Original Article

Morphometric analysis of Lumbricals in the Hand with Proximal origin of First and Second Lumbricals

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Abstract

Background: Lumbrical muscles, though small, play a significant role in precise digit movements. Variations in attachment and size are common, and proximal origin has been implicated in carpal tunnel syndrome. The aim and objective is to measure muscle belly length, width, thickness, and tendon length of the four lumbricals in cadaveric hands, and assess differences between right and left hands, and between male and female cadavers. Settings and Design is Cross-sectional study. **Material and Methods:** This descriptive cadaveric study examined 80 hand specimens (40 right, 40 left, paired by cadaver) from 40 embalmed cadavers (33 male, 7 female). Lumbrical morphometry was measured using a Vernier calliper. Statistical Analysis is right-left comparison used a paired-samples t-test matched by cadaver; sex comparison used an independent-samples t-test at cadaver level. Hands with absent or rudimentary third or fourth lumbricals were excluded from that analysis. **Results:** Tendon length of the first lumbrical was significantly longer in the right hand (2.62±0.98 cm) than the left (2.40±0.88 cm; P=0.009). No other dimension differed significantly between sides or sexes, though the sex comparison was limited by the small female sample (n=7). Proximal origin of the first lumbrical with hypertrophy was found in one hand (1.25%); proximal origin of a bipennate second lumbrical was found in another (1.25%). **Conclusion:** Tendon length of the first lumbrical differs significantly between right and left hands of the same individual. Proximal origin of the first and second lumbricals, with hypertrophy, was also noted, with potential to compress the median nerve and predispose to carpal tunnel syndrome.

Keywords: Lumbricals, flexor digitorum profundus, proximal origin, morphometry.

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Introduction

The lumbricals are four small intrinsic hand muscles that arise from the flexor digitorum profundus tendons and insert into the extensor expansion, uniquely originating and inserting on tendons. Their architecture—minimal cross-sectional area, long fibre-length ratio, and high spindle density—favours proprioceptive fine-tuning over power generation, enabling simultaneous MCP flexion and IP extension essential for precision grip. Clinically, proximal migration of the first and second lumbricals into the carpal tunnel during finger flexion raises intracanalicular pressure and is implicated in carpal tunnel syndrome. This study morphometrically characterises all four lumbricals in 80 cadaveric hands, comparing right-left and sex-based differences

Materials and Methods

This descriptive study was carried out on cadaveric specimens in the Department of Anatomy. The specimens comprised 80 human hands from 40 embalmed cadavers: each cadaver contributed one right and one left hand, correctly paired by cadaver of origin. Of the 40 cadavers, 33 were male (66 hands) and 7 were female (14 hands).

Dissection was performed according to Cunningham's Manual of Practical Anatomy, Volume 1, Upper Limb and Lower Limb, 15th edition, with additional dissection performed for further clarity. Photographs were taken with a Canon digital camera to illustrate the findings.

Muscle belly length, tendon length, width, and thickness of each of the four lumbricals (L1–L4) were measured in all 80 hands using a Vernier caliper. Width and thickness were measured at a level 2.5 cm distal to the distal border of the flexor retinaculum in all lumbricals.

Handling of absent lumbricals: The third lumbrical was absent or rudimentary in 5 of 80 hands (6.3%) and the fourth lumbrical in 13 of 80 hands (16.3%). These hands were excluded from the corresponding metric analysis for that digit (i.e., treated as missing rather than as a zero-length measurement), since coding a true absence as 0 cm would artificially inflate variance and depress the calculated mean for that digit. The n reported for each

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digit in Tables 1–4 reflects this exclusion and therefore varies between 80 (L1, L2) and 67–75 (L3, L4).

Statistical analysis: Because each cadaver contributed one right and one left hand, right and left measurements are paired, non-independent observations. Right–left comparison for each of the sixteen muscle–metric combinations (four digits × four dimensions) was therefore performed using a paired-samples t-test, matched by cadaver, with a two-tailed alpha of 0.05. Normality of the paired differences was assessed with the Shapiro–Wilk test, and the Wilcoxon signed-rank test was used as a non-parametric sensitivity check. Sex comparison was performed at the cadaver level: right and left hand values were averaged per cadaver (n=40; 33 male, 7 female) before comparison by independent-samples t-test (Levene's test used to determine whether equal variances could be assumed), with the Mann–Whitney U test as a non-parametric check. Analysis was performed using statistical software equivalent to SPSS (Paired-Samples t-test and Independent-Samples t-test procedures). A P-value of <0.05 was considered statistically significant.

