Prevalence of accessory carpal ossicles - a CT-based survey

Ozkan Kose[1,2], Levent Sarikcioglu[2], Mehmet Baris Ertan[1], Faruk Aykanat[3], Omer Faruk Egerci[1], Cemil Gurses[4]

[1] *University of Health Sciences, Antalya Training and Research Hospital, Department of Orthopedics and Traumatology, Turkey*

[2] *Akdeniz University, Medical Faculty, Department of Anatomy, Turkey*

[3] *Sanko University, Medical Faculty, Department of Orthopedics and Traumatology, Turkey*

[4] *University of Health Sciences, Antalya Training and Research Hospital, Department of Radiology, Turkey*

SUMMARY

This observational study aimed to determine the prevalence of accessory carpal ossicles (ACO) using a computerized tomography examination. The digital imaging database of the authors' institution was retrospectively reviewed, and all wrist computerized tomography examinations for any indication were identified between 2014 and 2021. Patients with previous wrist surgery and severely impaired carpal anatomy, such as severe osteoarthritis or congenital or acquired deformities that may preclude evaluation and identification of accessory carpal ossicles, were excluded from the study. Four orthopedic surgeons reviewed the computerized tomography scans and identified patients with accessory carpal ossicles on two-dimensional (coronal, axial, and sagittal planes) and three-dimensional computerized tomography reconstructions. Two thousand two hundred thirteen patients, with a mean age of 36.8±12.8 years, were identified and included. Accessory carpal ossicles were detected in 156 (7.1%) subjects, with 186 ACOs identified. The most common accessory carpal ossicles were os praetrapezium (n:34, 1.536%), os triquetrum secundarium (n:28, 1.265%), os epitriquetrum (n:20, 0.903%), os hamuli proprium (n:18, 0.813%), os ulnostyloideum (n:16, 0.723%), os epilunatum (n:12, 0.542%) and os styloideum (n:11, 0.497%) respectively. The study provides valuable information on the prevalence and distribution of accessory carpal ossicles, which can aid in accurately diagnosing and managing wrist pathologies. Further research is warranted to explore the clinical significance and potential impact of rare accessory carpal ossicles on wrist disorders.

Key words: Accessory carpal ossicles – Anatomic variation – Carpal ossicles – Computerized tomography – Wrist

ABBREVIATIONS

CT: Computerized tomography

ACO: Accessory carpal ossicles

INTRODUCTION

Accessory ossicles are defined as small supernumerary bony structures located around the consistent elements of the human skeleton. These ossicles can be found in various locations,

Corresponding author:
Dr. Ozkan Kose. Varlık mah., Kazım Karabekir cd., 07100 Muratpasa, Antalya, Turkey. E-mail: drozkankose@hotmail.com - ORCID: 0000-0002-7679-9635

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but the foot, ankle, and wrist are the most frequently observed anatomic sites (Keles-Celik et al., 2017; O'Rhailly, 1953). To date, twenty-five different accessory ossicles around the wrist have been described (O'Rhailly,1953; Pfitzner, 1900). Many accessory carpal ossicles (ACO) remain silent and do not impair the normal function of the wrist. However, in some instances, they might be the source of pain and other symptoms. For instance, the os styloideum, located on the dorsal aspect of the base of the 3rd metacarpal, is closely associated with carpal boss syndrome (Roulet et al., 2017). In the context of traumatic wrist injuries, ACOs can be confused with avulsion fractures during imaging examinations. Multiple studies have reported misdiagnosis of these ossicles as avulsion fractures (Yang et al., 1994; Bianchi et al., 1990; Weintraub et al., 2020). Thus, clinicians and radiologists should be aware of these normal variants to interpret radiographic workup and guide clinical management properly.

