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Prevalence of Persistent Median Arteries in the Pediatric Population Using Ultrasonography

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Abstract

Objective—To use real-time ultrasonography to estimate the prevalence of persistent median arteries in a cohort of pediatric orthopedic patients.

Methods—With IRB approval, subjects between the ages of 3 months and 19 years of age were recruited for this cross-sectional study. Variables of interest included demographics, underlying diagnosis, and the presence of a Doppler confirmed median artery. Ultrasonographic examination was performed on both upper extremities by a single investigator. Subject level and limb level analyses were performed. A multi-variable generalized logistic regression analysis was used to test the association between limb specific persistent median arteries prevalence and age. A generalized estimating equation was used to adjust for the inclusion of multiple limbs from the same subject.

Results—135 subjects (270 limbs) were evaluated. The subject specific prevalence rate (persistent median arteries present in one or both limbs) was 26.67%. Among these subjects (N = 36), a persistent median artery was present bilaterally in 55.6% (N = 20). The limb specific prevalence rate (proportion of limbs with a persistent median artery) was 20.7%. After adjusting for race, for every one year increase in age, the odds of a persistent median arteries decreased by 4.4%. After adjusting for age, African Americans were significantly more likely to present with a persistent median artery.

Conclusions—Ultrasonography can effectively visualize anatomical variants, such as persistent median arteries, in the pediatric population. The prevalence of persistent median arteries was higher than anticipated, especially among African American subjects.

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Keywords

Upper Extremity; Cross-Sectional Studies; Logistic Models; United States; African Americans; Arteries

INTRODUCTION

The median and interosseous arteries represent the sole blood supply to the hand and distal upper extremity in the first eight weeks of embryologic life¹⁻⁴. Beginning around the 8th week of development, the radial and ulnar arteries begin to form. This causes the median artery to regress forming the comitans nervi median^{2,4,5}. In a subset of individuals, however, the median artery persists into adulthood in two forms, the palmar type (persists into the hand) or the antebrachial type (terminates proximal to wrist). The prevalence of palmar type persistent median artery in adults has reported to range between 0.9 and 50%.^{5,6} Antebrachial type persistent median arteries are much more common, with a prevalence that ranges between 70 and 76%.^{7,8}

The large variability in persistent median artery prevalence reported in previous studies is likely attributable to numerous factors such as measurement technique, definition of a persistent median artery, as well as the ancestry of the study population. In pediatric studies, the age makeup of the respective study populations is another important factor to consider. Based on observations of an increased prevalence of persistent median artery among neonates relative to adults, there is some evidence that the median artery may continue to regress beyond embryologic life.^{1,2,4,9} However, persistent median artery prevalence as well as the timing of regression in pediatric populations is not well understood.

The presence of a persistent median artery has important clinical implications. Persistent median artery prevalence has been implicated in the etiology of numerous conditions such as carpal tunnel syndrome¹⁰⁻¹² as well as numerous other entrapment related neuropathies.¹³⁻¹⁵ The presence of this anatomical variant should also be considered to minimize risk of vascular injury during surgical dissection of the distal extremity as well as during peripheral nerve block placement.

The purpose of this study was two-fold. First, we aimed to estimate the prevalence of persistent median arteries in a cohort of pediatric subjects less than 19 years of age. Second, we aimed to test the relationship between the presence of a persistent median artery and age. We hypothesized that increasing age would be inversely associated with the presence of a persistent median artery.

MATERIALS & METHODS

A cross-sectional study design was utilized to estimate the prevalence of persistent median arteries in a cohort of pediatric orthopedic patients. Following institutional review board approval, eligible patients were identified from the pool of pediatric patients presenting for a clinical evaluation of an orthopedic related condition and/or were undergoing elective or traumatic upper extremity orthopedic surgical procedures at a single, large tertiary

Children's Hospital. Patients between the ages of 3 months and 19 years of age were included in this analysis. Subjects were excluded based on the following: missing data (N=13), non-orthopedic related diagnosis (N=6), sibling (N=3). Siblings were excluded from the statistical analysis due to concerns regarding lack of independence within sibling pairs. To minimize selection bias, we elected to focus on patients undergoing surgery for orthopaedic related conditions. Informed consent/assent was obtained from all subjects and their parents before any research procedures were performed.

Demographic and Ultrasonographic data was collected from all eligible subjects. Demographic variables included diagnostic category, age, gender, handedness, self-reported ethnicity, and self-reported race. The diagnostic category variable was defined as trauma/acquired musculoskeletal condition versus a neuromuscular/syndromic/congenital related musculoskeletal condition (see Table 1 for a complete list of all diagnoses included in these categories). The ultrasonographic variables were collected during a single examination of both upper extremities using a Logiq e ultrasound machine and a high-frequency (8–12 MHz) linear transducer (GE Milwaukee, WI). For the sake of consistency, the probe was positioned so that the vertical line on the probe was directed towards the radial side of the subject's forearm with the linear probe starting in the middle of the forearm in a neutral, supine position. The median nerve was utilized as an anatomical reference while the forearm was dynamically scanned at a frequency of 12 MHz in search of a persistent median artery using the color Doppler mode. Upon positive detection, the persistent median artery was followed proximally and distally.

