Normal ultrasound dimensions of newborn kidneys in Southwest Nigeria

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Abstract

Background/Aim: Accurate classification of renal size as normal and abnormal depends on precise knowledge of acceptable normal range for the population. Ultrasound (US) is an excellent tool for defining the norm and imaging neonates suspected with renal pathology because it is cheap, easy to perform, and harmless. Since the kidneys of neonates are distinct from those of older children and there is a paucity of data on normal renal size in neonatal population in sub-Saharan Africa, this study is to determine the normal range of renal size in a large cohort of Nigerian neonates.

Materials and Methods: In a cross-sectional study of 528 apparently healthy neonates from two large hospitals in Ibadan, Nigeria, clinical examination and renal US scans were performed in the first 28 days of life. Renal length and width were correlated with somatometric parameters and chronological age of neonates. Nomograms with point-wise 95% reference ranges were also constructed.

Results: Mean renal length and width were 4.31 ± 0.50 and 2.03 ± 0.28 and 4.33 ± 0.52 and 2.01 ± 0.31 on the right and left, respectively. Only the mean renal lengths were significantly different between males and females ($P < 0.01$) and there was no significant difference between the renal dimensions by sidedness. Body weight, chronological age, and to a minor extent, length were found to correlate positively with all renal dimensions.

Conclusions: This study of a large neonatal population has provided the normal range of US renal dimensions for neonates in the study area, using the age and weight in plotting the 95% reference ranges for the renal nomogram.

Keywords: Kidney size, neonates, nomogram, ultrasound

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INTRODUCTION

Neonates are not just smaller children as they have physiological differences from older children. Likewise, the kidneys in neonates are different from those of older children and adults for reasons beyond their small size and functional immaturity.[1] To overcome functional inefficiency occasioned by immaturity, the kidneys in newborns grow very rapidly during the 1st month of life through high rate of cellular hypertrophy and hyperplasia rather than through an increase in number of the nephrons.[2,3] This rapid growth

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distinguishes neonatal kidneys from those of older children and adults in terms of size, growth potential, and growth velocity. Therefore, data on normative morphometry of the kidneys from birth to the end of the neonatal period as determined by renal ultrasound (US) scans are important in clinical and research contexts to accurately classify normal-sized neonatal kidneys from abnormal. There are not many data on normal sizes of neonatal kidneys determined sonographically in the literature.[4-6] Fewer still are such data obtained in neonates from Nigeria where even those previously published are based on small sample sizes.[7] The aim of this study from two large hospitals done on neonates throughout the first 28 days of postnatal life was to provide reference data for clinical and research purposes primarily in sub-Saharan Africa.

MATERIALS AND METHODS

Study design

This was a prospective cross-sectional study of 528 apparently healthy neonates.

Study site

The study sites were (i) The University College Hospital - a tertiary health institution in the Ibadan metropolis which serves as a referral center in Southwest Nigeria and (ii) Adeoyo Maternity Hospital - a secondary health facility, which serves the Ibadan metropolis and its environs.

Ethical approval for the study was obtained from the Oyo State Research Ethical Review Committee (OYSRERC, Reference number AD 13/262/183). Informed written consent was obtained from the parents/caregiver of the neonates. Translation of the consent form was done to the local language and applied when needed.

Subjects

Apparently, healthy neonates from birth to 28th day of life delivered to consenting mothers or who presented for immunization at any of the two hospitals during the study period between May 2009 and May 2011, were included in the study.

Exclusion criteria

Neonates with perinatal asphyxia, neonatal sepsis, congenital heart diseases, congenital renal anomalies, solitary kidneys, and other systemic abnormalities were excluded. Neonates whose mothers or caregivers refused participation in the study were also excluded.

Clinical evaluation

All the neonates were evaluated by the neonatologist who performed a complete systemic examination, and the following relevant parameters were recorded in the pro forma questionnaire: age in days, sex, weight, and length at enrollment. The age was taken as the chronologic age in days. The neonatal weight and length were measured using Seca® weighing scale and infantometer. These were done using standard operating procedures for weight and height measurement.[8] The weighing scale was standardized at the beginning of the study and thereafter bimonthly using standard known weights.