Results

In the present study, muscle belly length, tendon length, width and thickness of all the lumbricals in right and left hands were measured in 80 hand specimens from 40 embalmed cadavers (40 right, 40 left, correctly paired by cadaver of origin). Of the 40 cadavers, 33 were male (66 hands) and 7 were female (14 hands). Width and thickness were measured at a level, 2.5cm distal to the distal border of flexor retinaculum in all lumbricals. Morphometric analysis was done in the hands, applying the test of significance (paired samples t-test and independent samples t-test).

Handling of absent lumbricals: 9 hands had an absent/rudimentary third lumbrical and 17 hands had an absent/rudimentary fourth lumbrical (recorded originally as 0 across all four measurements, or with an isolated stray zero alongside otherwise plausible values). These were coded as missing for that digit rather than as true zero values, and are reported separately as an absence rate. Including true absences as 0 cm would have artificially inflated variance and pulled down the mean length/width/thickness of L3 and L4, biasing any right–left or sex comparison for those digits.

Right vs left comparison: Because each cadaver contributed one right and one left hand, right and left measurements are not independent. A paired-samples t-test (two-tailed, α=0.05) was used for each of the 16 muscle-metric combinations (4 digits × 4 metrics), matched by cadaver. Normality of the paired differences was checked with the Shapiro–Wilk test; Wilcoxon signed-rank P values are reported alongside as a non-parametric sensitivity check.

[Tables 1–4] shows comparison of muscle belly length, tendon length, width and thickness of the lumbricals in right and left hands (paired analysis).With correct pairing, tendon length of the first lumbrical (L1) is the only statistically significant right–left difference (right > left, P=0.009).

Table 1: Comparison of muscle belly length of lumbricals in right and left hands (paired analysis)

Digit	n pairs	Right hand Mean ± SD	Right Min–Max	Left hand Mean ± SD	Left Min–Max	Mean difference (R−L) ± SD	t (df)	P value
L1	40	5.15 ± 1.63	1.00–8.00	5.00 ± 1.61	1.00–7.00	0.152 ± 0.800	1.206 (39)	0.235
L2	40	5.02 ± 1.61	0.70–7.00	5.08 ± 1.89	0.75–9.75	-0.058 ± 1.130	-0.322 (39)	0.749
L3	35	4.36 ± 1.63	0.65–6.90	4.42 ± 1.66	0.75–6.80	-0.059 ± 1.038	-0.334 (34)	0.741
L4	31	3.64 ± 1.45	0.50–6.50	3.77 ± 1.51	0.60–6.20	-0.129 ± 0.761	-0.944 (30)	0.353

Paired-samples t-test (two-tailed). *P<0.05, **P<0.01, ***P<0.001. n pairs = cadavers with the muscle present bilaterally (absent lumbricals excluded).

Table 2: Comparison of tendon length of lumbricals in right and left hands (paired analysis)

Digit	n pairs	Right hand Mean ± SD	Right Min–Max	Left hand Mean ± SD	Left Min–Max	Mean difference (R−L) ± SD	t (df)	P value
L1	40	2.62 ± 0.98	0.20–4.00	2.40 ± 0.88	0.25–3.60	0.217 ± 0.504	2.731 (39)	0.009**
L2	40	2.46 ± 0.91	0.20–4.00	2.29 ± 0.85	0.25–3.50	0.161 ± 0.550	1.853 (39)	0.071
L3	35	2.10 ± 0.85	0.20–3.30	2.05 ± 0.85	0.20–3.20	0.053 ± 0.542	0.577 (34)	0.568
L4	31	1.71 ± 0.79	0.17–2.60	1.72 ± 0.73	0.20–2.90	-0.017 ± 0.536	-0.177 (30)	0.860

Paired-samples t-test (two-tailed). *P<0.05, **P<0.01, ***P<0.001. n pairs = cadavers with the muscle present bilaterally (absent lumbricals excluded).

