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Morphological Variants of the Abductor Pollicis Longus and Extensor Pollicis Brevis Tendons. A Cadaveric Study

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SUMMARY

Background. The goal of the present research was to study the morphological variants of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendons and their distal insertions in the hand.

Methods. An aggregate of 115 embalmed cadaveric upper limbs were utilized for this descriptive cross-sectional study. The morphological variants of the APL tendon were divided into 4 categories, one (type 1), two (type 2), three (type 3) and more than three tendons (type 4). The variations of tendons of EPB were divided into 3 types, one tendon (type 1), two tendons (type 2) and the absence of muscle (type 0).

Results. It was observed that, only 22 upper limbs (19.1%) had single tendon of APL (type 1). The double tendon of APL was observed in 73 (63.5%) specimens (type 2). In 19 (16.5%) cases, there were three tendons of the APL (type 3). In one of the upper limbs (0.9%), there were six tendons of the APL (type 4). The present study also observed that, in 112 (97.4%) cases, EPB was having a single tendon (type 1) and in one specimen (0.9%), it had two tendons (type 2). The EPB muscle was absent in 2 (1.7%) cases (type 0).

Conclusions. The morphological knowledge about the APL and EPB tendons are of importance in the plastic and reconstructive hand surgeries. The present study observed that, the accessory tendons of APL have higher frequency than the expected.

KEY WORDS

Compartment syndromes; De Quervain stenosing tenosynovitis; forearm; plastic surgery; tendons.

BACKGROUND

The anatomy can only be encountered with a standard surgical approach. The competent hand surgery depends on understanding the dynamic interplay between the anatomy of the soft tissue and bone. However, it was reported that the anatomical variations are often unpredictable unless the surgeon is well experienced (1). The morphological variations can lead to pathological conditions, but some are considered as normal morphological variants and they can be utilized as grafts in the surgical reconstruction (2). Backhouse (3) used the abductor pollicis longus (APL) tendon to construct the ruptured extensor pollicis longus. The APL and extensor pollicis brevis (EPB) are muscles of back of the forearm, which enter the extensor retinaculum at its first compartment. It was reported that the anatomical variations of APL, can end up in the pathological conditions like De Quervain tenosynovitis, inflammation of the first carpometacarpal joint and subluxation of trapezio-metacarpal joint (4). The variability in the number of tendons of APL and their distal attachments have clinical significance (5, 6). De Quervain's syndrome occurs due to the stenosing tenosynovitis of the extenson retinaculum at its first compartment (7). It was reported that, De Quervain's syndrome is often seen in students and other populations, who frequently use the cell phones, because the speed of texting has been very fast (8). There will be sudden stress in the intrinsic tendons of the thumb, which cause pain and weakness over the base of the thumb. The young

people like as in students, who are addicted to cell phone usage are often tested positive for the De Quervain's syndrome (8).
The morphology of EPB tendon should also be looked into during the surgical procedure of the first compartment of extensor retinaculum performed for the decompression in De Quervain's syndrome (9). In the orthopedic hand surgery, the sound knowledge of anatomy of hand is essential for any of the procedure and prosthesis insertion. The complex movements of the hand and thumb require multiple muscles and their tendons, which run within this area. The higher frequency of morphological variation of the hand can be considered as a natural outcome due to the larger number of tendons (10).
It is well known that, few of the intrinsic muscles of thumb contain the sesamoid bones in their tendons. Balaji *et al.* (11) observed that, the sesamoid bones are found in the tendons of adductor pollicis, flexor pollicis brevis, abductor pollicis brevis and flexor pollicis longus. However, they are not observed in the APL and EPB tendons. The function of the sesamoid bones is that; they change the direction of the forces acting on these muscles. Since APL and EPB do not contain sesamoid bones, they are more prone for the stress and inflammation.
Karauda *et al.* (12) reported that, APL is characterized by the higher frequency of morphological variants. They categorized the APL into 3 types, among them type 1 was characterized by a single distal attachment into the tendon of the base of the first metacarpal bone. The type 2 had dual attachments and type 3 had accessory bands, which were fusing with the other tendons. El-Beshbishy *et al.* (13) observed the accessory tendons of APL in all of their specimens (100%) and the number of tendons were ranging between 1 and 6. They classified the APL tendons into medial and lateral, the lateral one was considered as the main tendon inserting into the base of the first metacarpal bone. The medial tendon slips were inserted into either trapezium, opponens pollicis, abductor pollicis brevis, thenar fascia or capsule of first carpometacarpal joint (13).
Brunelli and Brunelli (14) observed the absence of EPB in 3.8% of their specimens. They also observed few of the morphological variants of EPB, like insertion into the distal phalanx (7.7%) and into the dorsal digital expansion in 69.2% cases. Shiraishi and Matsumura (15) observed that, the number of tendons of EPB range between 1 and 3, whereas the number of tendons of APL varied between 1 and 7. It was reported that the accurate procedure of tenosynovectomy, which is performed for the De Quervain disease needs to evaluate for the accessory tendons of APL and EPB (16). It was also opined that the tendon injuries in the hand are frequent in rock climbers and sports person (17). The detailed knowledge about the etiology, diagnosis and management of tendon injury is required, because these injuries can also rarely occur in non-climbing people (17). Due to all these clinical implications in the hand pathology and surgery, the aim of this present anatomical research was to examine the morphological variants of the tendons of the APL and EPB and their distal insertions at the hand.

