RESEARCH ARTICLE

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Impact of Ureteral Stone Size and Location on Hydronephrosis Severity: A Retrospective Non-contrast CT Study

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Abstract

Objectives: To evaluate the relationship between stone size, stone location, and the presence and severity of hydronephrosis in patients with a single unilateral ureteral stone identified on non-contrast computed tomography (CT).

Methods: In this retrospective single-center study, adult patients with a single, unilateral ureteral stone detected on non-contrast CT examinations of the urinary tract performed between February 7, 2022, and April 13, 2026, were included. Stone size, location, hydronephrosis status and grade, and accompanying imaging findings were recorded. Associations between stone characteristics and hydronephrosis severity were assessed using correlation analyses, chi-square tests, and regression models. Receiver operating characteristic (ROC) analysis was performed to evaluate the ability of stone size to predict moderate-to-severe hydronephrosis.

Results: A total of 128 patients were included. The median age was 45 years; 77.3% were male. Hydronephrosis was present in 116 patients (90.6%), while 58 patients (45.3%) had moderate-to-severe hydronephrosis. Stone size increased significantly with greater hydronephrosis severity (rho=0.422, p<0.001). In multivariable ordinal logistic regression analysis, each 1-mm increase in stone size was independently associated with a higher hydronephrosis grade [odds ratio (OR): 1.20, 95% confidence interval (CI): 1.07-1.33, p=0.001]. Proximal or mid-ureteral stones were also independently associated with greater hydronephrosis severity compared with distal/ureterovesical junction stones (OR: 2.40, 95% CI: 1.14-5.07, p=0.022). The area under the curve for predicting moderate-to-severe hydronephrosis was 0.747.

Conclusion: Increasing stone size is independently associated with greater hydronephrosis severity in patients with a single unilateral ureteral stone. Proximal or mid-ureteral stone locations are also associated with more advanced hydronephrosis. These findings suggest that stone characteristics may provide valuable information regarding the severity of urinary tract obstruction.

Keywords: Ureteral stone, hydronephrosis, computed tomography, urinary obstruction

Introduction

Ureteral stones are a common cause of acute flank pain and can lead to urinary obstruction ranging from mild collecting system dilation to significant hydronephrosis requiring urgent treatment. Non-contrast computed tomography (CT) is a fundamental confirmatory imaging modality in patients with suspected acute ureteral stone because it accurately demonstrates the presence, size, and location of the stone and permits evaluation of accompanying urinary system dilation. These findings are clinically important because the likelihood of ongoing obstruction and spontaneous stone passage is low, which are key factors influencing the decision for active treatment.[1,2]

Stone size and location are well-known determinants of the likelihood of spontaneous passage. Small and distally located ureteral stones are more likely to pass spontaneously, while intervention is more frequently reported for large and proximally located stones.[3,4] Hydronephrosis, as an imaging finding of obstruction, can provide additional information to the clinical evaluation. In a large multicenter cohort including patients with confirmed ureteral stones via CT, it was reported that the frequency of stones of 5 mm and above and the rate of spontaneous passage failure increased with increasing severity of hydronephrosis.[5]

However, the number of studies directly evaluating the relationship between the size and localization of ureteral stones and the degree of hydronephrosis is limited. Song et al.[6] reported that in patients with a single unilateral ureteral stone, stone diameter was associated with the degree of hydronephrosis, but stone localization did not show a significant relationship. A study from Türkiye also showed that an increase in stone size was associated with a higher degree of hydronephrosis, while there was no significant relationship between

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stone localization and the degree of hydronephrosis.[7] In a more recent study, all urinary system stones were evaluated and it was reported that larger stones were associated with more advanced degrees of hydronephrosis; however, this study was not limited to ureteral stones only.[8]

The aim of this retrospective study was to evaluate the relationship between stone size and localization, and the presence and degree of hydronephrosis in patients with unilateral single ureteral stones identified on non-contrast CT scans.

Methods

Study Design and Patient Selection

The study was approved by the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (approval no: 2026-01/03; date: 08.01.2026). The requirement for informed consent from the ethics committee was waived. Non-contrast urinary system CT reports in our institution's radiology report archive, issued between February 7, 2022, and April 13, 2026, were searched using keywords related to ureteral stones. A total of 150 cases with reported ureteral stones were included in the initial dataset.

