIIa.[6] Aron and colleagues reported similar complication rates for superior and inferior calyceal punctures in complex inferior calyceal stones.[41] In another study, middle and lower calices accesses had similar complication rates and MCC.[42] In our study, calyx for access did not predict MCC in multivariate analysis. If the calyx is selected for access based on renal anatomy, stone location, operation condition and surgeon preference, the safe and successful access and removal of stone can be achieved.

The meta-analysis study revealed no significant difference between tubeless and standard PCNL regarding complication rate.[43] In our study, the tubeless approach had no significant effect on MCC.

There are different results about the effect of operative time on complications.[3,6,8,16,21] Onal and colleagues found that operative time significantly affected the complication rate in children.[21] Labate and colleagues found that prolonged operative time significantly predicted a higher

**Table 3. MCC and managements of PCNL complications**

| Type of complication | N (%) | Clavien grade | Management |
|---|---|---|---|
| Transient low-grade fever | 17 (5.2%) | Grade I | Conservative management |
| Bleeding requiring blood transfusion | 24 (7.3%) | Grade II | Blood transfusion |
| Transient low-grade fever and bleeding requiring blood transfusion | 6 (1.8%) | Grade II | Conservative management for fever, blood transfusion |
| Extravasation | 1 (0.3%) | Grade I | WW and conservative management |
| Bleeding requiring blood transfusion, extravasation | 1 (0.3%) | Grade II | Blood transfusion, WW and conservative management for extravasation |
| Gross hematuria | 3 (0.9%) | Grade I | WW and conservative management |
| Gross hematuria, bleeding requiring blood transfusion | 1 (0. 3%) | Grade II | WW and conservative management for hematuria, blood transfusion |
| Transient low-grade fever, gross hematuria, bleeding requiring blood transfusion | 1 (0.3%) | Grade II | Conservative management for fever, WW and conservative management for hematuria, blood transfusion |
| Transient low-grade fever, bleeding requiring blood transfusion, urinary leakage | 1 (0.3%) | Grade II | Blood transfusion, conservative management for fever, WW and conservative management for urinary leakage |
| Gross hematuria, bladder retention with blood clot, bleeding requiring blood transfusion | 1 (0.3%) | Grade III | WW and conservative management for hematuria, bladder catheterization and multiple washouts/irrigations and removal of clots, blood transfusion |
| Gross hematuria, bladder retention with blood clot, bleeding requiring blood transfusion | 1 (0.3%) | Grade III | WW and conservative management for hematuria, bladder catheterization and multiple washouts/irrigations and removal of clots, blood transfusion, angiography |
| Delayed gross hematuria, bleeding requiring blood transfusion | 2 (0.6%) | Grade II | Watchful waiting and conservative management for hematuria, blood transfusion |
| Delayed gross hematuria, bladder retention with blood clot, ureteral obstruction with clot | 1 (0.3%) | Grade III | WW and conservative management for hematuria, bladder catheterization and multiple washouts/irrigations and removal of clots, cystoscopy and ureteric double-J stent insertion |
| Delayed recurrent gross hematuria, bladder retention with blood clot, bleeding requiring blood transfusion, interlobar artery pseudoaneurism of lower pole of kidney | 1 (0.3%) | Grade III | Conservative management for hematuria, bladder catheterization and multiple washouts/irrigations and removal of clots, blood transfusion, angiography and coil angioembolization |
| Gross hematuria, bladder retention with blood clot, bleeding requiring blood transfusion, retroperitoneal hematoma and renal vein thrombosis | 1 (0.3%) | Grade III | Bladder catheterization and multiple washouts/irrigations and removal of clots, blood transfusion, cystoscopy and ureteric double-J stent insertion, WW and conservative management for hematuria and hematoma and renal vein thrombosis |
| Perinephric hematoma, bleeding requiring blood transfusion | 1 (0.3%) | Grade II | WW and conservative management for hematoma, blood transfusion |
| Extravasation, delayed gross hematuria, bladder retention with blood clot and organized hematoma formation, ureteral obstruction with clot, bleeding requiring blood transfusion, impaired renal function (serum creatinine 9.5 mg/dL) | 1 (0.3%) | Grade IV | WW and conservative management for extravasation and hematuria, bladder catheterization and multiple washouts/irrigations and removal of clots and organized hematoma, cystoscopy and ureteric double-J stent insertion, blood transfusion, hemodialysis |
| Colon injury, hemoperitoneoum and bleeding requiring blood transfusion leading to acute renal failure and death | 1 (0.3%) | Grade V | Nephrectomy, blood transfusion, IV fluid and antibiotics, ICU management |