Ultrasound examination

To minimize interobserver errors, all the US studies were performed at the neonates' bedside by AMA, a radiologist, using a SONOSITE portable US machine. A convex transducer with frequency range of 5–7.5 MHz was used on the neonates following application of a water-based, nonallergenic US gel. No preparation or sedation was required.

Ultrasound technique

The longitudinal (length) and anteroposterior (width) diameters of the right and left kidneys were obtained with the neonate in the prone position. On a longitudinal section of the kidney, renal length was taken as the maximum distance between the highest and lowest points of the respective upper and lower renal pole convexities [Figure 1] while the renal width was taken as the maximum distance between the anterior and posterior borders of the kidney on a plane perpendicular to the length [Figure 2]. To minimize intraobserver error, measurements were taken thrice for each neonate and the mean value in centimeter (cm) recorded to two decimal points.

Data management and statistical analysis

Clinical and US findings were documented in structured questionnaires which were immediately cross-checked for completeness and consistency by a research assistant. They were then double entered and cleaned using EpiData

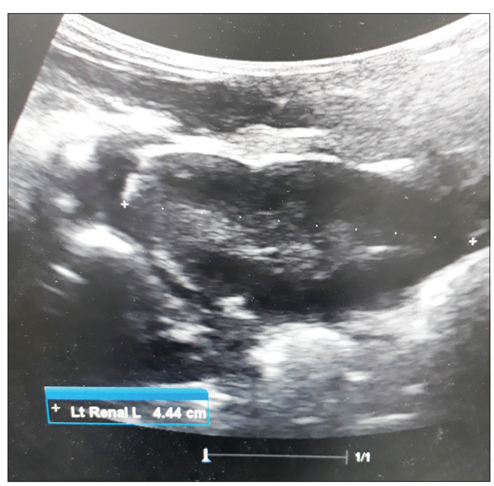

Figure 1: B-mode ultrasound: Longitudinal section of the kidney showing renal length measurement

version 3.1 by The EpiData Association Odense, Denmark. The cleaned and edited data were transferred to Stata version 13 by StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP. for analysis. Descriptive statistics were run for the baseline characteristics which included age, sex, weight, and length of the neonates as well as some kidney dimensions (length of right kidney, width of right kidney, length of left kidney, and width of left kidney).

The kidney dimensions (length of right kidney, width of right kidney, length of left kidney, width of left kidney) were then correlated with age, weight, and length of the neonates, and the parameters with strongest correlation coefficient were used in the development of the nomogram which was plotted with point-wise 95% reference ranges using normal approximation.

RESULTS

There were 528 neonates of which 50.6% were males. The ages of the participants ranged from 1 to 28 days with a mean of 9.56 ± 7.66 days. Other characteristics of the studied neonates such as weight, length, and their kidney parameters are shown in Table 1.

The mean kidney width was slightly higher on the right while the mean kidney length was slightly higher on the left. However, the differences were not statistically significant for both parameters [Table 1]. Overall, there is no significant difference in the right and left measurement of the kidney dimensions in the studied neonates.

The US measurements of the neonatal kidney dimensions in relation to the gender are as shown in Table 2. There was no statistical difference in the mean renal widths among both sexes (P = 0.8404 and 0.3091 on the right and left, respectively). However, male neonates had approximately 0.13 cm longer kidneys than females. This difference in length was statistically significant, P = 0.0019 and 0.0064 on the right and left, respectively.

Table 3 shows the correlation of neonatal age, weight, and length with kidney dimensions. For both renal length and width, the neonatal weight was found to have the strongest correlation (r = 0.49) with the kidney dimensions followed by age (r = 0.41). Hence, the weight and age were used in plotting the 95% reference ranges for the neonatal kidney nomogram. All correlations were significant at 5% level of significance.

Figures 3-6 shows the linear regression analysis of the kidney dimensions in relation to age of the neonates, respectively. These graphs show the degree of the correlations with the kidney dimensions.

Figures 3-6 also depict the 95% reference ranges for the kidney dimensions and age, respectively. This shows that age of the neonate in days can be used in determining the normal values of the kidney dimensions which is expected to be within these 95% reference ranges.