The study included adult patients whose non-contrast CT report clearly indicated a single unilateral ureteral stone, with stone size reported in millimeters and the presence and degree of hydronephrosis documented. Patients with bilateral ureteral stones, those with multiple ureteral stones on the same examination, and those with poor image quality were excluded. Based on these criteria, the main analysis cohort consisted of 128 patients.

Data Collection and Variable Definition

Information on patients' ages, gender, stone side, stone localization, stone size, presence and degree of hydronephrosis, concomitant renal stones, and contamination of the perirenal and periureteral fatty planes was extracted.

Stone localization was classified into three groups: proximal ureter, mid ureter, and distal ureter/ureterovesical junction (UVJ). Stones described as at the ureteropelvic junction or in the proximal ureter were evaluated in the proximal group; stones described as at the UVJ or in the distal ureter were evaluated in the distal/UVJ group. Stone size was recorded as a continuous variable in millimeters; it was also divided into three categories: <5 mm, 5-<10 mm, and ≥10 mm, similar to classifications in previous studies.[6,7] Hydronephrosis was graded on non-contrast CT according to the degree of dilatation of the renal collecting system and associated changes in the calyces and renal parenchyma. Hydronephrosis was classified into four categories: none, minimal/mild, moderate, and severe. No hydronephrosis was defined as the absence of dilatation of the collecting system. Minimal or mild hydronephrosis was defined as dilatation of the renal pelvis, calyces, or both with preservation of normal renal parenchymal thickness. Moderate hydronephrosis was defined as a more pronounced dilatation of the renal pelvis and calyces with calyceal rounding or increased calyceal prominence, without substantial renal parenchymal thinning. Severe hydronephrosis was defined as marked dilatation of the renal pelvis and calyces accompanied by renal parenchymal thinning. The grading approach was based on previously described imaging criteria for the assessment of hydronephrosis severity in patients with ureteral calculi.[8] Contamination of the perirenal and periureteral fatty planes was recorded.

Outcome Variables

The primary outcome of the study was the relationship of stone size and localization with the degree of hydronephrosis. In secondary analyses, hydronephrosis was classified as absent/minimal-mild and moderate/severe, the latter representing clinically more pronounced dilation. The predictive performance of stone size for moderate/severe hydronephrosis was also evaluated. The relationship between perirenal contamination and moderate/severe hydronephrosis was investigated in an exploratory analysis.

Statistical Analysis

The distribution of continuous variables was evaluated using visual and analytical methods. Continuous variables that were non-normally distributed were presented as median and interquartile range (IQR), and categorical variables as number and percentage. The Kruskal-Wallis test was used to compare stone size across hydronephrosis grades. The relationship between stone size and ordinal hydronephrosis grade was assessed using Spearman's rank correlation.

Relationships among stone size categories, stone localization, and the degree of hydronephrosis were examined using Pearson's chi-square test; p-values obtained using the Monte Carlo method were reported for comparisons in which the expected cell counts were low. In the multivariate logistic regression analysis, the presence of moderate/severe hydronephrosis was taken as the dependent variable, and stone size, stone localization, age, and gender were included as independent variables. In addition, an ordinal logistic regression was performed with the degree of hydronephrosis as the ordinal outcome.

The ability of stone size to differentiate moderate from severe hydronephrosis was evaluated using receiver operating characteristic analysis, and the area under the curve (AUC) was reported with its 95% confidence interval. The optimal threshold was determined in an exploratory manner using the Youden index. All tests were two-way, and $p<0.05$ was accepted as the level of statistical significance. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA).

Findings

Initially, 150 patients with reported ureteral stones were identified. Of these, 5 patients were excluded because of bilateral ureteral stones, 8 because of multiple ureteral stones, 4 because the stone localization could not be assigned to a single ureteral segment, and 5 because of insufficient image quality. Thus, 128 patients were included in the final analysis.