MCC: modified Clavien classification; PCNL: percutaneous nephrolithotomy; WW: watchful waiting; IV: intravenous; ICU: intensive care unit.

mean Clavien score and risk of grade ≥IIIa.[8] However, operative time did not predict grade ≥IIIa or complications in others studies.[3,6,16] In our study, operative time did not affect MCC. All PCNLs were performed by a single experienced endourologist. The learning curve and experience can affect performance of access, operative time, and complications.[3,15,18]

Hegarty and colleagues reported similar complication rates for single tract and multiple tracts accesses without consideration of transfusion.[44] Multi-puncture was not a significant

**Table 4. Patient-, stone- and operation-related parameters and modified Clavien grading of complications**

| Parameter | | Grade 0 | Grade I | Grade II | Grade ≥III | *p* value |
|---|---|---|---|---|---|---|
| Mean age (SE, range), year | | 49.64 ± 12.79 (0.80, 16–78) | 45.43 ± 10.42 (2.27, 26–66) | 49.05 ± 12.21 (2.01, 26–75) | 53.29 ± 14.76 (5.58, 27–70) | 0.471† |
| Age grouping, years, n (%) | 15–44 | 88 (77.2%) | 9 (7.9%) | 15 (13.2%) | 2 (1.7%) | 0.582§ |
| | 45–59 | 112 (80.6%) | 11 (7.9%) | 15 (10.8%) | 1 (0.7%) | |
| | ≥60 | 65 (84.4%) | 1 (1.3%) | 7 (9.1%) | 4 (5.2%) | |
| Gender, n (%) | Male | 155 (84.2%) | 11 (6.0%) | 14 (7.6%) | 4 (2.2%) | 0.040‡ |
| | Female | 110 (75.3%) | 10 (6.8%) | 23 (15.8%) | 3 (2.1%) | |
| Mean BMI (SE, range), kg/m$^2$ | | 28.14 ± 4.93 (0.31, 15.88–46.71) | 27.15 ± 3.70 (0.81, 20.95–36.99) | 27.29 ± 4.49 (0.76, 18.60–37.11) | 30.63 ± 2.85 (1.16, 28.34–36.20) | 0.476† |
| BMI grouping, n (%) | <25 kg/m$^2$ | 78 (83.0%) | 6 (6.4%) | 10 (10.6%) | 0 (0.0%) | 0.238§ |
| | 25–29.9 kg/m$^2$ | 97 (75.8%) | 10 (7.8%) | 16 (12.5%) | 5 (3.9%) | |
| | ≥30 kg/m$^2$ (obese) | 90 (83.3%) | 5 (4.6%) | 11 (10.2%) | 2 (1.9%) | |
| Mean preoperative hemoglobin (SE, range), g/dL | | 13.49 ± 1.51 (0.09, 9.6–18.0) | 13.71±2.18 (0.47, 9.1–19.1) | 12.39 ± 1.79 (0.30, 9.2–16.5) | 13.55 ± 1.92 (0.78, 10.0–15.4) | 0.015† |
| Hypertension, n (%) | Yes | 89 (80.2%) | 7 (6.3%) | 10 (9.0%) | 5 (4.5%) | 0.883‡ |
| | No | 176 (80.4%) | 14 (6.4%) | 27 (12.3%) | 2 (0.9%) | |
| DM, n (%) | Yes | 54 (84.4%) | 4 (6.2%) | 5 (7.8%) | 1 (1.6%) | 0.339‡ |
| | No | 211 (79.3%) | 17 (6.4%) | 32 (12.0%) | 6 (2.3%) | |
| IHD, n (%) | Yes | 20 (80.0%) | 1 (4.0%) | 1 (4.0%) | 3 (12.0%) | 0.790‡ |
| | No | 245 (80.3%) | 20 (6.6%) | 36 (11.8%) | 4 (1.3%) | |
| Renal dysfunction (serum Cr >1.4 mg/dL, n (%) | Yes | 18 (66.7%) | 5 (18.5%) | 4 (14.8%) | 0 (0.0%) | 0.111‡ |
| | No | 247 (81.5%) | 16 (5.3%) | 33 (10.9%) | 7 (2.3%) | |
| Anatomic upper urinary tract abnormality, n (%) | Yes | 3 (37.5%) | 2 (25.0%) | 1 (12.5%) | 2 (25.0%) | 0.002‡ |
| | No | 262 (81.4%) | 19 (5.9%) | 36 (11.2%) | 5 (1.5%) | |
| Preoperative UTI, n (%) | Yes | 82 (82.8%) | 10 (10.1%) | 3 (3.0%) | 4 (4.1%) | 0.368‡ |
| | | 183 (79.2%) | 11 (4.8%) | 34 (14.7%) | 3 (1.3%) | |
| Previous stone surgery, n (%) | Yes | 69 (77.5%) | 6 (6.7%) | 11 (12.4%) | 3 (3.4%) | 0.410‡ |
| | No | 196 (81.3%) | 15 (6.2%) | 26 (10.8%) | 4 (1.7%) | |
| Previous ESWL, n (%) | Yes | 113 (81.3%) | 10 (7.2%) | 13 (9.3%) | 3 (2.2%) | 0.650‡ |
| | No | 152 (79.6%) | 11 (5.7%) | 24 (12.6%) | 4 (2.1%) | |
| Stone number, n (%) | Single | 72 (82.8%) | 4 (4.6%) | 9 (10.3%) | 2 (2.3%) | 0.546‡ |
| | | 193 (79.4%) | 17 (7.0%) | 28 (11.5%) | 5 (2.1%) | |