Table 3: Comparison of width of lumbricals in right and left hands (paired analysis)

Digit	n pairs	Right hand Mean ± SD	Right Min–Max	Left hand Mean ± SD	Left Min–Max	Mean difference (R−L) ± SD	t (df)	P value
L1	40	0.55 ± 0.20	0.20–0.95	0.56 ± 0.17	0.25–0.86	-0.005 ± 0.161	-0.207 (39)	0.837
L2	40	0.44 ± 0.14	0.15–0.76	0.44 ± 0.13	0.25–0.74	-0.005 ± 0.148	-0.224 (39)	0.824
L3	35	0.36 ± 0.13	0.15–0.65	0.35 ± 0.10	0.20–0.65	0.015 ± 0.119	0.764 (34)	0.450
L4	31	0.30 ± 0.11	0.10–0.55	0.28 ± 0.07	0.18–0.46	0.014 ± 0.100	0.790 (30)	0.436

Paired-samples t-test (two-tailed). *P<0.05, **P<0.01, ***P<0.001. n pairs = cadavers with the muscle present bilaterally (absent lumbricals excluded).

Table 4: Comparison of thickness of lumbricals in right and left hands (paired analysis)

Digit	n pairs	Right hand Mean ± SD	Right Min–Max	Left hand Mean ± SD	Left Min–Max	Mean difference (R−L) ± SD	t (df)	P value
L1	40	0.33 ± 0.08	0.15–0.54	0.32 ± 0.08	0.20–0.50	0.006 ± 0.060	0.656 (39)	0.516

L2	40	0.27 ± 0.06	0.15–0.41	0.28 ± 0.06	0.20–0.51	-0.004 ± 0.051	-0.531 (39)	0.599
L3	35	0.23 ± 0.05	0.10–0.34	0.23 ± 0.05	0.15–0.36	-0.005 ± 0.048	-0.604 (34)	0.550
L4	31	0.21 ± 0.04	0.15–0.35	0.20 ± 0.04	0.15–0.30	0.010 ± 0.048	1.169 (30)	0.251

Paired-samples t-test (two-tailed). *P<0.05, **P<0.01, ***P<0.001. n pairs = cadavers with the muscle present bilaterally (absent lumbricals excluded).

Male vs female comparison: performed at the cadaver level (n=40; right and left hand values averaged per cadaver) rather than at the hand level (n=80), because the 80 hands are not 80 independent sampling units — two hands from the same cadaver share the cadaver's sex, and treating them as independent would double-count each cadaver and artificially inflate the sample size and the apparent precision of the sex comparison. Independent-samples t-test (Welch's or Student's, per Levene's test result) was used, with Mann–Whitney U as a non-parametric check. No statistically significant sex difference was found for any muscle-metric combination (all P>0.05).

[Table 5-8] shows comparison of muscle belly length, tendon length, width and thickness of the lumbricals -male vs female.

Table 5: Comparison of muscle belly length of lumbricals — male vs female

Digit	n (M/F)	Male Mean ± SD	Female Mean ± SD	Mean difference (M−F)	t	P value
L1	33/7	5.17 ± 1.59	4.66 ± 1.49	0.508	0.775	0.443
L2	33/7	5.10 ± 1.68	4.79 ± 1.69	0.319	0.457	0.651
L3	33/7	4.53 ± 1.53	4.31 ± 1.55	0.225	0.352	0.726
L4	31/5	3.83 ± 1.33	3.40 ± 1.49	0.431	0.661	0.513

Independent-samples t-test on cadaver-level means (right and left hand averaged per cadaver; n=40 cadavers: 33 male, 7 female). Equal variances assumed per Levene's test (P>0.05) for all comparisons.

Table 6: Comparison of tendon length of lumbricals — male vs female

Digit	n (M/F)	Male Mean ± SD	Female Mean ± SD	Mean difference (M−F)	t	P value
L1	33/7	2.54 ± 0.90	2.38 ± 0.96	0.158	0.419	0.678
L2	33/7	2.38 ± 0.82	2.36 ± 0.98	0.022	0.063	0.950
L3	33/7	2.13 ± 0.76	2.20 ± 0.91	-0.071	-0.215	0.831
L4	31/5	1.76 ± 0.66	1.75 ± 0.86	0.010	0.030	0.977

Independent-samples t-test on cadaver-level means (right and left hand averaged per cadaver; n=40 cadavers: 33 male, 7 female). Equal variances assumed per Levene's test (P>0.05) for all comparisons.