The description and nomenclature of these ossicles were established in the early 1900s through cadaveric dissections conducted by pioneering anatomists (Pfitzner, 1900; Schmidt and Freyschmidt, 1993; Keats and Anderson, 2012; Timins, 1999; Senecail et al., 2007). Since then, a limited number of studies have addressed the prevalence of ACO in contemporary literature (O'Rhailly, 1953; Gursoy et al., 2021; Bizarro, 1921; Bogart, 1932). All of these prevalence studies utilized direct radiography as the imaging method. However, due to the intricate anatomy of the wrist and the diminutive size of these ossicles, solely relying on two-view radiography, makes detection of these ossicles challenging. Alongside detection difficulties, the exact positioning of different ossicles that are proximate to one another is hard to discern due to superimposition. Based on these challenges, we hypothesized that the occurrence of these ossicles may be underreported in prior studies. This study aimed to determine the frequency of ACOs using advanced imaging techniques, specifically 2D and 3D computerized tomography wrist imaging, which were not available in earlier studies.

MATERIALS AND METHODS

Patients and study design

A retrospective review was conducted on the digital imaging archive to identify adult patients (>18 years of age) who underwent wrist CT scans between 2014 and 2021. A total of two thousand two hundred and thirteen individuals (696 females and 1517 males) were analyzed. Patients with a history of wrist surgery and those presenting with significantly altered carpal anatomy—such as severe osteoarthritis, congenital anomalies, or acquired deformities that could impede the evaluation and identification of accessory carpal ossicles—were excluded from the study. However, individuals with metacarpal, distal radial, or straightforward carpal bone fractures that did not hinder the identification of ACO were retained in the study. CT scans that failed to display all carpal bones within the field of view were also excluded. This research was conducted in alignment with the ethical standards set forth by the 1964 Declaration of Helsinki and its subsequent amendments. The Clinical Studies Ethics Committee approved the study protocol (Approval date/number: 06.01.2022 / 1-15).

Image acquisition

Wrist CT examinations were conducted using two distinct CT devices from the same manufacturer (Siemens go.Up, Siemens, Munich, Germany), situated in the radiology and emergency departments of the authors' institution. CT scans were captured with a tube voltage ranging from 120-130 kV and a tube current between 72-104 mA. The slice thickness varied from 0.5 to 1.5 mm. The field of view encompassed the distal radius, all carpal bones, and the proximal metacarpal bones, resulting in 100-350 axial sections.

Assessment of the CT examinations

Four orthopedic surgeons analyzed the CT scans, identifying patients with ACO. Radiological assessments were conducted on a digital workstation (Sectra Workstation IDS7; Sectra AB, Linköping, Switzerland). Both two-dimensional (in the coronal, axial, and sagittal planes) and three-dimensional (3D) reconstructions were employed sequentially. Each reviewer optimized their assessment by adjusting screen contrast, illumination, magnification, and color settings. Subsequent evaluations of patients with accessory carpal ossicles were undertaken collaboratively by a radiologist and an orthopedic surgeon. The joint decision determined the nomenclature of the accessory ossicles, ensuring that any errors in evaluations and nomenclature during the initial review were rectified. As informed by prior research, 25 distinct accessory carpal ossicles were scrutinized (O'Rhailly, 1953; Pfitzner, 1900; Keats and Anderson, 2012; Schmidt and Freyschmidt, 1993). The nomenclature of the ossicles adhered to the definitions and anatomical references delineated in these studies (Fig. 1).