MATERIALS AND METHODS

An aggregate of 115 embalmed cadaveric upper limbs (53 right and 62 left sided) were utilized for this descriptive cross sectional study. The age and gender of the specimens were not taken into consideration. The right and left sided upper limbs were chosen randomly and they are not completely corresponding from the same cadaver. The sample size was determined as per the previous publication by Kulthanan and Chareonwat (5). The back of forearm and hand region of the embalmed cadavers were carefully dissected. The APL and EPB were exposed from their origin and the tendons were carefully followed in the extensor retinaculum at the first compartment until their insertion. If any multiple tendons, they were also traced till their insertion. The tendons were defined as independent or easily divisible bands, which originated from the muscle. The tendons were considered as one tendon, two tendons, three tendons etc. by separating them from the APL at the myo-tendinous intersection.
The morphological variants of APL tendons in the first compartment were divided into 4 types, which are represented in **figure 1 A**, as: one tendon (type 1), two tendons (type 2), three tendons (type 3) and more than three tendons (type 4). Whereas the variations of tendons of EPB (**figure 1 B**) were divided into 3 types, one tendon (type 1), two tendons (type 2) and the absence of EPB muscle (type 0).
The present study has fulfilled the criteria and exempted from the ethics committee (Institutional Ethics Committee, Kasturba Medical College, Mangalore, India; Reg No. ECR/541/Inst/KA/2014/RR-20; DHR Reg. No. EC/

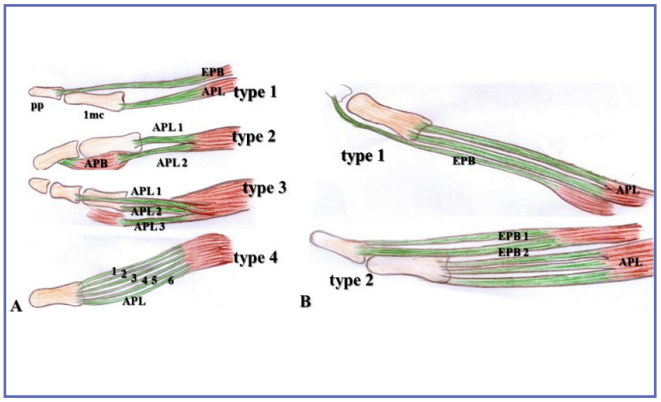

Figure 1. Morphological classification of the tendons in this study.
(**A**) Abductor pollicis longus (APL); (**B**) Extensor pollicis brevis (EPB).

NEW/INST/2020/742; Approval No. IEC KMC MLR 10/2021/321; Date: 10/21/2021). This study was approved by the scientific committee of the institution and was performed as per the international ethical standards laid by the declaration of Helsinki. Signed informed consents are not applicable to this cadaveric study.