Table 1: Background characteristics

Variable	Mean±SD	Range	95% CI of the difference between left and right	*P*
Age (days)	9.55±7.66	1-28		
Weight (kg)	3.18±0.58	1.5-5.19		
Neonatal length (cm)	53.85±5.76	39-68		
Sex, *n* (%)				
Male	267 (50.57)			
Female	261 (49.43)			
Length right kidney	4.31±0.50	1.97-5.82		
Length left kidney	4.33±0.52	1.93-8.9	−0.480-0.267	0.5755
Width right kidney	2.03±0.28	1.2-2.96		
Width left kidney	2.01±0.31	1.3-5.27	−0.008-0.447	0.1802

SD – Standard deviation; CI – Confidence interval

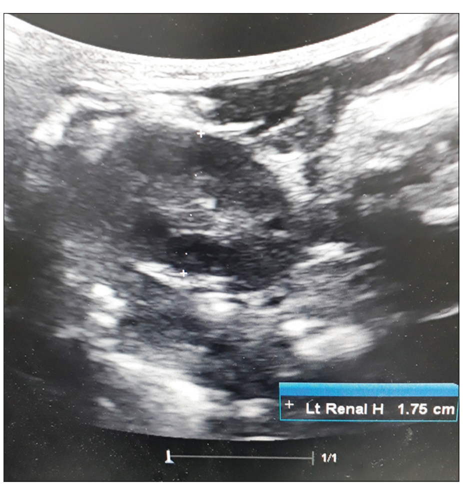

Figure 2: B-mode ultrasound: Transverse section of the kidney showing renal width (anteroposterior) measurement

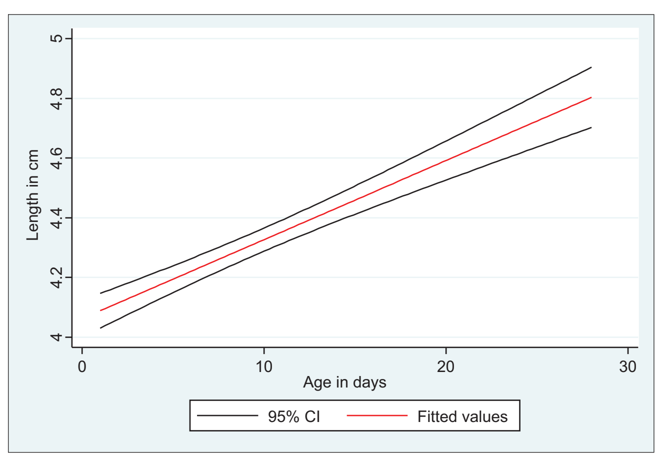

Figure 3: Length of right kidney with age

Figures 7-10 show the linear regression analysis of the kidney dimension in relation to weight (kg) of the neonates, respectively. These graphs show the degree of the correlations with the kidney dimensions.

Figures 7-10 also depict the 95% reference ranges for the kidney dimensions and weight, respectively. This shows that weight of the neonate in kilograms can be used in determining the normal values of the kidney dimensions which is expected to be within these 95% reference ranges.

These figures show that both kidney dimensions increase with the age of the neonates in days and weight in kilograms.

Kidney dimensions with values above normal range will fall above the 95% reference ranges while values below normal range will fall below the 95% reference ranges. A neonate with kidney dimension values above the 95% reference ranges has a greater kidney dimension (right or left) than for 97.5% of the reference population while a neonate with kidney dimensions (right or left) values below the 95% reference range has a smaller kidney dimension (right or left) than 97.5% of the reference population.

DISCUSSION

Renal length and breadth of the 528 pairs of neonatal kidneys were evaluated in this study. There was no significant difference in renal dimensions between the right and left side, but the kidney length was significantly higher in males by 0.14 cm ± 0.04 cm. Although statistically significant, the size of the difference between male and female is approximately 0.13 cm. The degree of significance of this finding is unclear. The kidney measurements showed stronger positive linear correlations with body weight and chronological age more than with the length of the neonates. Therefore, the 95% reference ranges of renal parameters for neonates in our Nigerian population were presented with respect to body weight and age.