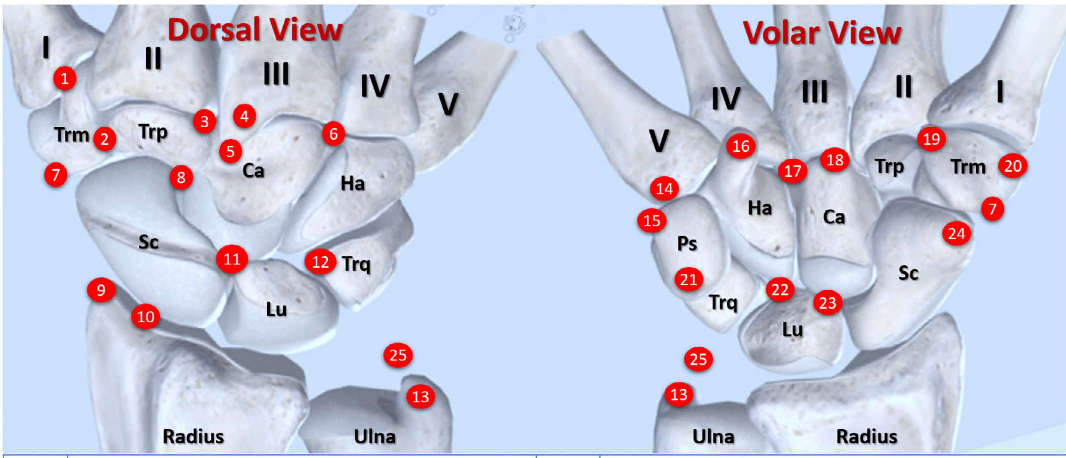
Statistical analysis

Descriptive statistics are provided as frequency and percentage for categorical data, and as mean ± standard deviation along with range for continuous data. The Kolmogorov-Smirnov test assessed data normality. Comparative analyses between independent groups were conducted using the Mann-Whitney U test and chi-square tests. A p-value of less than 0.05 was deemed statistically significant.

RESULTS

A total of 2,213 subjects, with a mean age of 36.8±12.8 years (range: 18-89 years), were included in the study. Male patients were significantly younger than females, with mean ages of 34.0±11.6 and 42.8±13.3 years, respectively (p=0.001). Out of the total participants, 1,517 (68.5%) were male and 696 (31.5%) were female. The study assessed 1,205 (54.5%) right wrist CTs and 1,008 (45.5%) left wrist CTs. ACOs were identified in 158 (7.1%) out of the 2,213 subjects. The frequency of ACO occurrence between genders was comparable (p=0.535) (Table 1).

Among the 158 patients with detected ACOs, a total of 186 individual ACOs were identified,



1	Os trapezium secundarium (multangulum majus secundarium, carpometacarpale II)	14	Os vesalianum manus (vesalii, carpometacarpale VIII)
2	Os trapezoideum secundarium (multangulum minus secundarium)	15	Os ulnare externum
3	Os parastyloideum (carpometacarpale III)	16	Os hamuli proprium
4	Os styloideum (carpometacarpale IV)	17	Os Gruberi (carpometacarpale VI)
5	Os metastyloideum	18	Os subcapitatum
6	Os capitatum secundarium (Carpometacarpale V)	19	Os praetrapezium (carpometacarpale I)
7	Os epitrapezium	20	Os paratrapezium (petrapezium)
8	Os carpi centrale	21	Os priforme secundarium (ulnare antebrachii, metapisoid)
9	Os radiostyloideum (persistent radial styloid)	22	Os hypotriquetrum
10	Os paranaviculare	23	Os hypolunatum (centrale III)
11	Os epilunatum	24	Os radiale externum (os parascaphoid)
12	Os epitriquetrum (epipyramis, centrale IV)	25	Os triquetrum secundarium (os triangulare - os intermedium antebrachii)
13	Os ulnostyloideum		

Fig. 1.- Schematic illustration of the carpus showing the various accessory bones and approximate locations. **(a)** Dorsal view. **(b)** Volar view. Abbreviations: I-V: First to fifth metacarpals, Sc: Scaphoid, Lu: Lunate, Trq: Triquetrum, Ps: Pisiforme, Ha: Hamate, Ca: Capitate, Trp: Trapezoid, Trm: Trapezium.

Table 1. Summary of demographic characteristics of the study population. Abbreviations, SD: standard deviation, Min: Minimum, Max: Maximum, ACO: Accessory carpal ossicle.

Variables	Total	Female	Male	p-value
Number of subjects (n, %)	2213 (100%)	696 (31.5%)	1517 (68.5%)	
Age (years)				0.001*
(Mean ± SD)	36.8±12.8	42.8±13.3	34.0±11.6	
(Min. – Max)	18-89	18-89	18-78	
Side (n, %)				0.019**
Right	1205 (54.5%)	356 (16.1%)	849 (38.4%)	
Left	1008 (45.5%)	340 (15.4%)	688 (30.2%)	
Frequency of ACO (n, %)	158 (7.1%)	46 (6.6%)	112 (7.4%)	0.535**

*Mann-Whitney-U test, ** Chi-square Test

Table 2. Frequency of accessory carpal ossicles (ACO) among the study population.