RESULTS

The frequency of number of tendons of APL in this study are represented in **figure 2**. Only 22 upper limbs (19.1%) revealed single tendon of the APL (**figure 3**). However, the most common finding was the double tendon of APL, which was observed in 73 (63.5%) specimens (**figure 4**). In 19 (16.5%) cases, there were three tendons of the APL (**figure 5**). In one of the upper limbs (0.9%), there were six tendons of the APL (**figure 6**). In all the specimens, the chief APL tendon was distally attaching into the first metacarpal base. The additional tendons inserted into the trapezium bone in 58 cases (62.3%), first metacarpal bone in 17 cases (18.3%) and to the abductor pollicis brevis in 17 cases (18.3%). In the morphological variant with six tendons of APL, all ended up in inserting into the first metacarpal bone at its base. In one specimen, the 3rd APL tendon was inserting into the proximal phalanx of the pollex at its base (1.1%) and in this specimen, EPB was absent (**figure 5**). This suggests that the EPB was replaced by the APL tendon in this morphological variant. The frequency of variant insertions of the accessory tendons of APL is represented in **table I**.

The frequency of number of tendons of EPB is represented in **figure 7**. The present study observed that, in 112 (97.4%) of the cases, EPB was having a single tendon with single inser-

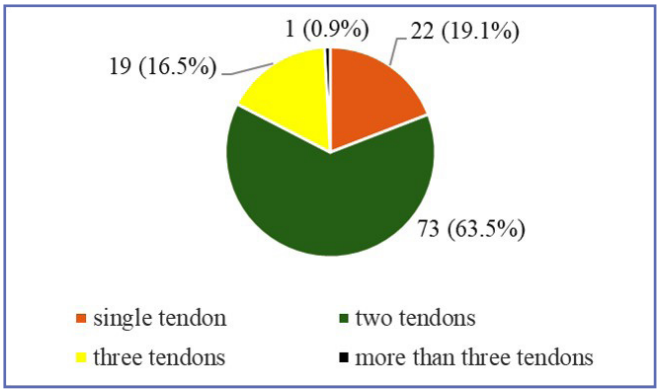

Figure 2. Frequency of number of tendons of abductor pollicis longus (n = 115).

Figure 3. Cadaveric right hand showing the single tendon of APL (type 1, 19.1%).

APL: abductor pollicis longus; EPB: extensor pollicis brevis; EPL: extensor pollicis longus; T: proximal phalanx of thumb; M: first metacarpal bone.

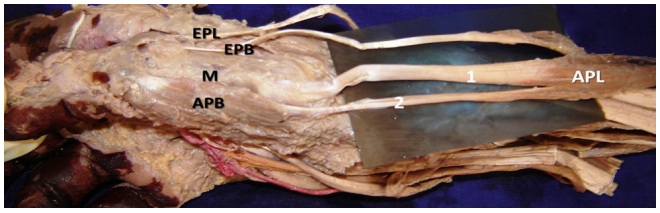

Figure 4. Cadaveric right hand showing the double tendons (1, 2) of APL (type 2, 63.5%).

APL: abductor pollicis longus; EPB: extensor pollicis brevis; EPL: extensor pollicis longus; M: first metacarpal bone; APB: abductor pollicis brevis.

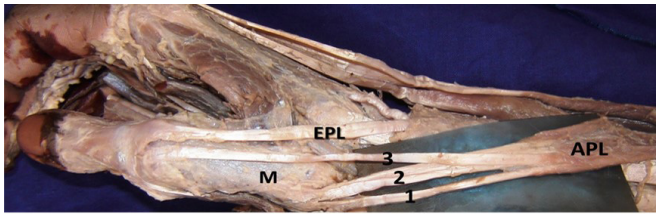

Figure 5. Cadaveric right hand showing the triple tendons (1-3) of APL (type 3, 16.5%).

APL: abductor pollicis longus; EPL: extensor pollicis longus; M: first metacarpal bone. The extensor pollicis brevis was absent in this case.

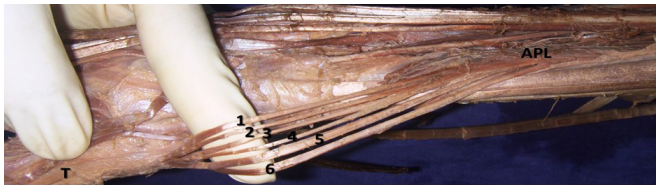

Figure 6. Cadaveric right hand showing the six tendons (1-6) of APL (type 4, 0.9%).