Table 7: Comparison of width of lumbricals — male vs female

Digit	n (M/F)	Male Mean ± SD	Female Mean ± SD	Mean difference (M−F)	t	P value
L1	33/7	0.57 ± 0.17	0.47 ± 0.13	0.105	1.582	0.122
L2	33/7	0.45 ± 0.12	0.41 ± 0.13	0.035	0.702	0.487
L3	33/7	0.38 ± 0.10	0.32 ± 0.10	0.056	1.315	0.197
L4	31/5	0.29 ± 0.08	0.25 ± 0.07	0.039	1.055	0.299

Independent-samples t-test on cadaver-level means (right and left hand averaged per cadaver; n=40 cadavers: 33 male, 7 female). Equal variances assumed per Levene's test (P>0.05) for all comparisons.

Table 8: Comparison of thickness of lumbricals — male vs female

Digit	n (M/F)	Male Mean ± SD	Female Mean ± SD	Mean difference (M−F)	t	P value
L1	33/7	0.33 ± 0.07	0.30 ± 0.06	0.028	0.916	0.366
L2	33/7	0.28 ± 0.05	0.25 ± 0.06	0.024	1.067	0.293
L3	33/7	0.23 ± 0.04	0.22 ± 0.06	0.010	0.548	0.587
L4	31/5	0.21 ± 0.04	0.21 ± 0.04	-0.005	-0.297	0.768

Independent-samples t-test on cadaver-level means (right and left hand averaged per cadaver; n=40 cadavers: 33 male, 7 female). Equal variances assumed per Levene's test (P>0.05) for all comparisons.

Absence of third and fourth lumbricals

Third lumbrical absent/rudimentary: 5/80 hands (6.3%) — 4 right, 1 left.

Fourth lumbrical absent/rudimentary: 13/80 hands (16.3%) — 9 right, 4 left.

McNemar's exact test on cadaver-paired presence/absence found no statistically significant right–left difference in absence rate for L3 (P=0.375) or L4 (P=0.063; borderline, right hands more often affected — worth mentioning descriptively even though not significant).

"Right and left lumbricals from the same cadaver were compared using a paired-samples t-test. The mean tendon length of the first lumbrical was significantly greater in the right hand (2.62 ± 0.98 cm) than the left hand (2.40 ± 0.88 cm; mean difference 0.22 cm, 95% CI derived from paired SD, t=2.73, df=39, P=0.009). No other muscle belly length, width, thickness, or tendon length measurement differed significantly between right and left hands (all P>0.05). Third and fourth lumbricals were absent or rudimentary in 5 (6.3%) and 13 (16.3%) of 80 hands respectively; this did not differ significantly by side (McNemar exact P=0.375 and P=0.063). On cadaver-level comparison, no lumbrical dimension differed significantly between male (n=33) and female (n=7) cadavers, though this comparison was limited by the small number of female specimens."

Proximal origin of first and second lumbricals: An additional observation was seen. First lumbrical in the left hand of a cadaver showed proximal origin from the tendon of flexor digitorum profundus [FDP] beneath the flexor retinaculum with the fingers in extension. Length of the bulky muscle belly was 7cm, tendon length was 2.6cm, and width 0.95cm and a thickness of 0.49cm [Figure 1]. In one left hand, the second lumbrical was the longest ,showed a proximal origin [Figure 2a]. The length of the muscle was 9.75cm cm and tendon length was 2.8cm [Figure 2b]. It showed a bipennate architecture with a sinuous pattern, the muscle had a tendinous origin, from the deep flexor tendon for the middle finger in the forearm, arose 0.67cm proximal to the proximal border of flexor retinaculum. The additional belly arose distal to the distal border of flexor retinaculum ,from the adjacent side of the deep flexor tendon for index finger. The muscle was inserted into the extensor expansion of middle finger.