The strength of this study lies in the large sample size from two hospital-based sources observed by the same experienced sonologist throughout the duration of the neonatal period. The previous studies on term neonates often confined their observations to the 1st week of life thereby leaving room for assumptions in the remainder of the neonatal period.[4,5] This study used simple parameters such as renal length and width as well as body weight and chronological age as against derived parameters, namely, renal volume and body surface area because the former are linear parameters which are easily measured in routine clinical practice. Although renal length may be less accurate than renal volume, it has been shown to be the most clinically useful of all measures of renal size by previous studies.[9,10] In addition, higher intra- and inter-observer

Table 2: Relationship between kidney dimensions and sex

Kidney parameter/sex	Mean±SD	95% CI	*P*
Right kidney			
Length			
Male	4.38±0.51	4.32-4.44	0.0019
Female	4.24±0.47	4.19-4.30	
Width			
Male	2.04±0.27	2.00-2.07	0.8404
Female	2.03±0.29	1.99-2.07	
Left kidney			
Length			
Male	4.39±0.55	4.32-4.45	0.0064
Female	4.26±0.48	4.20-4.32	
Width			
Male	2.03±0.33	1.99-2.07	0.3091
Female	2.00±0.30	1.96-2.04	

SD – Standard deviation; CI – Confidence interval

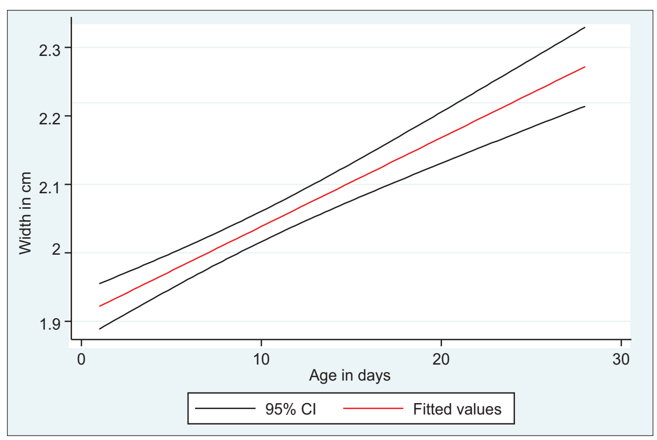

Figure 4: Width of right kidney with age

Table 3: Correlation of age, weight, and length with kidney dimensions

Variables	Age (days)	Weight (kg)	Length (cm)	Right kidney		Left kidney	
				Length	Width	Length	Width
Age (days)	1.0000						
Weight (kg)	0.3704	1.0000					
Neonatal length (cm)	0.3540	0.3801	1.0000				
Right kidney length	0.4093	0.4912	0.2097	1.0000			
Right kidney width	0.3589	0.4840	0.2839	0.4376	1.0000		
Left kidney length	0.3296	0.4661	0.1479	0.6326	0.3888	1.0000	
Left kidney width	0.2477	0.4455	0.1300	0.3445	0.4564	0.5826	1.0000