SE: standard error of the mean; BMI: body mass index; DM: diabetes mellitus; IHD: ischemic heart disease; UTI: urinary tract infection; ESWL: extracorporeal shock wave lithotripsy; †Spearman test; ‡Mann-Whitney test; §Kruskal-Wallis test.

factor predicting grade ≥IIIa.[6] Tract number[15,21] had no significant effect on complications in staghorn stones or children. But Netto and colleagues reported higher complication rates for multiple accesses versus upper pole and lower/middle calices accesses in staghorn stones.[45] In our experience, multiple tracts predicted higher complications in MCC. Many of our complications were related to vascular events, bleeding, and transfusion. The multiple tracts approach comes with increased blood loss and transfusion.[46,47]

In Onal study, postoperative hematocrit had no significant effect on complication rate in children.[21] In our experience, postoperative hemoglobin and hemoglobin drop significantly affected MCC. Most of our complications were bleeding events. Lower postoperative hemoglobin and higher postoperative hemoglobin drop can imply serious injury to the vascular system or parenchyma and predict increased Clavien grades.

Similarly, the success or stone-free status affected complications in the Onal[21] study and the group with residual fragments also had higher complications in univariate analysis. The PCNL complication was an outcome independent of the PCNL success. In multivariate analysis, the success had no significant effect on complication rates in children.[21] Similarly, the stone-free result did not predict complications based on MCC in multivariate analysis in our study.

