Renal calculi: trends in the utilization of shockwave lithotripsy and ureteroscopy

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Introduction: *To assess trends in the usage of extracorporeal shockwave lithotripsy (SWL) and ureteroscopy (URS) in the treatment of renal calculi.*

Materials and methods: *An analysis of the 5% Medicare Public Use Files (years 2001, 2004, 2007 and 2010) was performed to evaluate changes in the use of SWL and URS to treat renal calculi. Patients were identified using ICD-9 (cm) and CPT codes.*

Statistical analyses, including the Fisher, $\chi 2$ tests, and multivariate logistic regression analysis were performed using SAS 9.3 (SAS Institute Inc., Cary, NC, USA) and SPSS v20 (IBM Corp., Armonk, NY, USA).

Results: *The absolute number of patients diagnosed with (+85.1%) and treated for (+31.5%) kidney calculi increased from 2001 to 2010. The ratio of diagnosed/treated patients declined from 15.2% in 2001 to 10.8% in 2010. Whites (OR = 1.27, $p < 0.0001$), patients in the South (OR = 1.16, $p < 0.0001$) and those ≤ 84 years of age were more likely to be treated. The utilization of SWL (84.7%) was greater than URS (15.3%), but the utilization of URS increased over time from 8.4% in 2001 to 20.6% of cases by 2010 ($p < 0.0001$). Treatment via URS was more likely in women (OR = 1.28, $p < 0.0001$), in patients living outside the South (OR = 1.29-1.45, $p \leq 0.006$) and in later years of the study (OR = 2.87, $p < 0.0001$).*

Conclusions: *Treatment patterns for renal calculi changed from 2001 to 2010. The usage of URS increased at the cost of SWL. Multiple sociodemographic factors correlated with the likelihood of being treated surgically as well as the choice of the surgical approach.*

Key Words: kidney calculi, ureteroscopy, lithotripsy, surgical procedures, minimally invasive

Introduction

The introduction of extracorporeal shockwave lithotripsy (SWL) in the 1980s significantly altered the treatment patterns for nephrolithiasis, particularly for renal-based calculi. SWL represents a minimally invasive and highly effective treatment option for smaller renal calculi.[1] In recent years, however, minimally invasive ureteroscopic (URS) techniques have been introduced in the treatment of stone disease, providing urologists with an alternative treatment option to SWL for small renal calculi.

Previously published research suggests a rise in surgical procedures for upper urinary tract calculi, but the literature regarding contemporary management of renal calculi by URS versus SWL is limited, and potential changes in treatment patterns are not well understood.[2-4] Trends in the utilization of SWL and URS in renal calculi are of particular interest, especially as data providing head-to-head comparisons between these two treatment modalities are limited and inconsistent.[5-7]

In the present study we sought to assess national trends in the surgical management of renal calculi with SWL versus URS from 2001 to 2010 by analyzing claims from Medicare beneficiaries in the United States.

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Material and methods

After obtaining Institutional Review Board approval, Medicare claims data from the years 2001, 2004, 2007 and 2010 generated by the Centers for Medicare and Medicaid Services were analyzed. The Public Use Files include multiple datasets with information regarding physician and hospital inpatient and outpatient medical claims from a 5% national random sample of beneficiaries. Patients with a diagnosis of renal calculi were identified using the International Classification of Diseases, 9th Edition (ICD-9). Patients with a diagnosis of 1) both renal and ureteral calculi or 2) with an unknown location within the upper urinary tract were excluded from this study to create a homogenous cohort of patients diagnosed with only calculi located in the kidney. Patients undergoing surgery were then identified on the basis of Current Procedure Terminology (CPT-4) and ICD-9 (cm) codes.

Individual de-identified subjects were tracked using the encrypted beneficiary identification numbers to link data across the multiple datasets representing care in inpatient and outpatient settings. The national estimates of service use were obtained by multiplying counts by a constant weight of 20.[8] Patients were categorized according to gender, ethnicity, age and their geographical residence (defined by the United States Census Bureau, whose definitions are also used by the CMS when creating Medicare Public Use data).

Statistical tests used included the χ^2 and Fisher tests and multivariate logistic regression analyses and were performed using SAS v9.3 (SAS Institute Inc., Cary, NC, USA) and SPSS v20 (IBM Corp., Armonk, NY, USA). A p value of < 0.05 was considered significant.