All correlations are significant at 5% level of significance

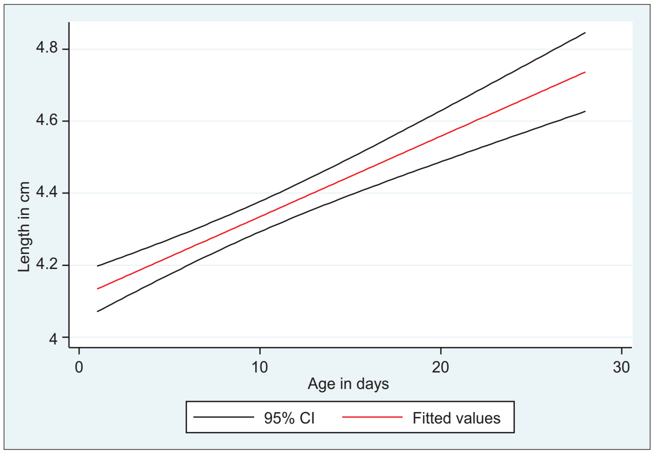

Figure 5: Length of left kidney with age

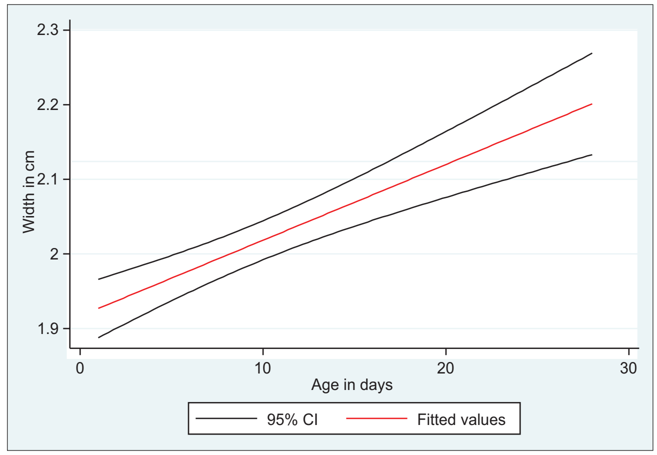

Figure 6: Width of left kidney with age

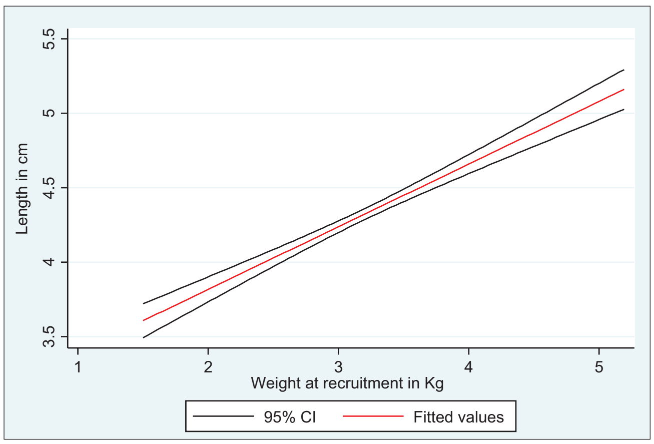

Figure 7: Length of right kidney with weight

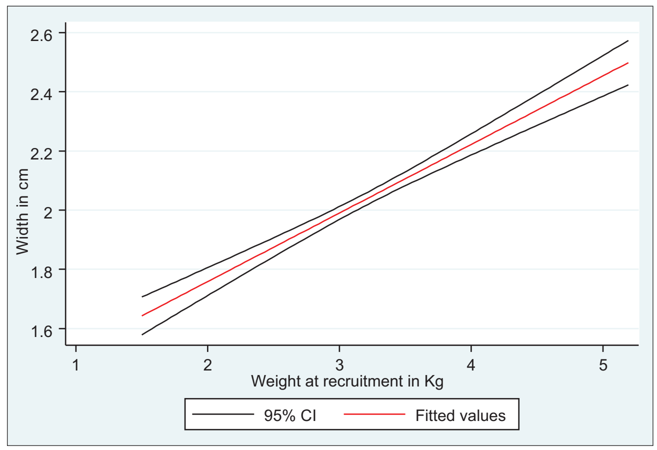

Figure 8: Width of right kidney with weight

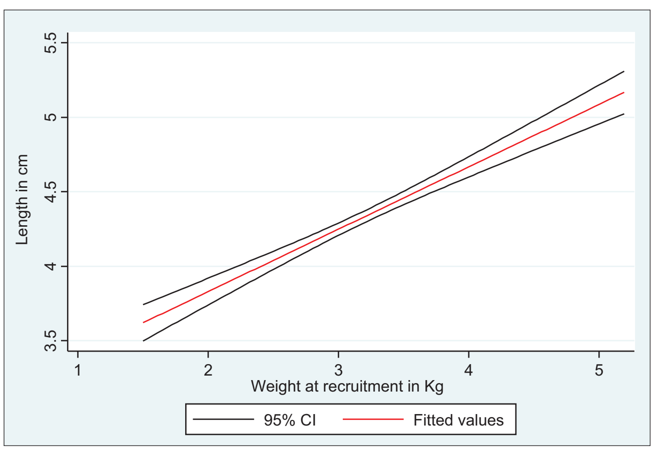

Figure 9: Length of left kidney with weight

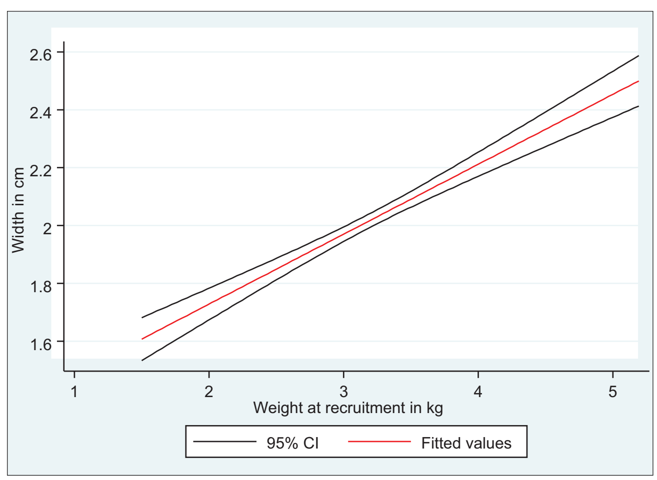

Figure 10: Width of left kidney with weight

variability which gets amplified to exponential proportions with derived parameters of renal size has also been reported.[4,9,10] Gestational age (GA) at birth was not used as a variable in this study since the information would have to be provided by the mothers and this may not always be accurate. Nevertheless, only apparently healthy controls were recruited and previous studies found GA to be a source of statistical noise and a poor substitute for birth weight.[4,6,11] This is however a limitation of this study as preterm neonates may have been included.

The maximum renal length of 4.31 ± 0.50 obtained in our participants is similar to some reported previously in neonates from other populations. Maximum renal length of 4.32 ± 0.46, 4.30 ± 0.6, 4.47 ± 0.30, and 4.49 ± 0.32 were reported in a British, Indian, Korean, and Nigerian population, respectively.[4,7,12,13] Lower values of 4.0 ± 0.4 and 2.79 ± 0.74 were however reported in some Asian populations, but the studies had small sample sizes which also included preterm babies in India.[5,13] Drnasin *et al*. in Croatia found a higher mean renal length of 5.2 ± 0.46 in neonates who formed a minor subgroup of 935 infants in the study.[14] While it appears that the mean renal length in neonates lies between 4.30 ± 0.6 and 4.49 ± 0.32 cm in most populations, determination of reference range of normal values in well-characterized groups of neonates from different populations is still necessary to prevent misclassification in view of the noted few but indispensable outliers.