The median age of the main cohort was 45.0 years (IQR, 37.0-56.2); 99 (77.3%) patients were male. 66 (51.6%) of the stones were located in the right ureter, and 62 (48.4%) were located in the left ureter. The median stone size was 6.0 mm (IQR, 4.0-8.5; range, 2.0-27.0 mm). 52 (40.6%) of the stones were located in the proximal ureter, 8 (6.2%) in the mid-ureter, and 68 (53.1%) in the distal ureter or at the UVJ. The median stone size was 6.0 mm (IQR, 4.5-9.0 mm) in the proximal ureter, 5.5 mm (IQR, 4.0-7.0 mm) in the mid-ureter, and 5.5 mm (IQR, 3.5-8.0 mm) in the distal ureter/UVJ. Hydronephrosis was present in 116 patients (90.6%), with moderate or severe hydronephrosis detected in 58 patients (45.3%) (Table 1, Figure 1).

Stone size increased with the severity of hydronephrosis. Median stone sizes were 5.0 mm (IQR, 4.0-6.0); 4.75 mm (IQR, 4.0-6.5); 6.5 mm (IQR, 5.5-10.0); and 9.0 mm (IQR, 7.0-9.93) in patients without hydronephrosis, with minimal or mild, moderate, and severe hydronephrosis, respectively. The difference between the groups was statistically significant (Kruskal-Wallis H=26.434; p<0.001). A moderate positive correlation was found between stone size and the degree of hydronephrosis (rho=0.422; p<0.001) (Table 2, Figure 2).

Table 1. Demographic and imaging characteristics of the main analysis cohort

Variable	Value
Total number of patients	128
Age, years; median (IQR)	45.0 (37.0-56.2)
Gender	
Male	99 (77.3)
Female	29 (22.7)
Stone side	
Right	66 (51.6)
Left	62 (48.4)
Stone size, mm; median (IQR)	6.0 (4.0-8.5)
Stone size, mm; range	2.0-27.0
Stone location	
Proximal ureter	52 (40.6)
Mid-ureter	8 (6.2)
Distal ureter/UVJ	68 (53.1)
Presence of hydronephrosis	
Absent	12 (9.4)
Present	116 (90.6)
Grade of hydronephrosis	
Absent	12 (9.4)
Minimal/mild	58 (45.3)
Moderate	48 (37.5)
Severe	10 (7.8)
Moderate/severe hydronephrosis	58 (45.3)
Concomitant renal stone	63 (49.2)
Perirenal/periureteral stranding	47 (36.7)

Categorical variables are presented as number and percentage
IQR, Interquartile range; UVJ, Ureterovesical junction

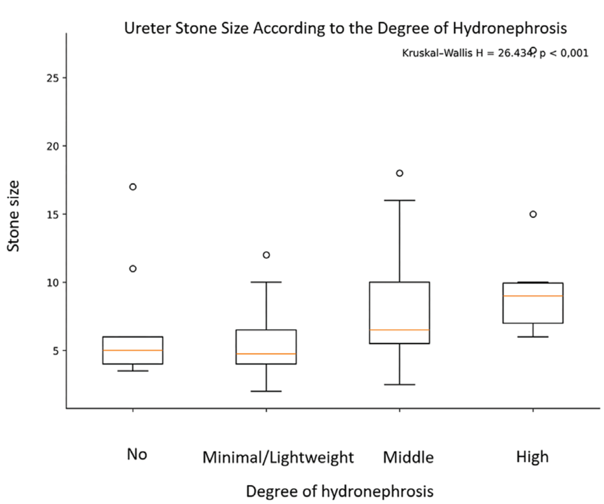

Figure 1. Ureter stone size according to degree of hydromephrosis

The rates of moderate-to-severe hydronephrosis differed significantly across stone size categories. Moderate/severe hydronephrosis was observed in nine patients (20.9%) with <5 mm stones, in 33 patients (51.6%) with 5-<10 mm stones, and in 16 patients (76.2%) with ≥10 mm stones (χ^2=21.755; Monte Carlo p<0.001) (Table 2).

Stone localization was also related to the degree of hydronephrosis. The rate of moderate/severe hydronephrosis was 61.5% (32/52) in patients with proximal ureteral stones, 75.0% (6/8) in mid-ureteral stones, and 29.4% (20/68) in distal/UVJ stones (χ^2=19.153; Monte Carlo p=0.005) (Table 3).