Results

A total of 950,360 patients with the diagnosis of renal-only calculi were identified during the study period. The number of patients with renal calculi increased from 162,760 to 301,380 (+85.1%) between 2001 to 2010, Table 1. Most patients were white (88.2%), male (57.9%) and lived in the South (39.5%). While the overall number of

TABLE 1. **Characteristics of patients**

Covariates	Renal calculi diagnosis	(%)	Renal calculi treatment	(%)	Ratio diagnosis/ treatment	p value
Gender						0.004
Male	550,640	(57.9)	69,820	(58.4)	12.7%	
Female	399,720	(42.1)	49,780	(41.6)	12.5%	
Ethnicity						< 0.0001
Whites	834,700	(88.2)	107,100	(90.0)	12.8%	
Minorities	112,060	(11.8)	11,960	(10.0)	10.7%	
Age (yrs)						< 0.0001
< 65	191,320	(20.1)	24,580	(20.6)	12.8%	
65-69	223,440	(23.5)	31,940	(26.7)	14.3%	
70-74	196,780	(20.7)	26,480	(22.1)	13.5%	
75-79	163,040	(17.2)	20,980	(17.5)	12.9%	
80-84	106,060	(11.2)	10,920	(9.1)	10.3%	
> 84	69,720	(7.3)	4,700	(3.9)	6.7%	
Geography						< 0.0001
Northeast	195,720	(20.7)	24,180	(20.3)	12.4%	
Midwest	252,180	(26.7)	29,540	(24.9)	11.7%	
South	373,780	(39.5)	49,800	(41.9)	13.4%	
West	122,680	(13.0)	15,340	(12.9)	12.5%	
Years						< 0.0001
2001	162,760	(17.1)	24,660	(20.6)	15.2%	
2004	229,080	(24.1)	31,780	(26.6)	13.9%	
2007	257,140	(27.1)	30,740	(25.7)	12.0%	
2010	301,380	(31.7)	32,420	(27.1)	10.8%	
Total	950,360		119,600		12.6%	

treated patients increased from 24,660 in 2001 to 32,420 patients in 2010 (+31.5%), the percentage of diagnosed patients undergoing surgical treatment actually decreased from 15.2% to 10.8% ($p < 0.0001$, Table 1.

Slightly more men were treated than women (12.7% versus 12.5%, $p = 0.004$). In addition, more whites were treated than minorities (12.8% versus 10.7%, $p < 0.0001$), more patients in the South than in other regions (South 13.4% versus Midwest 11.7%, $p < 0.0001$) as well as more younger than older patients ($p < 0.0001$), Table 1.

Of the 119,600 patients undergoing surgical treatment, a total of 148,740 procedures were performed. Overall, the use of SWL was greater than URS (84.7% versus 15.3%, Table 2. However, a temporal increase in the use of URS from 8.4% to 20.6% was noted as the use of SWL decreased (91.6% to 79.4%, $p < 0.0001$, Table 2 and Figure 1.

The choice of treatment itself was correlated with multiple demographic factors, Tables 2 and 3. When URS was used, it was performed more often in women (10.9%-23.0%, $p = 0.02$ to $p < 0.0001$), minorities (15.0%-22.3%, $p = 0.02$ to $p < 0.0001$) and in patients at the ends of the age range studied, i.e. < 65 and > 84 years old (7.5%-25.9% and 11.5%-26.8%; $p < 0.0001$, Table 2. URS was most commonly performed in the West (9.5%-24.0%)

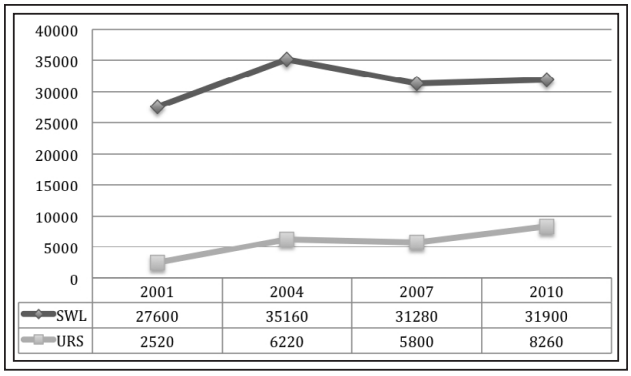

Figure 1. Utilization of shockwave lithotripsy and ureteroscopy for the treatment of renal calculi from 2001-2010.