Discussion

Right–left comparison: Because each cadaver in this series contributed one right and one left hand, right and left measurements are not independent observations but paired data from the same individual. The present analysis therefore used a paired-samples t-test for each muscle dimension, matched by cadaver — the statistically appropriate design for this kind of bilateral, within-subject comparison. On this basis, the only statistically significant right–left difference identified was in the tendon length of the first lumbrical, which was longer on the right hand (2.62 ± 0.98 cm) than the left (2.40 ± 0.88 cm; mean difference 0.22 cm, t=2.73, df=39, P=0.009). No significant difference was found for muscle belly length, width, or thickness of any of the four lumbricals, nor for tendon length of the second, third, or fourth lumbricals (all P>0.05).

This finding sits within a mixed literature. Mutalik,[4] reported that the first lumbrical was significantly longer on the left hand (P=0.049) — the opposite side to the present finding — and also found the breadth of the fourth lumbrical to be significantly greater on the left. Modasiya et al,[3] found no significant right–left difference in first lumbrical length (P=0.390), concordant with the present study for that specific measurement, though their analysis did not extend to tendon length. Taken together, the available evidence does not point to a single consistent direction of right–left asymmetry across studies, digits, or dimensions; this is not unexpected, given that intrinsic hand muscle morphometry is influenced by a combination of individual variation, measurement technique, sample composition, and — plausibly — hand dominance, which none of the available cadaveric studies, including the present one, were able to record.

The mechanism underlying the right-sided lengthening of the first lumbrical tendon observed here is not established from cadaveric material alone. One biologically plausible contributor is asymmetric use associated with hand dominance: because roughly nine in ten individuals are right-hand dominant, the right first and second lumbricals - which are directly involved in the precision pinch and pen/tool-grip actions of the index and middle fingers - may be subject to greater repetitive loading over a lifetime than their left-sided counterparts. Musculoskeletal asymmetries attributable to hand preference have been documented elsewhere in the human body, including at muscle entheses and in the cortical representation of the hand in the motor cortex, providing indirect support for the biological plausibility of use-dependent asymmetry in intrinsic hand muscle architecture, although direct evidence for the lumbricals specifically is lacking. As this was a cadaveric study, handedness could not be verified, and this explanation remains speculative rather than demonstrated.

Sex comparison: No statistically significant sex difference was found for any lumbrical dimension in the present series when compared at the cadaver level (33 male, 7 female cadavers). This contrasts with Maindarkar and Dope,[8] who — in a comparably sized series (42 male, 8 female hands) — found the length of all four lumbricals to be significantly greater in males (P=0.001–0.019), along with the first lumbrical's tendon length (P=0.024) and breadth (P=0.097). The discrepancy most plausibly reflects the limited statistical power of the present sex comparison: with only 7 female cadavers, the study is underpowered to detect anything short of a large effect size, and a true sex difference of the magnitude reported by Maindarkar and Dope cannot be excluded on the basis of a non-significant result here. This should be regarded as a limitation of sample composition rather than evidence that no true sex difference exists, and is discussed further below.

The third and fourth lumbricals were absent or rudimentary in a minority of hands (5/80 and 13/80 respectively) and were excluded from the corresponding metric analyses on that basis, as noted in Methods; a fuller morphological account of this and other anatomical variations encountered in this series is reserved for a separate report.

Proximal origin and clinical correlation: Proximal origin of the first lumbrical, extending into the carpal tunnel, was observed in one hand in the present series (1.25%), with the muscle belly notably hypertrophied (length 7 cm, tendon length 2.6 cm, width 0.95 cm, thickness 0.49 cm) — each of these values lying at or beyond the upper end of the normal range recorded for the remainder of the series. A hypertrophied lumbrical muscle extending into the carpal tunnel can cause carpal tunnel syndrome.

[Table 9] shows comparison of proximal origin of first lumbrical in different studies. Ashwini M Mutalik (2011),[4] and Modasiya et al (2013),[3] observed proximal origin in 12 hands. Neelima P et al (2016),[5] observed hypertrophied lumbrical with proximal origin in 2 hands . Nithya J Mahendra et al (2013) [6] reported a case of proximal origin of first lumbrical in a study on 30 hands. A second hand showed proximal origin of a bipennate second lumbrical (1.25%), which was also the longest muscle recorded in the entire series (9.75 cm). These findings are consistent with, and add to, a literature that has consistently linked proximal lumbrical origin- particularly when combined with hypertrophy -to a mechanical contribution to carpal tunnel syndrome. Cobb et al,[9] demonstrated in cadaveric pressure studies that lumbrical incursion into the carpal tunnel during finger flexion measurably raises intracanalicular pressure, and Siegel et al,[10] found that lumbrical origins were significantly more proximal in patients undergoing surgery for idiopathic carpal tunnel syndrome than in cadaveric controls, particularly in younger patients whose occupations required repetitive hand movement. A recent cadaveric mapping study has further characterised the second lumbrical as the digit most consistently found to have the most proximal origin among the four, reinforcing its proposed role as a dynamic — rather than purely static — content of the carpal tunnel.[11]

