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Assessment of normal renal size in healthy individuals in Pakistan and its influencing factors: A cross-sectional study

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ABSTRACT

Background and objectives. In order to address the need to establish normative benchmark of kidney size in healthy population of Pakistan, this study aimed to assess and quantify the renal sizes in healthy individuals within the Pakistani population using ultrasound imaging. Secondary objectives included examining age-related variations, gender-specific differences, and the correlation between Body Mass Index (BMI) and kidney measurements.

Materials and methods. A five-year retrospective investigation of 509 patients undergoing non-renal abdominal ultrasounds at NIKUD Research Hospital employed strict participant criteria, excluding those with diabetes, hypertension, abnormal eGFR, or urinalysis. Ultrasound data was collected from medical record of patients aged 18-80 years without a history or ongoing renal disease, excluding any conditions impacting renal size.

Results. In 480 participants meeting stringent health criteria, the right kidney measured 10.45 ± 0.97 cm, and the left kidney measured 10.64 ± 0.95 cm. Age-related variations included increasing renal length until the fifth decade, followed by decline. Gender-specific differences, though statistically non-significant, suggested slightly larger renal sizes in females. A positive BMI and renal length relationship indicated increased sizes in obese individuals.

Conclusions. This study establishes renal size benchmarks in a healthy Pakistani population, highlighting demographic factors' role in assessments. Variations across age, gender, and BMI underscore the need for population-specific norms in clinical evaluations.

Keywords: kidney size, ultrasound imaging, cross-sectional study, demographic factors

List of abbreviations (in alphabetical order):

BMI	– Body Mass Index
CKD	– Chronic Kidney Disease
ESRD	– End-Stage Renal Disease
GFR	– Glomerular Filtration Rate
HbA1c	– Hemoglobin A1c

INTRODUCTION

The global surge in kidney diseases poses a significant healthcare challenge, fuelled by factors like aging, chronic conditions, and lifestyle changes [1]. This escalation results in chronic kidney disease (CKD) and, in severe cases, progresses to end-stage renal disease (ESRD), and necessitating renal replacement therapy. Environmental factors, healthcare access

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disparities, and inadequate infrastructure compound the global prevalence of kidney diseases [2]. This upward trend requires a multifaceted approach, including preventive measures, early detection, and efforts to enhance global healthcare accessibility and education.

In South Asia, particularly Pakistan, kidney disease has become a major public health concern due to genetic, environmental, and socioeconomic factors [3]. The rising prevalence of CKD and ESRD, coupled with a high incidence of non-communicable diseases, underscores the healthcare burden. Challenges include limited healthcare access and affordability of renal replacement therapies [4]. Addressing kidney disease in Pakistan requires comprehensive strategies, including awareness campaigns, preventive measures, improved healthcare infrastructure, and equitable access to renal care services.

The measurement of kidney size is crucial for screening and diagnosing kidney disease, playing a key role in assessing renal health [6]. Kidney size indicators offer insights into structural integrity and function, aiding in early detection and disease progression evaluation. Imaging techniques like ultrasound enable precise measurements, facilitating the detection of abnormalities and providing real-time assessments. Ultrasound's non-ionizing nature, safety for repeated examinations, cost-effectiveness, and applicability in various clinical settings make it an invaluable tool for kidney size assessment [8].

RATIONALE

This cross-sectional study addresses the scarcity of normative benchmarks for kidney sizes in the Pakistani population, emphasizing the need for region-specific data amid global concerns about kidney-related issues [9]. Being the fifth-most populous country in the world, the absence of comprehensive information on normal kidney dimensions in Pakistan presents major challenges for accurate clinical assessments and diagnostics [10]. Notably, this study uniquely imposes strict participant selection criteria, excluding individuals with diabetes or hypertension, ensuring normal eGFR and urinalysis. By focusing on this healthy subset, the research aims to establish baseline data on normal kidney sizes in Pakistan, contributing crucial insights for clinical assessments and public health initiatives. The study's emphasis on population-specific norms is vital for distinguishing between normal anatomical variations and potential abnormalities, thereby enhancing the precision of healthcare interventions and diagnostics in the realm of renal health in Pakistan.

OBJECTIVE

Primary objective

To assess and quantify the renal sizes in healthy individuals within the Pakistani population using ultrasound imaging.