TABLE 2. **Surgical treatments: entire study population**

	Shockwave lithotripsy	**(%)**	**Ureteroscopy**	**(%)**	**p value**
Gender					< 0.0001
Male	74,380	(86.0)	12,100	(14.0)	
Female	51,560	(82.8)	10,700	(17.2)	
Ethnicity					< 0.0001
Whites	112,820	(84.9)	20,140	(15.1)	
Minorities	12,640	(83.4)	2,520	(16.6)	
Age (yrs)					< 0.0001
< 65	25,820	(81.0)	6,040	(19.0)	
65-69	34,040	(85.7)	5,700	(14.3)	
70-74	27,940	(86.1)	4,520	(13.9)	
75-79	22,480	(86.9)	3,380	(13.1)	
80-84	11,000	(83.8)	2,120	(16.2)	
> 84	4,660	(81.8)	1,040	(18.2)	
Geography					< 0.0001
Northeast	25,640	(83.6)	5,020	(16.4)	
Midwest	30,840	(84.0)	5,860	(16.0)	
South	53,840	(86.6)	8,340	(13.4)	
West	14,940	(81.2)	3,460	(18.8)	
Years					< 0.0001
2001	27,600	(91.6)	2,520	(8.4)	
2004	35,160	(85.0)	6,220	(15.0)	
2007	31,280	(84.4)	5,800	(15.6)	
2010	31,900	(79.4)	8,260	(20.6)	
Total	125,940	(84.7)	22,800	(15.3)	

TABLE 3a. **Surgical treatments: distribution in 2001 and 2004**

	Shockwave lithotripsy	(%)	Ureteroscopy	(%)	p value
2001					
Gender					< 0.0001
Male	16,660	(93.4)	1,180	(6.6)	
Female	10,940	(89.1)	1,340	(10.9)	
Ethnicity					0.11
Whites	24,400	(91.7)	2,200	(8.3)	
Minorities	3,000	(90.9)	300	(9.1)	
Age (yrs)					< 0.0001
< 65	4,960	(92.5)	400	(7.5)	
65-69	7,680	(91.9)	680	(8.1)	
70-74	6,700	(90.3)	720	(9.7)	
75-79	5,020	(92.6)	400	(7.4)	
80-84	2,160	(92.3)	180	(7.7)	
> 84	1,080	(88.5)	140	(11.5)	
Geography					< 0.0001
Northeast	5,680	(89.3)	680	(10.7)	
Midwest	7,260	(92.1)	620	(7.9)	
South	11,700	(92.9)	900	(7.1)	
West	2,680	(90.5)	280	(9.5)	
2004					
Gender					< 0.0001
Male	20,960	(86.3)	3,340	(13.7)	
Female	14,200	(83.1)	2,880	(16.9)	
Ethnicity					0.02
Whites	31,140	(85.2)	5,420	(14.8)	
Minorities	3,940	(85.0)	760	(15.0)	
Age (yrs)					< 0.0001
<65	6,780	(80.9)	1,600	(19.1)	
65-69	9,240	(85.1)	1,620	(14.9)	
70-74	7,540	(86.1)	1,220	(13.9)	
75-79	6,680	(86.5)	1,040	(13.5)	
80-84	3,360	(87.0)	500	(13.0)	
> 84	1,560	(86.7)	240	(13.3)	
Geography					< 0.0001
Northeast	6,920	(84.8)	1,240	(15.2)	
Midwest	8,620	(85.2)	1,500	(14.8)	
South	15,120	(87.0)	2,260	(13.0)	
West	4,220	(78.4)	1,160	(21.6)	

and least often in the South (7.1%-18.4%), where SWL was most commonly performed (81.6%-92.9%, p < 0.0001).