The ultrasonographic and clinical exam related variables included the presence of a median artery (as confirmed by Doppler arterial flow) and persistent median artery regression level. Prior to the exam, the forearm was divided into five levels according to methods described by McCartney et al.¹⁶, elbow crease, distal wrist crease, mid-forearm (midway point between elbow crease and distal wrist crease), proximal forearm (between elbow crease and mid forearm level) and distal forearm (between mid-forearm level and wrist crease). The persistent median artery regression level was defined as the forearm section in which the persistent median artery could no longer be detected.

All ultrasound data collection procedures were performed by a single investigator (AN). Ultrasound images were captured at each of four pre-defined sections described above (Figure 1). When a persistent median artery was detected additional images of the origin and regression points were captured (Figure 2). All images were reviewed by an experienced anesthesiologist (GM) to confirm the presence or absence of a persistent median artery.

Statistical Methods

Due to the collection of data from both limbs, we conducted a subject level and a limb level analysis. For the subject level analysis, descriptive statistics were used to estimate the subject specific persistent median artery prevalence rate and summarize the demographics of all subjects included in the cohort. The subject specific persistent median artery prevalence rate was defined as the proportion of subjects with a persistent median artery in one or both limbs. Chi square tests and Fisher's Exact tests, when appropriate, were used to compare the distribution of the demographic and clinical characteristics among subjects with a persistent

median artery in one or both limbs compared to subjects that did not present with a persistent median artery in either limb.

For the limb level analysis, a generalized logistic regression analysis was used to estimate the limb specific, persistent median artery prevalence rate. A multi-variable, generalized logistic regression analysis was also used to test the association between persistent median artery prevalence and age. Based on previous literature as well as the subject level analysis, race (African American vs. Non-African American) was included in the multi-variable logistic regression analysis^{5, 17}. In the limb level analysis, generalized estimating equations were used to account for correlation due to the inclusion of multiple limbs from the same subject.

RESULTS

Subject Level Analysis

Data was collected from 135 subjects (270 limbs). The demographics and clinical characteristics of these subjects are displayed in Table 2. The mean age of subjects with a persistent median artery in one or both limbs versus subjects without a persistent median artery in either limb was 9.23 years (± 5.64) and 10.35 years (± 5.11), respectively. The subject specific prevalence rate was 26.62% (95% CI: 19.3 to 34.0%). Among these subjects (N = 36), a persistent median artery was present bilaterally in 55.6% (N = 20) subjects, present in the left extremity only in 17.0% (N = 6) of the subjects and located in the right extremity only in 29.7% (N = 10) of the subjects.

Limb Level Analysis

After adjusting for the inclusion of multiple limbs from the same subject, the limb specific prevalence rate was 20.74% (95% CI: 15.22 to 27.61%). Blood flow was confirmed in 100% of the persistent median arteries. The origin and regression levels of all persistent median arteries are described in table 3. In the generalized multi-variable logistic regression analysis, age was not significantly associated the presence of a persistent median artery. After adjusting for race, for every one year increase in age the odds of a persistent median artery decreased by 4.4% (95% CI: Ranges from a 2.51% increase to a 10.91% decrease, see Figure 3). After adjusting for age, African Americans were significantly more likely to present with a persistent median artery than non-African Americans (Odds Ratio: 3.78, 95% CI: 1.25 to 11.48).

DISCUSSION

The prevalence of persistent median arteries in this cohort of pediatric subjects was one in every four individuals. This estimate represents the proportion of subjects that presented with a persistent median artery in one or both limbs. However, in clinical situations such as unilateral, upper extremity surgical procedures, this estimate may not be as relevant as a limb specific prevalence rate. Therefore, we estimated the limb specific prevalence rate to be one in every five limbs. The difference in the subject specific and limb specific rates demonstrates that persistent median arteries are not consistently bilateral in nature. Only

55.6% of subjects with a persistent median artery presented with persistent median arteries in both limbs.

The persistent median artery prevalence observed in this study is similar to the literature reported prevalence. Namely studies evaluating palmar type persistent median arteries (0.9 to 50%^{5,6}). However, our study had a much lower prevalence than the estimates of antebrachial type persistent median arteries (70 to 76%^{7,8}). The large variability in persistent median artery prevalence reported in both adult and pediatric studies is likely attributable to due differences in measurement technique, definition of a persistent median artery (inclusion of arteries that do versus do not persist into in the hand), limb specific versus individual specific estimates, as well as the racial/ethnic makeup of the study populations. Studies of persistent median arteries have traditionally been restricted to cadavers. Recent technologic advances have increased interest in the use of ultrasonic techniques. The benefit of non-invasive imaging techniques such as ultrasound in living subjects is that the function of median artery can be evaluated. In this study, the Doppler mode was used to confirm the presence of arterial blood flow in all persistent median arteries detected during the study period. Therefore, the prevalence of persistent median arteries reported in current study represents proportion of subjects in the pediatric cohort that presented with a patent persistent median artery.