APL: abductor pollicis longus; T: thumb.

Table I. Topography of insertion and frequency of accessory tendons of APL (n = 115).

Insertion site	Number	Frequency
Trapezium bone	58	62.3%
First metacarpal bone	17	18.3%
Abductor pollicis brevis Muscle	17	18.3%
Proximal phalanx of thumb	1	1.1%

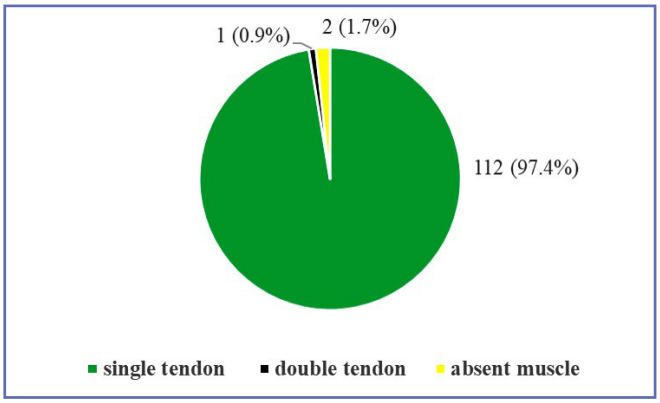

Figure 7. Frequency of number of tendons of extensor pollicis brevis (n = 115).

tion. In one specimen (0.9%), EPB had two tendons, and both were inserted separately into the proximal phalanx of the pollex at its base (**figure 8**). EPB muscle was absent in 2 (1.7%) cases (**figure 5**).

In one of the specimens of this study, a rare variation of an accessory muscle was observed, which was originating by two slips. One slip was originating from the inferior aspect of the shaft of the radius and the other was taking origin from the extensor carpi radialis longus muscle. Both slips joined together and inserted into the tendon of APL (**figure 9**).

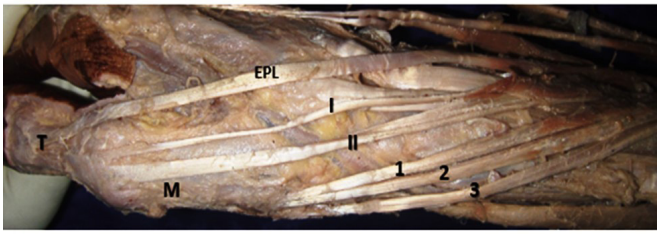

Figure 8. Cadaveric right upper limb showing the triple tendons (1-3) of APL and double tendons (I, II) of EPB.

M: first metacarpal bone; T: thumb.

Figure 9. Cadaveric upper limb showing the double tendon of APL and an accessory muscle was taking origin from the ECRL and inserted to the APL-1.

APL-1 and APL-2: two tendons of APL; EPB: extensor pollicis brevis; AM: accessory muscle; ECRL: externsor carpi radialis longus; ECRB: extensor carpi radialis brevis.

DISCUSSION

During the development, a single muscular mass gets separated into the APL and EPB, phylogenetically. It was reported that, there will be complete separation of APL and EPB in gorillas and human beings (18). However, morphologically variant insertions of APL and EPB are observed in different primates (19). The accessory slips of APL have been observed in other primates like gibbons and gorillas, suggesting the atavistic factor (6). In chimpanzees, the APL distally has insertion at the lateral aspect of the shaft of the first metacarpal bone, however in gorillas, this attaches to the trapezium bone. Ontogeny repeats phylogeny and it is not a surprise to see the morphological variants of these tendons in man (19). During the intrauterine development in humans, the APL tendon will usually have three slips, morphologically. The anterior, middle, and posterior slips, which insert at the first metacarpal, trapezium bone and opponens pollicis respectively. Eventually, the posterior slip gets detaches from the opponens pollicis and joins the abductor pollicis brevis muscle. It has been described that the persistence of the embryological patterns of the tendons of APL, can lead to the multiple tendons in the postnatal life (20).