Our study has its limitations. Although we included all cases during the study period, we had low number of cases in the higher Clavien grades and some subgroups of variables. Also some techniques were not used due to surgeon. We did not assess the following factors that may affect

| Table 4. Patient-, stone- and operation-related parameters and modified Clavien grading of complications (cont'd) | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | | **Grade 0** | **Grade I** | **Grade II** | **Grade ≥III** | ***p* value** |
| Mean stone burden (SE, range), mm | | 34.97 ± 17.26 (1.06, 10–200) | 33.90 ± 16.86 (3.68, 20–78) | 37.10 ± 16.84 (2.85, 12–85) | 34.14 ± 15.24 (5.76, 17–61) | 0.846† |
| Stone opacity, n (%) | Radio-opaque | 229 (80.3%) | 17 (6.0%) | 32 (11.2%) | 7 (2.5%) | 0.941‡ |
| | Radiolucent | 36 (80.0%) | 4 (8.9%) | 5 (11.1%) | 0 (0.0%) | |
| Stone location, n (%) | One calyx | 55 (77.5%) | 5 (7.0%) | 9 (12.7%) | 2 (2.8%) | 0.860§ |
| | Pelvis | 46 (83.6%) | 6 (10.9%) | 3 (5.5%) | 0 (0.0%) | |
| | Upper ureter | 7 (87.5%) | 0 (0.0%) | 0 (0.0%) | 1 (12.5%) | |
| | Multiple locations | 130 (79.8%) | 9 (5.5%) | 20 (12.3%) | 4 (2.4%) | |
| | Staghorn | 27 (81.8%) | 1 (3.0%) | 5 (15.2%) | 0 (0.0%) | |
| Staghorn stone, n (%) | Yes | 27 (81.8%) | 1 (3.0%) | 5 (15.2%) | 0 (0.0%) | 0.847‡ |
| | No | 238 (80.1%) | 20 (6.7%) | 32 (10.8%) | 7 (2.4%) | |
| Complex stones, n (%) | Yes | 157 (80.1%) | 10 (5.1%) | 25 (12.8%) | 4 (2.0%) | 0.818‡ |
| | No | 108 (80.6%) | 11 (8.2%) | 12 (9.0%) | 3 (2.2%) | |
| Hydronephrosis, n (%) | Moderate or severe (significant) | 171 (88.1%) | 11 (5.7%) | 7 (3.6%) | 5 (2.6%) | <0.0001‡ |
| | Nil or Mild | 94 (69.1%) | 10 (7.3%) | 30 (22.1%) | 2 (1.5%) | |
| Type of anesthesia, n (%) | General | 256 (80.0%) | 20 (6.2%) | 37 (11.6%) | 7 (2.2%) | 0.377‡ |
| | Spinal | 9 (90.0%) | 1 (10.0%) | 0 (0.0%) | 0 (0.0%) | |
| Kidney side, n (%) | Right | 136 (80.0%) | 12 (7.0%) | 20 (11.8%) | 2 (1.2%) | 0.975‡ |
| | Left | 129 (80.7%) | 9 (5.6%) | 17 (10.6%) | 5 (3.1%) | |
| Imaging for access, n (%) | Fluoroscopy | 238 (79.1%) | 19 (6.3%) | 37 (12.3%) | 7 (2.3%) | 0.054‡ |
| | Ultrasonography | 27 (93.1%) | 2 (6.9%) | 0 (0.0%) | 0 (0.0%) | |
| Calyx for access, n (%) | Upper calyx group | 16 (76.2%) | 1 (4.8%) | 4 (19.0%) | 0 (0.0%) | 0.019§ |
| | Middle calyx group | 64 (83.1%) | 5 (6.5%) | 6 (7.8%) | 2 (2.6%) | |
| | Lower calyx group | 179 (81.7%) | 12 (5.5%) | 24 (11.0%) | 4 (1.8%) | |
| | Multiple calices group | 6 (46.1%) | 3 (23.1%) | 3 (23.1%) | 1 (7.7%) | |
| Number of tract, n (%) | Single tract | 247 (82.3%) | 17 (5.7%) | 30 (10.0%) | 6 (2.0%) | 0.004‡ |
| | Multiple tracts | 18 (60.0%) | 4 (13.3%) | 7 (23.4%) | 1 (3.3%) | |
| Nephrostomy tube insertion, n (%) | Yes (standard) | 17 (73.9%) | 1 (4.4%) | 5 (21.7%) | 0 (0.0%) | 0.404‡ |
| | No (tubeless) | 248 (80.8%) | 20 (6.5%) | 32 (10.4%) | 7 (2.3%) | |
| Mean operative time (SE, range), minute | | 56.37 ± 29.80 (1.89, 10–195) | 61.39 ± 32.30 (7.61, 15–120) | 62.41 ± 21.04 (3.61, 20–110) | 47.50 ± 18.64 (7.61, 20–75) | 0.124† |
| Mean postoperative hemoglobin (SE, range), g/dL | | 12.49 ± 1.60 (0.10, 8.1–16.4) | 12.61 ± 1.95 (0.42, 9.0–16.5) | 9.47 ± 1.33 (0.22, 7.0–13.7) | 11.00 ± 2.36 (0.96, 8.0–14.0) | <0.0001† |
| Mean postoperative hemoglobin drop (SE, range), g/dL | | 1.02 ± 1.04 (0.06, 0.0–7.5) | 1.13 ± 1.06 (0.23, 0.0–3.1) | 2.92 ± 1.72 (0.29, 0.0–6.7) | 2.55 ± 2.74 (1.12, 0.0–7.4) | <0.0001† |
| Stone-free result, n (%) | Stone-free | 211 (83.1%) | 13 (5.1%) | 23 (9.0%) | 7 (2.8%) | 0.032‡ |
| | Residual fragments | 54 (71.1%) | 8 (10.5%) | 14 (18.4%) | 0 (0.0%) | |