Secondary objective:

To analyze kidney size variations across different age groups, genders and Body Mass Index (BMI) categories.

MATERIALS AND METHODS

Data collection

This cross-sectional study analyzed five years of retrospective medical records, encompassing 509 patients who underwent abdominal ultrasound at NIKUD Research Hospital from 7 September 2018 to 7 September 2023, for non-renal reasons. The research, conducted in adherence to the Declaration of Helsinki, obtained ethical approval for data extraction. Extracted data included examination dates, chart numbers, renal lengths, and observed abnormalities. Additional demographic and health information, such as age, gender, height, weight, BMI, and prevalent morbidities, was sourced. Confidentiality was maintained throughout the study.

All ultrasounds conducted in the above said periods of patient's ages between 18-80 years at NIKUD Research hospital for reasons other than renal diseases were included in the study. All individuals with history of any renal disease or with on-going renal disease or any condition that could abnormally impact renal size were excluded from the study. Therefore, all patients with an eGFR of <60 mL/min/1.73 m² (using the CKD EPI Equation), abnormal urinalysis results, HbA1c levels ≥6.5 mg/dL, a medical history involving hypertension, diabetes mellitus, or any renal disease, and the presence of abnormal ultrasonographic findings that could potentially impact renal size such as cortical atrophy, renal agenesis, medullary calcinosis, polycystic kidney disease, renal duplication, atrophic kidney, chronic progressive nephropathy, renal stones, renal masses, hydronephrosis, diabetic nephropathy, status post-nephrectomy, renal cysts, and pyelonephritis were excluded from the study.

A real-time grayscale ultrasound examination was conducted using a Toshiba UICW-660A: Xario ultrasound machine, equipped with a 3.5–5 MHz curvilinear probe. Patients underwent sonography in a prone position with an empty bladder. To enhance imaging, acoustic gel was applied to the skin, eliminating air interfaces between the probe and the skin. The kidney was distinguished by its brightly echogenic renal capsule and central echogenicity.

In the longitudinal scan, both superior and inferior poles of the kidney were distinctly identified and marked. The renal length (L) was measured as the longest distance between these poles using an electronic caliper. All measurements were recorded in centimeters (cm).

Statistical analysis

Data were entered and analyzed using Statistical Package for Social Sciences (SPSS) Statistics version 22. Descriptive statistics was used to display frequencies, mean and standard deviations. Comparison between genders was made using Independent t test. Total population was grouped according to age and BMI categories, one-way analysis of variance were used to compare means of different group. A p-value of <0.05 was considered as statistically significant.

RESULTS

A total of 509 participants were enrolled, and 29 were excluded due to incomplete data. Out of 480 participants, 204 (42.5%) participants were female, and 276 (57.5%) participants were male. Regarding age, 216 (45.0%) participants were 18-35 years of age, 180 (37.5%) participants were 36-50 years of age, and 84 (17.5%) participants were 50+ years of age. Regarding BMI category, 180 (37.5%) participants were normal weight, 120 (25.0%) participants were obese, 144 (30.0%) participants were overweight, and 36 (7.5%) participants were underweight (Table 1, Figures 1 and 2).

The mean size of Right kidney is 10.45 ±0.97 cm, with minimum size of 8.6 cm, and maximum size of 12.3 cm. The mean size of Left Kidney is 10.64 ± 0.95

TABLE 1. Basic characteristics of participants

Basic characteristics of participants			
		N	Percent
Gender	Male	276	57.5
	Female	204	42.5
Age	18-35	216	45.0
	36-50	180	37.5
	50+	84	17.5
BMI	Normal weight	180	37.5
	Obesity	120	25.0
	Overweight	144	30.0
	Underweight	36	7.5