#	Name of the Ossicle	Frequency (n, %)	
		Within all cases	Within ACOs
1	*Os trapezium secundarium*	1 (0.045%)	0.538%
2	*Os trapezoideum secundarium*	1 (0.045%)	0.538%
3	*Os parastyloideum*	1 (0.045%)	0.538%
4	*Os styloideum*	11 (0.497%)	5.914%
5	*Os metastyloideum*	3 (0.135%)	1.613%
6	*Os capitatum secundarium*	1 (0.045%)	0.538%
7	*Os epitrapezium*	0	%0
8	*Os carpi centrale*	6 (0.271%)	3.226%
9	*Os radiostyloideum*	2 (0.094%)	1.075%
10	*Os paranaviculare*	0	0%
11	*Os epilunatum*	12 (0.542%)	6.452%
12	*Os epitriquetrum*	20 (0.903%)	10.753%
13	*Os ulnostyloideum*	16 (0.723%)	8.602%
14	*Os vesalianum manus*	1 (0.045%)	0.538%
15	*Os ulnare externum*	7 (0.316%)	3.763%
16	*Os hamuli proprium*	18 (0.813%)	9.677%
17	*Os Gruberi*	0	0%
18	*Os subcapitatum*	1 (0.045%)	0.538%
19	*Os praetrapezium*	34 (1.536%)	18.280%
20	*Os paratrapezium*	3 (0.135%)	1.613%
21	*Os psiforme secundarium*	3 (0.135%)	1.613%
22	*Os hypotriquetrum*	4 (0.180%)	2.151%
23	*Os hypolunatum*	10 (0.452%)	5.376%
24	*Os radiale externum*	3 (0.135%)	1.613%
25	*Os triquetrum secundarium*	28 (1.265%)	15.054%