SE: standard error of the mean; BMI: body mass index; DM: diabetes mellitus; IHD: ischemic heart disease; UTI: urinary tract infection; ESWL: extracorporeal shock wave lithotripsy; †Spearman test; ‡Mann-Whitney test; §Kruskal-Wallis test.

access to the collecting system, stone manipulation and complication rate: vertebral column, pelvis and upper ureter anatomy, mobility of kidney, location of calyceal puncture, diameter of calyceal infundibulum, angle between calyces, angle between calyx tract with pelvis and long axis of kidney or vertebra, inflammation around ureteropelvic junction or upper ureteral stone, adequate visibility during access (in severe bleeding or complete space-occupying stone and stone fragments migration into other calyces.

**Table 5. Factors affecting modified Clavien grading of complications in multivariate analysis**

| Parameter | | Estimate | SE | *p* value | OR | 95% CI of OR |
|---|---|---|---|---|---|---|
| Postoperative hemoglobin | | -0.444 | 0.106 | <0.0001 | 0.64 | 0.52–0.79 |
| Postoperative hemoglobin drop | | 0.448 | 0.124 | <0.0001 | 1.57 | 1.23–2.00 |
| Renal dysfunction | No | -1.125 | 0.504 | 0.026 | 0.32 | 0.12–0.87 |
| | Yes | 0 | | | | |
| Anatomic upper urinary tract abnormality | No | -3.085 | 0.734 | <0.0001 | 0.05 | 0.01–0.19 |
| | Yes | 0 | | | | |
| Significant (moderate-severe) hydronephrosis | No | 0.841 | 0.331 | 0.011 | 2.32 | 1.21–4.43 |
| | Yes | 0 | | | | |
| Number of tract | Single | -0.999 | 0.471 | 0.034 | 0.37 | 0.15–0.93 |
| | Multiple | 0 | | | | |

SE: standard error of the mean; OR: odds ratio; CI: confidence interval.

## Conclusion

In complete supine PCNL, many complications were in the lower Clavien grades and major complications were uncommon. We found that renal dysfunction, upper urinary tract abnormality, significant hydronephrosis, multiple tracts, postoperative hemoglobin and hemoglobin drop predicted MCC complications.

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