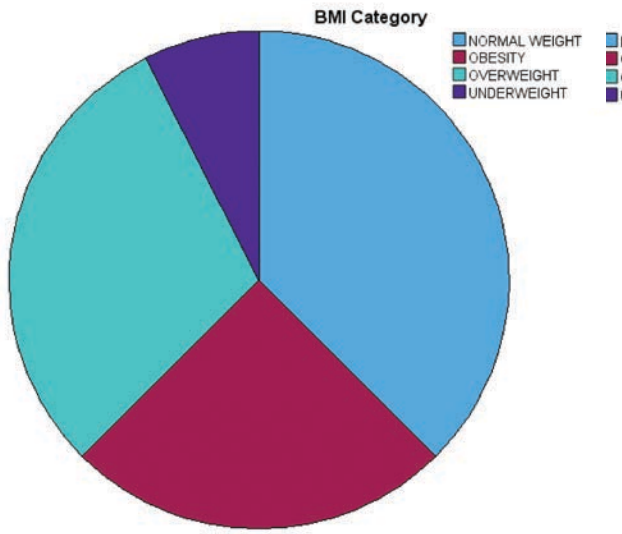

FIGURE 2. BMI Category

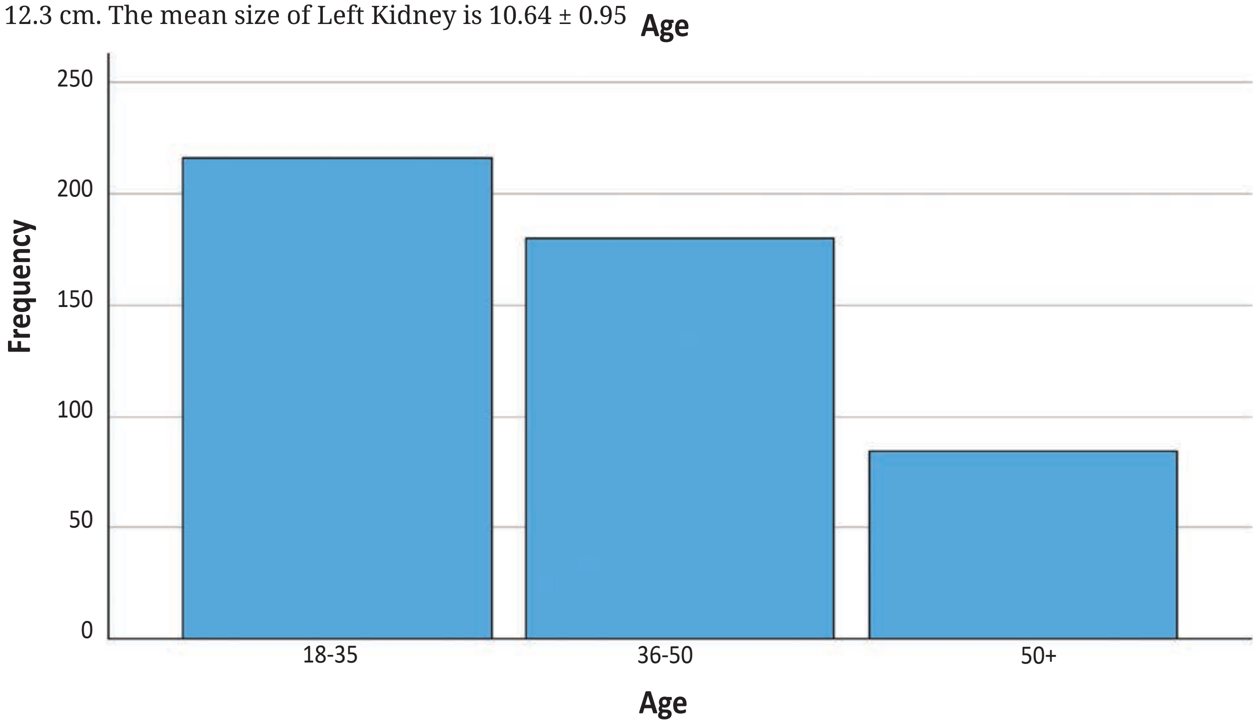

FIGURE 1. Age categories

cm, with minimum size of 9.0 cm and maximum size of 12.5 (Table 2).