In multivariate ordinal logistic regression analysis, each 1 mm increase in stone size was associated with an increased probability of a higher degree of hydronephrosis (OR, 1.20; 95% CI: 1.07-1.33; p=0.001). Proximal- or middle-located stones were also independently associated with a higher degree of hydronephrosis compared with distal- or UVJ-located stones (OR, 2.40; 95% CI: 1.14-5.07; p=0.022). Age and gender were not significant independent predictors (Table 4).

In the logistic regression analysis, in which hydronephrosis was classified as absent/minimal-mild and moderate/severe, each 1-mm increase in stone size was associated with an increased probability of moderate/severe hydronephrosis (OR, 1.28; 95% CI: 1.09-1.50; p=0.002). Proximal or middle location was also associated with moderate to severe hydronephrosis (OR, 2.40; 95% CI: 1.06-5.45; p=0.036) (Table 4).

The ability of stone size to distinguish moderate from severe hydronephrosis was moderate (AUC, 0.747; 95% CI: 0.663-0.828). For the exploratory threshold of ≥5.2 mm, sensitivity was 82.8% and specificity was 61.4% (Table 4). This threshold was derived from the present dataset for exploratory purposes and should not be interpreted as a clinical decision threshold. No significant association was found between the presence of perirenal/periureteral contamination and moderate/severe hydronephrosis (p=0.417).

Discussion

In this study, the relationship between stone size and location and the degree of hydronephrosis was evaluated in patients with single unilateral ureteral stones identified on non-contrast CT scans. The main finding was that the degree of hydronephrosis increased significantly with stone size: each 1 mm increase in stone size was associated with a 20% increased probability of a higher degree of hydronephrosis (OR, 1.20; 95% CI: 1.07-1.33; p=0.001) and a 28% increased probability of moderate/severe hydronephrosis (OR, 1.28; 95% CI: 1.09-1.50; p=0.002). Furthermore, proximal- and middle-located stones were associated with a higher degree of hydronephrosis compared to distal/UVJ stones (OR, 2.40; 95% CI: 1.14-5.07; p=0.022).

The association between stone location and hydronephrosis severity persisted after adjustment for stone size, age, and gender in the multivariable ordinal logistic regression model. Proximal/middle ureteral location was associated with higher odds of having a greater hydronephrosis grade compared with the distal/UVJ location (OR, 2.40; 95% CI: 1.14-5.07; p=0.022), indicating that the observed association was not explained solely by stone size. One possible explanation is that the anatomical level of obstruction may influence the extent of

Table 2. Relationship between stone size and grade of hydronephrosis

A. Stone size according to grade of hydronephrosis

Grade of hydronephrosis	Number of patients	Stone size, mm; median (IQR)	Stone size, mm; mean ± SD
None	12	5.00 (4.00-6.00)	6.25±3.92
Minimal/mild	58	4.75 (4.00-6.50)	5.27±2.14
Moderate	48	6.50 (5.50-10.00)	7.95±3.88
Severe	10	9.00 (7.00-9.93)	10.67±6.28

A. Statistical analysis: Kruskal-Wallis H=26.434; p<0.001. Spearman correlation between stone size and grade of hydronephrosis: rho=0.422; p<0.001

B. Distribution of hydronephrosis according to stone size categories

Stone size category	Number of patients	No HN	Minimal/mild HN	Moderate HN	Severe HN	Moderate/severe HN, n (%)
<5 mm	43	5	29	9	0	9 (20.9)
5-<10 mm (51.6)	64	5	26	26	7	33
≥10 mm (76.2)	21	2	3	13	3	16

B. Statistical analysis: Monte Carlo Pearson chi-square test: χ^2=21.755; p<0.001

C. Pairwise comparison of stone size across hydronephrosis grades

Comparison	Adjusted p-value
None vs. minimal/mild	0.621
None vs. moderate	0.116
None vs. severe	0.024
Minimal/mild vs. moderate	<0.001
Minimal/mild vs. severe	<0.001
Moderate vs. severe	0.141

Holm correction was applied for pairwise comparisons
HN: Hydronephrosis, IQR: Interquartile range, SD: Standard deviation