Multivariate logistic regression analysis was performed to evaluate the influence of demographic factors and time on whether patients underwent surgical treatment for stone disease, Table 4. White patients were more likely to undergo surgical treatment than minorities (OR = 1.27, p < 0.0001). Younger patients had a higher likelihood of being surgically treated (OR = 1.58-2.29, p < 0.0001). Patients in the South were more likely to undergo surgery than those in other parts of the country (OR = 1.16, p < 0.0001). Patients treated in the earlier years of the study were more likely to undergoing surgery (OR = 1.14-1.48, p ≤ 0.001). Gender

TABLE 3b. **Surgical treatments: distribution in 2007 and 2010**

	Shockwave lithotripsy	(%)	Ureteroscopy	(%)	p value
2007					
Gender					0.02
Male	17,880	(84.7)	3,220	(15.3)	
Female	13,400	(83.9)	2,580	(16.1)	
Ethnicity					0.11
Whites	24,400	(91.7)	2,200	(8.3)	
Minorities	3,000	(90.9)	300	(9.1)	
Age (yrs)					< 0.0001
< 65	7,060	(81.7)	1,580	(18.3)	
65-69	8,720	(84.8)	1,560	(15.2)	
70-74	6,860	(87.5)	980	(12.5)	
75-79	4,980	(87.1)	740	(12.9)	
80-84	2,680	(80.2)	660	(19.8)	
> 84	980	(77.8)	280	(22.2)	
Geography					< 0.0001
Northeast	6,500	(81.9)	1,440	(18.1)	
Midwest	7,180	(83.3)	1,440	(16.7)	
South	13,360	(86.4)	2,100	(13.6)	
West	4,180	(83.9)	800	(16.1)	
2010					
Gender					< 0.0001
Male	18,880	(81.2)	4,360	(18.8)	
Female	13,020	(77.0)	3,900	(23.0)	
Ethnicity					0.01
Whites	29,020	(79.6)	7,420	(21.7)	
Minorities	2,720	(77.7)	780	(22.3)	
Age (yrs)					< 0.0001
< 65	7,020	(74.1)	2,460	(25.9)	
65-69	8,400	(82.0)	1,840	(18.0)	
70-74	6,840	(81.0)	1,600	(19.0)	
75-79	5,800	(82.9)	1,200	(17.1)	
80-84	2,800	(78.2)	780	(21.8)	
> 84	1,040	(73.2)	380	(26.8)	
Geography					< 0.0001
Northeast	6,540	(79.8)	1,660	(20.2)	
Midwest	7,780	(77.2)	2,300	(22.8)	
South	13,660	(81.6)	3,080	(18.4)	
West	3,860	(76.0)	1,220	(24.0)	

did not influence the likelihood of undergoing surgical treatment.

Logistic regression analysis was also carried out to evaluate the influence of demographic factors and time on the choice of stone procedure if patients were treated surgically, Table 5. Women demonstrated a 1.28 increased odds of undergoing URS (OR = 1.28, $p < 0.0001$). Patients aged 65-79 years were more likely to be treated with URS (OR = 0.66-0.75, $p \leq 0.003$). Living outside the South was associated with higher odds of being treated with URS (OR = 1.29-1.45, $p \leq 0.006$). Patients in the later years of the study showed increasing odds of being treated with URS (OR = 1.52-2.87, $p \leq 0.001$). Ethnicity did not influence the choice of surgical treatment.

TABLE 4. **Likelihoods of being treated**

	Treatment versus no treatment*		
Categories	**OR**	**CI**	**p value**
Gender			
Female	1.02	0.97-1.08	0.41
Male	1.00		
Ethnicity			
White	1.27	1.16-1.39	< 0.0001
Minority	1.00		
Age (yrs)			
< 65	2.08	1.79-2.40	< 0.0001
65-69	2.29	1.98-2.64	< 0.0001
70-74	2.14	1.84-2.47	< 0.0001
75-79	2.01	1.73-2.33	< 0.0001
80-84	1.58	1.35-1.86	< 0.0001
> 84	1.00		
Geography			
Midwest	1.00		
Northeast	1.07	0.99-1.16	0.11
South	1.10	1.08-1.24	< 0.0001
West	1.10	0.10-1.20	0.06
Year			
2001	1.48	1.36-1.60	< 0.0001
2004	1.35	1.25-1.45	< 0.0001
2007	1.14	1.05-1.22	0.001
2010	1.00		