TABLE 2. Kidney sizes in cm

OVERALL KIDNEY SIZES in cm					
	N	Minimum	Maximum	Mean	Std. Deviation
Right Kidney	480	8.6	12.3	10.448	0.9731
Left Kidney	480	9.0	12.5	10.638	0.9480

Distribution of kidney sizes according to age group (Table 3)

The total study subjects were divided according to age groups (Table 3). For participants with 18-35 years of age, the right kidney size mean size was 10.39, standard deviation 1.09, minimum size 8.6, maximum size 12.3, and the left kidney size mean size was 10.54, standard deviation 1.04, minimum size 9.0, maximum size 12.5. For participants with 35-50 years of age, the right kidney size mean size was 10.53, standard deviation 0.93, minimum size 9.0, maximum size 12.1, and the left kidney size mean size was 10.92, standard deviation 0.92, minimum size 9.6, maximum size 12.5. For participants with 50+ years of age, the right kidney size mean size was 10.41, standard deviation 0.68, minimum size 9.3, maximum size 11.5, and the left kidney size mean size was 10.27, standard deviation 0.47, minimum size 9.5, maximum size 11.0 as shown in Table 3. One-way analysis of variance between means of renal sizes with regard to age groups, showed that renal length increases to the fifth decade and beginning to decreases after fifth decade (P<0.05).

TABLE 3. Distribution of kidney sizes according to age groups

Distribution of kidney sizes according to age groups							
		N	Mean	Std. Deviation	Minimum	Maximum	P-Value
Right kidney measurement	18-35	216	10.389	1.0928	8.6	12.3	0.320
	36-50	180	10.533	.9340	9.0	12.1	
	50 & above	84	10.414	.6811	9.3	11.5	
Left kidney measurement	18-35	216	10.544	1.0418	9.0	12.5	<0.001
	36-50	180	10.920	.9185	9.6	12.5	
	50 & above	84	10.271	.4740	9.5	11.0	

TABLE 4. Kidney sizes with reference to gender

Kidney sizes with reference to gender							
	Gender	N	Mean	Std. Deviation	Minimum	Maximum	P-Value
Right kidney measurement	Male	276	10.42	0.89	8.6	12.0	0.50
	Female	204	10.48	1.07	9.0	12.3	
Left kidney measurement	Male	276	10.68	0.95	9.1	12.5	0.274
	Female	204	10.58	0.95	9.0	12.5	

TABLE 5. Kidney sizes with reference to BMI category

Distribution of kidney sizes according to BMI category							
		N	Mean	Std. Deviation	Minimum	Maximum	P-Value
Right kidney measurement	Underweight	36	9.87	0.25	9.6	10.2	<0.001
	Normal weight	180	10.62	0.94	9.0	12.2	
	Over weight	144	10.04	0.89	8.6	11.6	
	Obesity	120	10.84	0.99	9.5	12.3	
Left kidney measurement	Underweight	36	10.33	1.26	9.0	12.0	<0.001
	Normal weight	180	10.67	1.00	9.1	12.5	
	Over weight	144	10.43	0.76	9.5	11.8	
	Obesity	120	10.92	0.88	9.6	12.5	

Distribution of kidney sizes according to gender (Table 4)

For female participants, the right kidney size mean size was 10.48, standard deviation 1.07, minimum size 9.0, maximum size 12.3, and the left kidney size mean size was 10.58, standard deviation 0.95, minimum size 9.0, maximum size 12.5. For male participants, the right kidney size mean size was 10.42, standard deviation 0.89, minimum size 8.6, maximum size 12.0, and the left kidney size mean size was 10.68, standard deviation 0.95, minimum size 9.1, maximum size 12.5. As shown in Table 4. Independent t test between means of renal sizes with regard to gender, showed no significant difference in renal size with regard to gender (P<0.05).

Distribution of kidney sizes according to BMI (Table 5)

Regarding BMI, for participants with BMI in the normal range, the right kidney size mean size was

10.62, standard deviation 0.94, minimum size 9.0, maximum size 12.2, and the left kidney size mean size was 10.67, standard deviation 1.00, minimum size 9.1, maximum size 12.5. For participants with BMI in the obesity range, the right kidney size mean size was 10.84, standard deviation 0.99, minimum size 9.5, maximum size 12.3, and the left kidney size mean size was 10.92, standard deviation 0.88, minimum size 9.6, maximum size 12.5. For participants with BMI in the overweight range, the right kidney size mean size was 10.04, standard deviation 0.89, minimum size 8.6, maximum size 11.6, and the left kidney size mean size was 10.43, standard deviation 0.76, minimum size 9.5, maximum size 11.8. For participants with BMI in the underweight range, the right kidney size mean size was 9.87, standard deviation 0.25, minimum size 9.6, maximum size 10.2, and the left kidney size mean size was 10.33, standard deviation 1.26, minimum size 9.0, maximum size 12.0. As shown in Table 5. One-way analysis of variance between means of renal sizes with regard to BMI Categories, showed that renal length significantly increases as the BMI increases ($P<0.05$).