The influence of gender on renal size in neonates is equivocal. In this study, male neonates had larger kidneys than female noenates which is in agreement with some previous studies but at variance with some other studies.[4-7,12,14-16] The reason for the discordant reports may not be exclusive to race since intraracial differences are also observed in the literature.[5,7,15,17] Another plausible explanation proffered by Scott *et al*. relates to postnatal sustenance of intrauterine differentials in growth velocity of organs which may be attributed to stimulatory actions of male hormones, but this is yet to be substantiated.[4,18,19] The observed gender difference in renal size is therefore of doubtful significance because, though statistically significant when reported, the difference was usually not more than 1–2 mm between both genders in previous studies.[4,5,14] Chronological age in days was emphasized in this study rather than GA. Estimated GA at birth is unreliable in our population where late booking of pregnancy, late or no prenatal US, and erroneous date for last menstrual period are frequent.[20] Furthermore, postnatal assessment of GA by external Ballard examination was reported to be inaccurate in rural Africa.[21] The positive correlations between the renal dimensions and body weight as well as with chronological age observed in this study concur with preponderance of opinion in the literature.[4-7,12,14-16]

It is interesting to note that length of the baby correlated weaker with renal parameters than age and weight in agreement with previous authors.[7] This may imply a disparity between the rates of increase in renal size and lengths in neonates. The growth rate of the kidneys however slows down towards the end of the 1st year of life and after this period, the renal size then correlates strongly with body height as reported in older children.[14-16] This is informative as body height has also been reported to be the main determinant of the smaller kidney sizes reported in malnourished children.[22,23] Therefore, nomograms of neonatal renal dimensions should not be plotted against neonatal length as obtained in older children, especially in countries where malnutrition is prevalent. In addition, locally generated nomograms should be generated for use in such countries rather than relying on Western-derived charts.

CONCLUSIONS

The length and width of kidneys in neonates correlate linearly with chronological age and body weight. Use of nomograms based on age or weight as against length-based ones should be used for appropriate classification of renal size in neonates.

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Conflicts of interest

There are no conflicts of interest.

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