TABLE 5. **Likelihoods of ureteroscopy versus shockwave lithotripsy**

	Ureteroscopy versus shockwave lithotripsy		
Categories	**OR**	**CI**	**p value**
Gender			
Female	1.28	1.12-1.49	< 0.0001
Male	1.00		
Ethnicity			
White	1.13	0.91-1.40	0.28
Minority	1.00		
Age (yrs)			
< 65	1.00		
65-69	0.75	0.62-0.90	0.003
70-74	0.73	0.60-0.90	0.002
75-79	0.66	0.53-0.83	< 0.0001
80-84	0.84	0.65-1.09	0.18
> 84	0.95	0.67-1.40	0.78
Geography			
Midwest	1.29	1.08-1.55	0.006
Northeast	1.30	1.09-1.54	0.003
South	1.45	1.18-1.80	0.001
West	1.00		
Year			
2001	1.00		
2004	1.52	1.20-1.93	0.001
2007	2.08	1.65-2.03	< 0.0001
2010	2.87	2.29-3.26	< 0.0001

Discussion

The prevalence of stone disease is increasing in the US population.[9,10] In this study, we examined national trends in renal pelvis stone disease with corresponding surgical treatments from 2001 to 2010 in the Medicare beneficiaries. Interestingly, while the prevalence of renal calculi increased by 85% between 2001-2010 in this population, the percentage of diagnosed patients undergoing surgical treatment with SWL or URS actually decreased from 15.2% to 10.8% ($p < 0.0001$). Part of this decline trend may be caused by an increased detection of asymptomatic renal calculi.[11,12] For instance, Edvardsson et al reported that the incidence of asymptomatic calculi increased threefold from 1985 to 2008 primarily in patients aged above 50 years due to the increased utilization of high resolution imaging studies.[11] Indeed, for asymptomatic calculi sized less than 5 mm, 92% of US urologists would recommend observation instead of intervention.[13] The relative decline in the use of SWL and URS was also not driven by substitution with other surgical stone procedures typically used for greater or complex stone burden, like percutaneous or open nephrolithotomy, as their utilization also dropped from 3.1% to 2.5% during the same period ($p < 0.0001$).[3]

In the present study we also sought to evaluate changes the use of URS and SWL in renal calculi. Significant changes were seen in the choice of treatment modalities for renal calculi over the study period. The utilization of URS increased from 8.4% in 2001 to 20.6% to 2010 ($p < 0.0001$) while the use of SWL declined (91.6% to 79.4%, $p < 0.0001$). This may be partially due to dissemination of URS technique as well as improvements in URS technology. This shift is notable with regard to head-to-head studies comparing the two modalities.[5-7] To date, a single randomized study reported by Pearl et al failed to show superior stone clearance with URS over SWL for isolated lower pole calculi ≤ 1 cm (50% versus 35% $p = 0.92$). While the two modalities demonstrated similar complication rates (21% versus 23%, $p = 0.84$), treatment with URS interestingly led to lower patient satisfaction ratings

(63% versus 90%, p = 0.03).[5] In contrast, however, more recent non-randomized studies however have favored URS, although this benefit was largely seen in treatment of larger calculi.[6,7] El-Nahas et al for example reported higher stone-free rates with flexible URS in lower pole calculi sized 1 cm-2 cm (86.5% versus 67.7%, p = 0.04) with similar complication rates (13.5 versus 4.8%, p = 0.15) and higher retreatment rates for SWL (59.7% versus 8% p < 0.001).[6] Resorlu et al also reported high success rates with URS (87% versus 66.5%, p < 0.001) in renal calculi sized 1 cm-2 cm not restricted to the lower pole with a lower rate of secondary procedures (8.7% versus 21.9% p < 0.001) but at the cost of a higher rate of minor complications (10.9% versus 7.6% p < 0.001).[7] Interestingly, flexible URS has been shown to also serve as an effective and safe treatment option for treatment of proximal ureteral calculi. Hyams et al recently reported on a prospective, multi-institutional trial analyzing surgical outcomes for 71 patients with proximal ureteral calculi undergoing flexible URS. The authors noted stone-free rates of 95% with low intraoperative complication rates of 2.8%, making it a reasonable alternative to SWL and semirigid URS.[14]