DISCUSSION

Our study, involving 480 participants, aimed to establish nomograms for renal measurements and identify differences in kidney sizes among healthy individuals in the Pakistani population. A notable aspect of our methodology was the careful exclusion of participants with comorbidities, specifically diabetes and hypertension. Additionally, those with abnormalities in eGFR or urinalysis were excluded during data analysis, ensuring a focused investigation into kidney sizes within a cohort deemed healthy by stringent standards. This study is unique in Pakistan for its strict criteria, providing an unparalleled level of certainty that the cohort comprises individuals with truly healthy kidneys, setting it apart from previous research

The results provided variety of information, providing mean values for the renal sizes in healthy Pakistani population and also revealing variations across age, gender, and BMI categories. The mean size of the right and left kidneys in the healthy Pakistani population, as determined by ultrasound, was found to be 10.45 ± 0.97 cm and 10.64 ± 0.95 cm, respectively, with varying minimum and maximum sizes. When comparing these findings to global populations, it is evident that renal size varies among different ethnicities and geographical regions. For instance, a study in Taiwan reported that the mean renal length of healthy adults ranged from 9.6 cm in India to 11.44 cm in Serbia, with significant variations among various ethnicities and countries [11]. Another study in Pakistan found that the Pakistani population has a mean renal size smaller than the reference values available in the international literature, highlighting the importance of considering population-specific norms when assessing renal size [12]. These findings emphasize the need to account for ethnic and regional differences when interpreting renal size measurements and establishing reference ranges.

The age-specific analysis unveiled intriguing patterns in kidney sizes. For instance, participants aged 18-35 displayed a right kidney mean size of 10.39 and a left kidney mean size of 10.54. In contrast, the 35-50 age group exhibited a larger mean size for the left kidney (10.92), suggesting potential age-related variations. The 50+ age group, however, displayed a decrease in mean sizes, particularly for the left kidney (10.27). This dynamic interplay of age and kidney sizes necessitates a nuanced understanding of the physiological changes occurring over a lifespan.

Existing literature often associates age with alterations in renal structure and function [13-15]. The observed decrease in mean sizes among older participants aligns with studies suggesting age-related changes in kidney morphology, such as cortical thinning and reduced renal blood flow [16]. However, the precise mechanisms underlying these age-related variations merit further investigation. Factors such as vascular changes, nephron loss, and alterations in renal perfusion may contribute to the observed differences and should be explored in subsequent research endeavors.

Regarding gender-specific differences in kidney sizes. It is noteworthy that in comparison to other studies in Pakistan [10], that showed significantly smaller Females renal sizes, our study displayed slightly larger mean sizes for both the right (10.48) and left (10.58) kidneys in female as compared to males (right: 10.42, left: 10.68) however the difference is statistically non-significant. This can be attributed to obesity as well because the proportion of obese female was significantly higher in our study as compared to males. Longer relative renal length in female has been observed in similar study in Geneva [17]. In contrast to this, other studies shows higher absolute renal lengths in male as compared to female [18]. Gender-based dissimilarities in renal anatomy and physiology have been documented in other literature as well [19], with studies suggesting variations in renal blood flow, glomerular filtration rate (GFR), and hormonal influences. For instance, female kidney size disparity can be a result of influence of estrogens. Estrogens have been implicated in nephron development and may contribute to the observed differences [20]. Exploring the hormonal milieu and its impact on kidney sizes could provide valuable insights into gender-specific renal dynamics.

The relationship between BMI and kidney sizes introduces another layer of complexity. Normal weight participants displayed balanced mean sizes (right: 10.62, left: 10.67), while individuals with obesity exhibited larger sizes (right: 10.84, left: 10.92).

Overweight individuals, conversely, showed slightly smaller mean sizes (right: 10.04, left: 10.43), and underweight participants displayed the smallest mean sizes (right: 9.87, left: 10.33). These findings prompt a closer examination of the interplay between body composition and renal morphology.