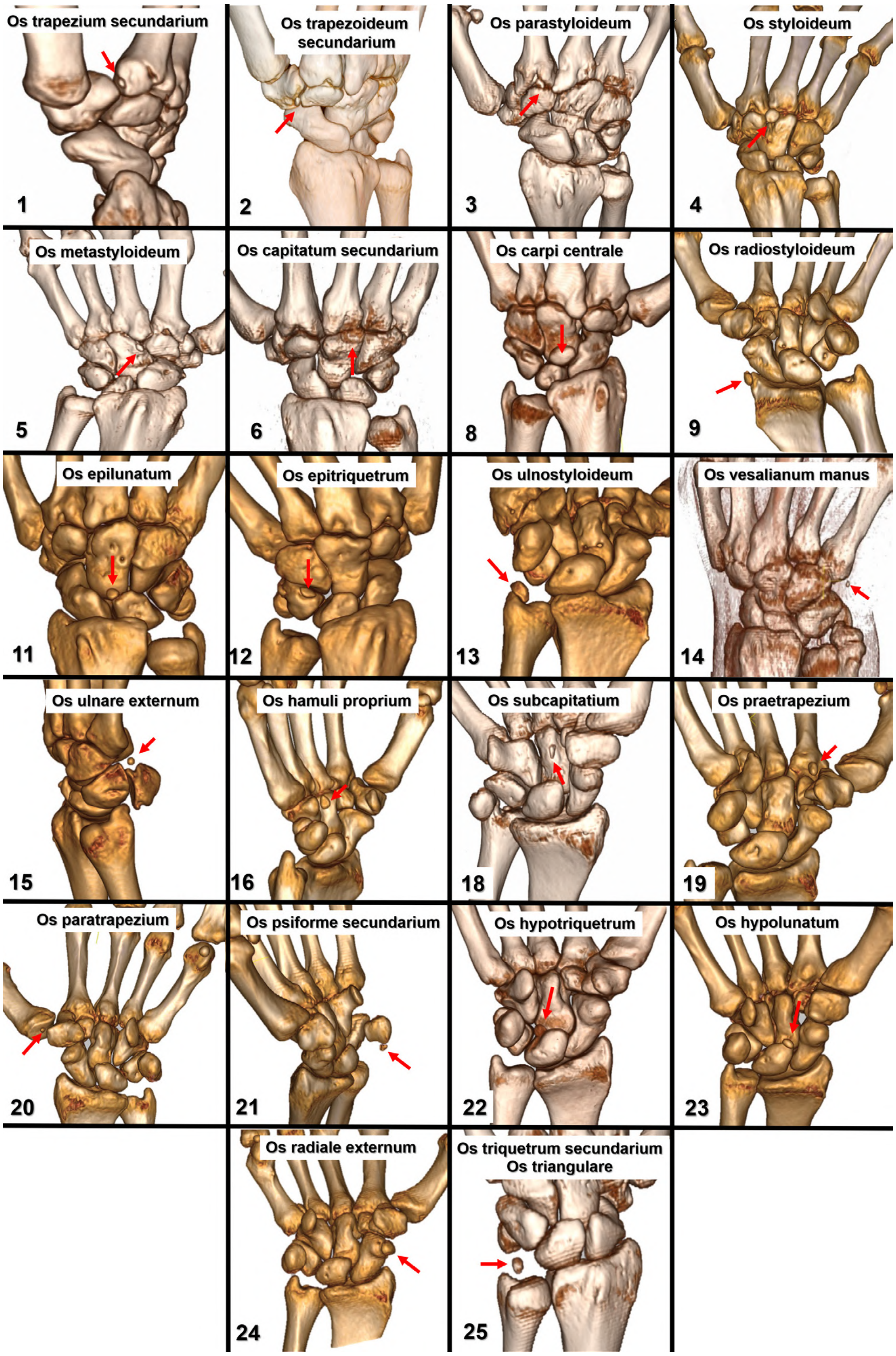


Fig. 2.- The representative 3D appearance of each detected accessory carpal ossicle.

ranging from 1 to 4 per patient. Specifically, four ossicles were found in two patients, three in four patients, two in 14 patients, and one bone in 139 patients. The most commonly observed ACOs included: os praetrapezium (n=34, 1.536%), os triquetrum secundarium (n=28, 1.265%), os epitriquetrum (n=20, 0.903%), os hamuli proprium (n=18, 0.813%), os ulnostyloideum (n=16, 0.723%), os epilunatum (n=12, 0.542%), and os styloideum (n=11, 0.497%), respectively. A comprehensive frequency and distribution of the ACOs are delineated in Table 2. A representative 3D visual representation of each detected ACO can be found in Fig. 2.

DISCUSSION

The present study comprehensively examines ACOs in a large cohort using advanced imaging techniques. Notably, the overall prevalence of ACOs in the studied population was 7.1%. Among the various ACOs identified, the most common ones were os praetrapezium, os triquetrum secundarium, os epitriquetrum, os hamuli proprium, os ulnostyloideum, os epilunatum, os styloideum, and os hypolunatum. The exact incidence of ACOs in the wrist remains uncertain due to the limited number of studies on this subject. To provide a context for our findings, we compared them with previous studies. Bogart (1932) examined 1452 wrist radiographs and documented an ACO incidence of 0.4%, while O'Rahilly (1953) examined 743 wrist radiographs and found a rate of 1.6%. Another study by Bizarro (1921) reported the presence of accessory bones in only four out of 100 wrist radiographs (4%). A more recent study by Gursoy et al. (2021) examined 1,146 digital wrist radiographs and detected ACOs at a higher rate of 9.7%, attributing the increased detection to improved image quality in digital radiography. In our study, while we observed a higher ACO rate than in previous studies, the number of ACOs detected was lower than that reported by Gürsoy et al. (2021). Besides the discrepancy in the frequency of ACOs, the distribution was also inconsistent. It is important to note that evaluating complex carpal bone anatomy solely based on direct radiographs is challenging due to superimposition and the relatively small size of the bones. Additionally, distinguishing between nonunion of avulsion fractures and traumatic calcifications can be difficult (O'Rahilly, 1953). Cross-sectional and three-dimensional examinations, such as computed tomography (CT), provide superior results. In our study, we employed CT as a screening method, which, to our knowledge, is the first study of its kind in the current literature. We consider the data obtained from CT to be more reliable for evaluating ACOs.