Multiple sociodemographic factors correlating with the likelihood of undergoing surgical treatment were identified. Whites were more likely than minorities to undergo surgery (OR = 1.27, p < 0.0001). Furthermore, if patients underwent surgery, women were more likely than men to be treated via URS (OR = 1.28, p < 0.0001). These differences in practice patterns may reflect disparities in access to medical care, cultural perceptions on the part of the patient affecting their treatment preference, as well as treatment selection by the physician.[15,16]

Geography also influenced treatment patterns. Patients in the South were most likely to be treated (OR = 1.16, p < 0.0001), yet surprisingly had the lowest likelihood of being treated with URS compared to other parts of the US (OR = 1.0 versus 1.29-1.45, p ≤ 0.006). The geographical distribution of treatment mirrors regions with higher prevalence of urolithiasis as for example is seen with the so-called stone belt mainly located in the Southeast.[17] Geographical discrepancies in the utilization of SWL and URS have been also noted by others such as Wang et al who reported that the use of SWL was greater in the South and West compared to the Northeast where the use of URS was more prevalent.[18] Kauer et al also reported on geographic disparity of stone treatment patterns in Europe.[19] For instance, urological departments in northern Europe performed 41 SWL treatments per month on average compared to 79 treatments in southern Europe. They surmised that this discrepancy was likely a function of different healthcare systems, access to medical care and medical cultures within northern versus southern Europe.

Treatment patterns were also influenced by patient age. Younger patients were more likely to be treated than older patients (OR = 1.58-2.29, p < 0.0001). Interestingly, if patients were treated, younger patients tended to be treated with URS more than older counterparts (OR = 1.00 versus 0.66-0.75, p ≤ 0.003). The disparity in treatment with age may be due to poorer surgical candidacy with rising age.[20] The use of URS may also be considered to be more invasive, thus leading to a greater use of SWL in older patients. The greater use of SWL in older patients is interesting, particular since others have reported decreased efficacy with SWL in the elderly. Ng et al for example demonstrated that patients aged > 60 years have a 0.64 odds of being stone free compared to 0.71 for those less aged 41 to 60 years (p < 0.001).[21] They hypothesized that age-related glomerulosclerosis may diminish the effectiveness of shockwave transmission to renal stones, resulting in lower stone free rates. The greater use of URS also mirrors the experience reported by Krambeck et al who noted that younger patients in Olmsted County, Minnesota typically underwent URS more frequently than older patients who underwent SWL more often for the treatment of upper urinary tract calculi (60-69 years versus ≥ 70 years: 23% versus 8%, p < 0.0001).[22]

The study most similar to ours was reported by Scales et al who analyzed medical claims of privately insured beneficiaries treated with SWL or URS for kidney stones from 2002-2010.[4] Contrary to our results, the authors observed that the utilization of URS was greater than that of SWL (54.2% versus 45.8%) in these patients. In addition, the need for a second stone intervention was greater after SWL than URS (23.6% versus 18.7%, p < 0.001). Only minor geographical variation in the use of SWL versus URS was seen. The comparison of Scales et al's study with our present one reveals important differences in treatment patterns among different cohorts living within the same healthcare system. Patients in the Scales et al study were younger (mean ages of 42.5 URS versus 43.5 for SWL) and mainly healthy, with over 90% of patients possessing a Charlson comorbidity index of 0 to 1.

Multiple limitations exist in our study. Although the sample size was large, it was retrospective and non-randomized in nature. Patient and provider level data were not contained in the Public Use Files. As such, stone size and location within the kidney were unknown which may have influenced choice of

surgical treatment. The impact of surgeon-specific factors, such as association with academic urology versus community practices, recent completion of urologic training, and shockwave lithotripsy ownership, which could influence the choice of URS versus SWL could not be ascertained.[23] The role of patient preferences for less invasive therapies such as SWL could not be determined. Medicare billing codes may not have reliably distinguished between renal and ureteral calculi.[24] Finally, the trends reported in this Medicare-specific population may not be generalizable to the general population, i.e. to those aged less than 65.

Conclusions

Treatment patterns for renal calculi have significantly changed from 2001 to 2010. A relative decline in treatment for patients diagnosed with renal calculi was observed. SWL still represents the mostly commonly performed procedure in these patients, but URS rates have been increasing in recent years. Multiple sociodemographic factors including age, race, gender, and geography influenced the likelihood of being treated and the choice of the surgical approach used in these patients. □

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