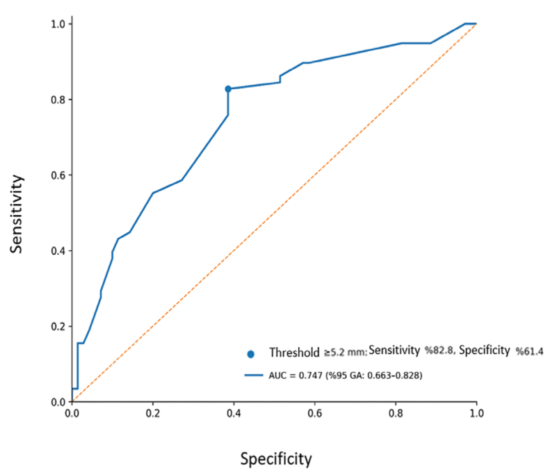

Figure 2. Performance of stone size in distinguishing moderate from severe hydronephrosis

AUC: Area under the curve

upstream urinary tract dilatation. However, this interpretation should be considered with caution because data on symptom duration, obstruction duration, and other clinical factors that may affect hydronephrosis were not available in our dataset. In addition, the small number of mid-ureteral stones limits the precision and generalizability of the localization findings.

The relationship between stone size and the degree of hydronephrosis is generally consistent with findings from previous studies. Song et al.[6] reported that stone diameter and craniocaudal stone length were significantly associated with the degree of hydronephrosis in 248 patients with unilateral single ureteral stones. Akçiçek and Buğday[7] from Türkiye also showed that the degree of hydronephrosis increased with increasing stone size in a cohort of 105 patients. Similarly, Alshoabi et al.[9] reported that larger stones were associated with higher-grade hydronephrosis; however, their study only evaluated stones causing hydronephrosis and included stones from the renal pelvis and pelviureteric junction. Our study evaluates this relationship in a more homogeneous clinical cohort, as it includes patients without hydronephrosis and focuses exclusively on solitary unilateral ureteral stones.

It has previously been shown that hydronephrosis is not merely a secondary diagnostic finding but may also be related to stone burden and the clinical course. Innes et al.[5] reported that in a large multicenter cohort with CT-confirmed ureteral stones, the frequency of stones larger than 5 mm and spontaneous passage failure increased with increasing severity of hydronephrosis. Goertz and Lotterman showed that the rate of stones larger than 5 mm was higher in patients with moderate/severe hydronephrosis compared to those with no/mild hydronephrosis.[10] Leo et al.[11] reported that the absence of hydronephrosis reduced the likelihood of larger ureteral stones and that stones larger than 5 mm may be associated with short-term clinical events. In our study, the AUC for stone size in differentiating moderate from severe hydronephrosis

Table 3. Relationship between stone location and grade of hydronephrosis

	Stone location	Number of patients no HN	Minimal/mild HN	Moderate HN	Severe HN	Moderate/severe HN, n (%)
Proximal ureter	52	2	18	28	4	32 (61.5)
Mid-ureter	8	0	2	4	2	6 (75.0)
Distal ureter/UVJ	68	10	38	16	4	20 (29.4)

Statistical analysis: Monte Carlo Pearson chi-square test: χ^2=19.153; p=0.005
Due to the low number of patients in the mid-ureter group, the rates for this group should be interpreted with caution
HN: Hydronephrosis, UVJ: Ureterovesical junction

Table 4. A. Multivariate analyses and ROC analysis for hydronephrosis grade and moderate/severe hydronephrosis

Variable	OR	95% CI	p value
Stone size, per 1 mm increase	1.20	1.07-1.33	0.001
Proximal/mid location vs. distal/UVJ	2.40	1.14-5.07	0.022
Age, per 1-year increase	1.00	0.98-1.03	0.677
Female vs. male	1.42	0.64-3.15	0.392
B. Binary logistic regression analysis for moderate/severe hydronephrosis			
Variable	**OR**	**95% CI**	**p value**
Stone size, per 1 mm increase	1.28	1.09-1.50	0.002
Proximal/mid location vs. distal/UVJ	2.40	1.06-5.45	0.036
Age, per 1-year increase	1.01	0.98-1.03	0.643
Female vs. male	1.74	0.68-4.46	0.252
C. Performance of stone size in discriminating moderate/severe hydronephrosis			
ROC analysis parameter	Result		
AUC	0.747		
95% CI	0.663-0.828		
Exploratory optimal cutoff value	≥5.2 mm		
Sensitivity	82.8%		
Specificity	61.4%		