Tewari *et al.* (4) observed that, it is quiet common to see the dual tendons of the APL. These tendons get distal attachment at the first metacarpal base and the trapezium bone. Paul and Das (21) reported a case of three tendons of APL, which formed an aponeurosis and finally ended up in the first metacarpal. Tewari *et al.* (4) also observed four and six tendons of APL in some of their specimens. It was opined that the multiple tendons of APL and EPB can lead to formation of multiple osseofibrous tunnels in the extensor retinaculum first compartment, which may lead to De Quervain syndrome (5). The response to the treatment of De Quervain syndrome and arthritis of the first carpo-metacarpal joint are altered due to the morphologically variant tendons of the APL (4). It was also opined that, ethnic variations seemed to exist with respect to the tendinous morphological variants (22).

De Quervain syndrome of the first compartment of the dorsal retinaculum of hand is a usual pathology. In this disease, the pain results from the resisted movement of the APL and EPB tendons in the canal at the first compartment. It was described that the number and dimensions of additional tendons of APL may have an efficient role in etiopathogenesis of De Quervain's disease (23, 24). The number of tendons of EPB and their variability in the distal attachment should be examined by the hand surgeon, during the surgical release of the extensor retinaculum in De Quervain's disease.

In the present study, majority of the hands (63.5%) had splitting of APL tendon and they were getting inserted as double tendons. In only 19.1% of hands, it was inserted as single tendon. It was inserted as triple tendon in 16.5% of hands. In a study conducted by Jackson *et al.* (25), only 25% of cadavers showed single insertion of the APL. In 57% of hands, they found double tendon of the APL. Our present study has reported almost similar finding with respect to this observation of dual insertion. Jackson *et al.* (25) detected that the additional tendons were inserted either into the trapezium or blended with the origin of abductor pollicis brevis. Fabrizio and Clemente (26), found multiple tendons of APL in 30% of their cadavers. Vollala (27) found single tendon of APL in only 30% of their hand specimens from cadavers. In 50% cases, it was two tendons and 20% of hands had multiple tendons. In our study, the incidence of single APL tendon (19.1%) is still further lesser frequency in comparison to Vollala (27). Kulthanan and Chareonwat (5) found multiple tendons of APL in 89% cases of cadaver samples and 49% of their patients. The comparison of frequency of accessory tendons of APL of the present study with other population is represented in **table II**.

We found six tendons of APL in one of the right sided specimens and it was observed that, all these tendons distally attached to first metacarpal base. Similar finding was reported by Mehta *et al.* (28) as they found an anomalous arrangement of APL into four tendons and there was bifurcation of the medial most tendon. Melling *et al.* (29) reported an unusual finding of APL dividing into 7 tendons in the first compartment of the extensor retinaculum. In their finding, the actual main tendon of APL attached into the first metacarpal base and the supernumerary tendons were attached to various locations like opponens pollicis, lateral part of abductor pollicis brevis and dorso-lateral part of the first metacarpal base. In the present investigation, additional tendons of APL inserted into the first metacarpal bone in 18.3% cases and at the abductor pollicis brevis in 18.3% cases. In one of the specimens, the 3rd tendon of APL had distal insertion at the proximal phalanx of the pollex at the base. There were no cases with insertion of the APL into the opponens pollicis muscle in this study.

Jabir *et al.* (24) recommended the preoperative ultrasound scanning to study the anatomy of the EPB during the surgical reconstructive procedures of this muscle. They also reported that, there are ethnic variations in the anatomy of the EPB, which require further study (24). Nayak *et al.* (20) found single tendon of EPB in 85.2% cases, which was attaching into the base of the proximal phalanx of pollex, two tendons in 10.9% cases and three tendons in 3.8% cases. The EPB in the present study, was a solitary tendon in 97.4% of cases and dual in 0.9% cases. In 1.7% of cases in this investigation, the EPB muscle was not observed. This outcome is analogous to the study done by Jackson *et al.* (25), in which they found absence of EPB in 2% of cases. They also found double tendons of EPB in 0.7% cases. Kulthanan and Chareonwat (5) found solitary tendon of EPB in 98% of cadavers and 94% of patients studied. They found multiple tendons of EPB in 20% of cadavers and 38% of patients respectively. These were higher frequency in comparison to our findings with reverence to the accessory tendons of the EPB. The comparison of frequency of accessory tendons of EPB of the present study with other population is represented in **table III**.