The exact etiology of these ossicles remains disputed, but few theories address the formation of certain ossicles. The first theory proposes that these structures are formed when there is a defect in the coalescence of secondary ossification centers with the main structure. In such instances, the accessory element complements the constant element, and they form the normal structure together. This theory can account for the presence of the os styloideum. In the initial stages of carpal embryological development, a primordial cartilaginous structure is typically observed at the site of the second metacarpal bone's styloid process. This eventually merges with the metacarpal to form the styloid process (Kootstra et al., 1974). A lack of fusion between these entities can lead to the emergence of the os styloideum. Notably, a fibrocartilaginous junction typically connects the ossicle to the metacarpal base. In a parallel manner, the os hamuli proprium originates from a fusion anomaly in the secondary ossification center located in the hook of the hamate bone (Greene and Hadied, 1981).

The second theory posits that these ossicles have a phylogenetic origin and they are atavistic remnants. Some of these ossicles consistently appeared in subspecies but regressed or disappeared entirely over the course of evolution. In most primates, the carpus comprises nine bones, compared to eight in humans. The ninth bone is named the "os carpi centrale". This bone locks and stabilizes the midcarpal joint, making the wrist suitable for weight-bearing. The upright posture of humans and the evolution of our forelimbs, once used for walking, into upper extremities are believed to be major factors behind the disappearance of the os carpi centrale (Kivell, 2016; Lewis, 1985). The os radiale externum and epitrapezium ossicles are thought to be remnants of the prepollex found in our mammalian ancestors' wrists (Le Minor 1994).

The third theory suggests that these ossicles arise from nonunion traumatic avulsion fractures or osseous metaplasia in surrounding soft tissues like the capsule and ligaments (O'Rahilly, 1953). A prime example is the os epitriquetrum. Triquetral fractures are the second most common carpal bone fractures, following scaphoid fractures. A large portion of triquetral fractures are dorsal cortical chip fractures. These can often go unnoticed in direct radiographs, and untreated cases might result in nonunion (Vigler et al., 2006; Suh et al., 2014). Due to the traction from the dorsal triquetroscaphoid and radiotriquetral ligaments, these fragments can move radially from the triquetrum, resembling a distinct accessory bone. Pfitzner (1900) once labeled this fracture as an ACO without complete knowledge of the injury mechanism or radiological characteristics. We believe this labeling was a misinterpretation. An instance of ectopic calcification is the os triangulare. The triangular fibrocartilage complex (TFCC) frequently exhibits ectopic calcification due to both traumatic and non-traumatic degenerative wrist diseases and certain deposition diseases (Bade et al., 1996; Yang et al., 1995). Regrettably, such structures have sometimes been mistakenly classified as accessory elements in direct radiographs. O'Rahilly (1953) noted in a study of 743 wrist radiographs that 6% showed accessory calcific structures. Only 1.6% were genuine ACOs, while the remaining 4.4% were lesions resulting from trauma. As we gain a deeper understanding of the etiology of these structures, we expect modifications in the official list of ACOs.

The current study presents both strengths and limitations. Its primary strength lies in the methodology used to screen for the presence of ACOs, making it the most comprehensive study on the topic to date. However, there are notable limitations. The data were collected from a local institution, so the findings may not be generalizable to other ethnic groups. Four different observers reviewed The CT scans once, potentially leading to discrepancies in their assessments. Nonetheless, every observer noted any suspicious structure during their initial review, and a joint decision was made independently afterward. This process possibly enhances the reliability of our data. As a retrospective study, the detailed past medical history, especially regarding traumatic hand injuries of the patients, remained unknown.

In conclusion, this study represents a landmark in the literature on ACOs. Properly identifying these ossicles is crucial for precise diagnosis and intervention. While many of these ossicles are clinically insignificant and are often found incidentally during imaging, others can be associated with specific medical conditions and might be mistaken for fractures. Conducting comparable research on various ethnic populations would broaden our understanding of their distribution. Understanding the origins of these ossicles is crucial to accurately defining them.

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Ethical approval: We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. The Institutional Review Board approved the study protocol (Date/Issue: 06.01.2022 / 1-15).

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