In the ordinal logistic regression analysis, the outcome variable was hydronephrosis grade: 0=none, 1=minimal/mild, 2=moderate, 3=severe. In the binary logistic regression analysis, the outcome variable was defined as the presence of moderate/severe hydronephrosis. The threshold value in the ROC analysis is exploratory in nature
AUC: Area under the curve, CI: Confidence interval, OR: Odds ratio, ROC: Receiver operating characteristic, UVJ: Ureterovesical junction

was 0.747. In our study, the AUC value of stone size in differentiating moderate/severe hydronephrosis was 0.747. This level suggests that stone size carries significant information regarding the severity of hydronephrosis but is not sufficient alone for clinical decision-making. The exploratory threshold of ≥5.2 mm was derived from this dataset and should not be considered a validated clinical cut-off or used as an independent threshold for clinical decision-making. Further studies with larger and independent cohorts are needed to determine whether a clinically meaningful threshold can be established.

Our finding that proximal/middle-located stones are associated with more advanced hydronephrosis differs from the results of Song et al.[6] and Akçiçek and Buğday,[7] who showed no significant association in terms of stone localization. This difference may be attributable to variations in cohort size, the creation of localization categories, or the timing of patient presentation. Indeed, it has been shown that secondary findings of ureteral obstruction on CT are affected not only by stone characteristics but also by symptom duration; Varanelli et al.[12] reported that the frequency of hydronephrosis and other secondary findings increased as the duration of pain increased. Therefore, our finding regarding localization should be interpreted cautiously because information on clinical duration and symptom onset is not available.

The association between stone location and hydronephrosis severity persisted after adjustment for stone size, age, and gender in the multivariable ordinal logistic regression model. Proximal/middle ureteral location was associated with higher odds of a greater hydronephrosis grade compared with distal/UVJ location (OR, 2.40; 95% CI: 1.14-5.07; p=0.022), indicating that the observed association was not explained solely by stone size. One possible explanation is that the anatomical level of obstruction may influence the extent of upstream urinary tract dilatation. However, this interpretation should be considered cautiously because symptom duration, duration of obstruction, and other clinical factors that may affect hydronephrosis were not available in our dataset. In addition, the small number of mid-ureteral stones limits the precision and generalizability of the localization finding.

No significant association was found between perirenal/periureteral contamination and moderate/severe hydronephrosis. This finding can be explained by the fact that perirenal contamination can reflect not only the severity of obstruction but also other factors, such as the duration of obstruction, pressure changes, and the local inflammatory response. Previous studies have also reported that the relationship between secondary CT findings and stone size or degree of hydronephrosis is variable.[12,13]

Study Limitations

This study has some limitations. First, the retrospective, single-center design is susceptible to selection bias. Second, clinical outcomes such as symptom duration, renal function, indicators of infection, treatments administered, and spontaneous stone passage were not available. Finally, the generalizability and robustness of the localization analysis are limited by the small number of patients with mid-ureteral stones (n=8). Therefore, the findings regarding mid-ureteral stone location should be interpreted cautiously and confirmed in larger cohorts with more balanced distributions of stone locations.

Conclusion

In patients with unilateral single ureteral stones, increased stone size was independently associated with a higher degree of hydronephrosis, specifically moderate/severe hydronephrosis. Proximal or mid-ureteral stone location was also associated with greater severity of hydronephrosis in our cohort; however, this finding should be interpreted cautiously, given the small number of mid-ureteral stones and the retrospective study design. These findings should be validated in larger, prospective cohorts incorporating clinical and laboratory data before their potential implications for clinical decision-making can be determined. Future studies may further clarify the contribution of hydronephrosis to clinical decision-making by combining stone size and degree of hydronephrosis with symptom duration, laboratory results, and treatment requirements.

Ethics

Ethics Committee Approval: The study was approved by the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (approval no: 2026-01/03; date: 08.01.2026).

Informed Consent: The requirement for informed consent from the ethics committee was waived.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.F.Ö., Concept: M.F.Ö., Design: M.F.Ö., A.O.G., Data Collection or Processing: BA.O.G., Analysis or Interpretation: A.O.G., Literature Search: M.F.Ö., Writing: M.F.Ö., A.O.G.

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