Patel and Desai (30) observed that the APL and EPB muscle bellies extending into the first compartment of the extensor retinaculum without forming the tendon in two of their patients. Such morphological variants of extension of the muscle bellies into the retinaculum were not detected in this present research. However, the present research observed an accessory muscle, which inserted into the tendon of APL by two slips. One slip was taking origin from the extensor carpi radialis longus and the other slip was originating from the radius bone. This morphologically variant muscle was not reported previously by the other authors.

Table II. Comparison of frequency of accessory tendons of APL with other population.

Authors	Frequency	Population
Present study	80.9%	Indian
Kulthanan and Chareonwat (5)	89%	Thai
Jackson *et al.* (17)	75%	Caucasian
Karauda *et al.* (12)	88%	Polish
El-Beshbishy and Abdel-Hamid (13)	100%	Arabian
Motoura *et al.* (16)	98.9%	Japanese

Table III. Comparison of frequency of accessory tendons of EPB with other population.

Authors	Frequency	Population
Present study	0.9%	Indian
Kulthanan and Chareonwat (5)	20%	Thai
Motoura *et al.* (16)	10.9%	Japanese
Jackson *et al.* (17)	0.7%	Caucasian

It is important to recognize the anatomical dissimilarities of the APL and EPB as they help the orthopedic surgeons in understanding the pathological conditions (4). It is emphasized that, all the tendons of APL should be released in the surgical release procedure, which is performed for treating the De Quervain tenosynovitis. If the surgeon is not aware of the morphological variants of multiple tendons, it can lead to persistence of the symptoms even after the surgery. In some situations, the multiple tendons can cause failure of the local steroid injection therapy, if the surgeon is not aware of these variations.

The knowledge about the morphological variants of the tendons of EPB is essential to understand the thumb extension. The data will be enlightening to the reconstructive hand surgeons. The APL and EPB tendons are useful in the plastic and reconstructive surgeries, where they can be harvested as the tendon grafts. The additional tendons of APL can be transferred in cases of ruptured or divided extensor pollicis longus muscle (3, 31). The knowledge about multiple tendons of APL can help in choosing them as the tendon grafts (32). The volar translocation of the APL can be done as a treatment modality for the recurrent subluxation of the first carpometacarpal joint with intact articular surface (33).

The present study observed that, both the muscles in the first compartment of the extensor retinaculum had higher frequency of variability in their number of tendons and their insertions. It is suggested that, the accessory tendons need to be considered along with the main tendon during the local steroid injections, which is performed for the tenosynovitis. If the accessory tendons are not injected, this leads to recurrence of the symptoms. The findings of this study about the accessory tendons and their variable insertions will also help the plastic surgeon in choosing the grafts and assist in the tendon transfer procedures of the hand. The details about the anatomical variations of APL and EPB are helpful to the radiologists and hand surgeons in making the accurate diagnosis and the best management of thumb pathologies.

The present study had some limitations like the gender of the cadavers and age of the cadavers, which were not taken into considerations. The right and left sided data was not analyzed statistically, because all the right and left specimens were not from the same individual correspondingly. The clinical data of the donors were not available; hence it was not possible to correlate the morphological variants of the tendons with the orthopedic clinical conditions. The other limitation is that the morphometry of the accessory tendons was not performed in this study. The data about the dimensions of the accessory tendons of APL and EPB will particularly have implications in the plastic surgeries of the hand. The neurovascular pedicles of the APL and EPB were also not studied in this anatomical investigation. This can also be considered as the potential limitation of this anatomical study.

CONCLUSIONS

The present study has offered supplementary information about the inconsistency in the number and insertion location of the tendons of APL and EPB in a sample Indian population. It was observed that the APL has higher frequency of accessory tendons. It is believed that the morphological data provided in this study are enlightening to the orthopaedic surgeons and plastic surgeons. The accessory tendons can be utilized as transplants in the reconstructive surgeries.

FUNDINGS

None.

DATA AVAILABILITY

The data are available to the repository links:
https://rms.manipal.edu/
https://eprints.manipal.edu/
https://impressions.manipal.edu/

CONTRIBUTIONS

LVP: conceptualization. MDP: data collection. BVM, CGK: data analysis and interpretation. BVM: drafting of the manuscript. MMP: critical revision of the manuscript. All authors: approval of the final version of the manuscript.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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