The prevalence of proximal first lumbrical origin reported in the literature varies considerably by series — from 1.25% in the present study to 20% in Mutalik's series of 60 hands[4]– a range that likely reflects genuine population variation as well as differences in dissection technique and the threshold used to define "proximal." Table 9 situates the present finding within this range. Regardless of the precise prevalence, the clinical implication is consistent across studies: clinicians, hand surgeons, and radiologists should maintain awareness that an anomalously proximal or hypertrophied lumbrical is a structurally plausible and recurrently documented contributor to median nerve compression, particularly in patients whose occupation or habitual hand use involves repetitive finger flexion.

Table 9: Comparison of proximal origin of first lumbrical in different studies

Author	No of hands	Proximal origin
Modasiya et al [2013] [3]	80	12(15%)
Ashwini M Mutalik [2011] [4]	60	12(20%)
Neelima P et al [2016] [5]	32	2(6.25%)
Nithya J Mahendra et al [2013] [6]	30	1(3.33%)
Present study	80	1(1.25%)

Strengths and limitations: This study's principal methodological strength is the use of a paired analytical design that correctly reflects the bilateral, within-subject structure of the data — each cadaver contributing a right and a left hand — which has not been consistently applied in comparable published series. Hands in which the third or fourth lumbrical was absent or rudimentary were identified and excluded from the corresponding metric analysis rather than being treated as zero-length measurements, avoiding a systematic downward bias in the mean length, width, thickness, and tendon length of these digits.

The principal limitation is the marked sex imbalance in the cadaveric pool (33 male: 7 female), which limits the statistical power of the sex comparison and should temper interpretation of the negative (non-significant) result reported above. Hand dominance of the cadavers was not recorded, which limits the ability to directly test the use-dependent asymmetry hypothesis proposed to explain the right-sided lengthening of first lumbrical tendon length. As with all cadaveric morphometric studies, measurements were taken from embalmed, non-living tissue, which may not fully replicate the mechanical or dimensional properties of the lumbricals in vivo.

Conclusion

The present study examined the lumbrical muscles in 80 cadaveric hands from 40 embalmed cadavers, comprising an important part of the intrinsic musculature of the palmar aspect of the hand. Muscle belly length, width, thickness, and tendon length of all four lumbricals were measured and compared between the right and left hand of the same individual, and between male and female cadavers.

Because right and left hands in this series originated from the same cadavers, right–left comparison was performed using a paired-samples t-test.On this basis, tendon length of the first lumbrical was found to be significantly greater in the right hand than the left (P=0.009); no other dimension of any of the four lumbricals differed significantly by side. No lumbrical dimension differed significantly between male and female cadavers, although this comparison was limited by the small number of female specimens available and should be interpreted with appropriate caution rather than as evidence of a true absence of sex-based difference.

Proximal origin of the first lumbrical, with hypertrophy, and proximal origin of a bipennate second lumbrical were each noted in one hand. These variations carry recognised clinical significance: a hypertrophied or proximally originating lumbrical can extend into the carpal tunnel and has been repeatedly implicated in the literature as a mechanical contributor to median nerve compression, particularly in individuals whose occupations involve repetitive finger movement. Hypertrophied lumbricals may additionally compress the radial and ulnar digital arteries, leading to chronic ischaemia. Clinicians and hand surgeons should therefore remain aware of the range of normal and variant lumbrical morphometry described here, particularly when planning microsurgical procedures of the hand or investigating the aetiology of carpal tunnel syndrome. A fuller account of the morphological variations encountered in this series, including patterns of lumbrical absence, is intended to form the subject of a separate report.

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Conflicts of interest

There are no conflicts of interest.

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