Obesity is often associated with structural and functional alterations in the kidneys. Increased adiposity can lead to changes in renal hemodynamic, glomerular hypertrophy, and alterations in tubular function. The observed larger kidney sizes among individuals with obesity align with previous research indicating a positive correlation between BMI and kidney dimensions [12,15,21,22]. However, the mechanisms underlying these associations, including the role of adipokines, inflammation, and insulin resistance, warrant meticulous exploration.

Conversely, the smaller mean sizes among underweight participants may be indicative of potential nutritional influences on renal development. Malnutrition has been linked to impaired nephron endowment and altered renal structure [23,24]. Investigating the nutritional status and its impact on kidney sizes could unveil critical insights into the developmental aspects of renal morphology.

Overall, In comparison to previous studies in Pakistan [10,12], our study shows slightly longer renal length as compared to the right side this is similar to other studies on this topic. Regarding the relation to age, our findings are similar in comparison to other previous studies' data, there is a decline in renal sizes with old age. Moreover, as discussed above our study's results are different than other previous studies in regards to the gender related differences in renal size. In our data female renal sizes are shown to be larger than male however the difference was statistically insignificant, but this is noteworthy keeping in view that other similar studies have shown significantly larger male renal sizes, however the higher proportion of obese female in our study can be the reason of this difference. Additionally our results showed a significant positive relationship when BMI were correlated with renal volume and length. This finding has been supported by many previous works in Pakistan as well as internationally [10,12,15,21].

Understanding the demographic factors influencing kidney sizes holds significant clinical implications. Tailoring renal assessments based on age, gender, and BMI could enhance the accuracy and relevance of diagnostic procedures. Clinicians should be mindful of these variations when interpreting ultrasound results, particularly in populations with diverse demographic characteristics.

STUDY LIMITATIONS AND PROSPECTIVE DIRECTIONS

While our study offers valuable insights, there are limitations. The cross-sectional design impedes establishing causal links between demographic factors and kidney sizes. Longitudinal studies are recommended for a more comprehensive understanding. Being conducted in a single hospital may introduce selection bias, and the sample's demographics may not fully represent the diverse Pakistani population. A broader multicenter study would enhance external validity. Additionally, future assessments should include cortical thickness alongside renal length for a more comprehensive exploration of normative benchmarks.

CONCLUSION

In conclusion, our cross-sectional study meticulously explores kidney sizes in a healthy Pakistani population, establishing specific normative benchmarks. Rigorous exclusion criteria ensure a targeted investigation into individuals with genuinely healthy kidneys. Variations in renal dimensions across age, gender, and BMI categories highlight the significance of demographic factors in renal assessments. Although our findings align with global trends, such as the link between obesity and larger kidneys, gender-specific differences, though statistically insignificant, warrant further investigation. Our study contributes to the scant literature on kidney sizes in Pakistan, emphasizing the necessity for population-specific norms to improve clinical accuracy.

Conflict of interest:
No conflict of interest to declare.

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Author's contributions:
Conceptualization, Syed Muhammad Kashif Kazmi; methodology, Umm-e-Rabab; software, Umm-e-Rabab, validation, Adnan Hashmi, Umm-e-Rabab; formal analysis, Syed Muhammad Kashif Kazmi, Umm-e-Rabab, Adnan Hashmi; investigation, Syed Muhammad Kashif Kazmi, Adnan Hashmi; resources, Najiya Amanat Khan, Misbah Fatima Shaikh, Finza Kanwal; data curation, Inshal Jaffery, Sehar Gul Sadruddin, Najiya Amanat Khan, Misbah Fatima Shaikh, Finza Kanwal, Adnan Hashmi; writing—original draft preparation, Syed Muhammad Kashif Kazmi; writing—review and editing, Syed Muhammad Kashif Kazmi, Zakiuddin G. Oonwala, Misbah Fatima Shaikh, Najiya Amanat Khan, Adnan Hashmi; visualization, Syed Muhammad Kashif Kazmi, Umm-e-Rabab; supervision, Zakiuddin G. Oonwala, Syed Muhammad Kashif Kazmi; project administration, Syed Muhammad Kashif Kazmi.

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