An association between persistent median artery prevalence and race/ethnicity has also been reported. For unknown reasons, the prevalence of persistent median arteries is higher among subjects of African descent.^{5,17} Furthermore, among studies of East Asian populations, median arteries have been reported to be more prevalent among subjects of Japanese ancestry.^{3,6} The relationship between the presence of a persistent median artery and race was supported by the results of the current study. Subjects that identified themselves as being African American were significantly more likely to present with a persistent median artery than subjects that identified themselves as belonging to a non-African American racial group.

In pediatric populations, the relationship between age and presence of a persistent median artery is another potentially important factor to consider. It is assumed that the regression of the median artery, beginning after the 8th week of gestation, results in the complete or nearly complete disappearance of the median artery following the maturation of the radial and ulnar arteries.¹⁻⁴ However, some evidence suggests that the median artery may continue to regress during development.^{1,2,4,9} Therefore, we also aimed to test the association between age and the presence of a persistent median artery. Although not statistically significant, increasing age tended to be inversely associated with the presence of a persistent median artery. For every one year increase in age, the likelihood of presenting with a persistent median artery decreased by 4%.

The absence of a strong association between age and the presence of a persistent median artery may be due to the inclusion of all median arteries as a single group. In previous literature, authors have made the distinction between palmar (persists into the palm and joins the superficial palmar arch or the common digital arteries to supply blood to the digits of the hand) and antebrachial persistent median arteries (regresses in mid forearm, terminating

proximal to the wrist within the median nerve sheath)^{3,8,9}. It is possible that the increased prevalence of median arteries reported in this as well other pediatric studies may be due to the identification of smaller antebrachial median arteries that may not be as discernible later in life when the forearm achieves its adult length. In partial support of this notion, among median arteries that regressed proximal to the wrist crease, the median age of median arteries observed to regress between the elbow crease and midpoint of the forearm (6 years) tended to be younger than the median age of median arteries that regressed between the midpoint of the forearm and wrist crease (11 years old). However, as we did not trace median arteries past the distal wrist crease, it was not possible to conclusively differentiate antebrachial from palmar type persistent median arteries in the present study. Future longitudinal studies are needed to better understand median artery post-natal regression patterns as well as their potential clinical implications.

Strengths & Limitations

This is the largest study of persistent median artery prevalence in a pediatric population. Upon identification, the Doppler detection mode was used to confirm the presence of arterial flow. In contrast to previous cadaveric-based studies, our study provides an estimate of the prevalence of patent median arteries in a pediatric population. There are several limitations to this study. We utilized a cross-sectional study design to examine the association between age and presence of a persistent median artery. Additional research is needed to elucidate the mechanism of median artery regression. Longitudinal studies are needed to better understand the relationship between persistent median artery prevalence and age. The underlying diagnoses and/or clinical characteristics of the subjects included in the study population were very diverse. We elected to focus on patients undergoing surgery for orthopaedic related conditions. As a result, the study results are only generalizable to the typical patient population a pediatric orthopaedic surgeon is likely to treat in his or her practice. Finally, we did not distinguish between palmar and antebrachial persistent median artery types.

Clinical Implications

The anatomical position of the persistent median artery highlights its clinical relevance to several pathologic conditions. Multiple studies have confirmed that an enlarged, thrombosed or calcified persistent median artery contributes to the etiology of Carpal Tunnel Syndrome.^{10–12} Proximal Median nerve neuropathies have been noted in cases where the median artery perforates or splits the median nerve.¹³ The presence of the median artery has also been shown to contribute to entrapment neuropathies including pronator teres syndrome¹⁴ and anterior interosseous nerve syndrome.¹⁵

Persistent median artery prevalence also has important implications for invasive hand and upper extremity related procedures (see Figure 4). During reconstructive surgery, persistent median arteries have been reported to complicate forearm flap procedures, leading the authors to conclude that the presence of a persistent median artery should be considered during pre-operative surgical planning.^{18,19} In the case of trauma, the potential role of the median artery in providing circulatory support should be considered. Muratore and Ozer²⁰ described a case of an 18 month old female that suffered a complete transection of the radial

and ulnar arteries. Based on Doppler signals observed during surgery, the authors reported that the viability of the hand was most likely preserved by an intact persistent median artery. Furthermore, during surgical dissection of the distal upper extremity, the surgeon should be cognizant of the fact that additional anatomical variants such as multiple median nerves and a high bifurcation of the median nerve often accompany the presence of a persistent median artery^{13,21}. Similarly, careful attention should be given to the presence of a persistent median artery during peripheral nerve blocks. If ignored, accidental injury to the persistent median artery, secondary to iatrogenic hematoma, may be possible.

The present study confirmed that ultrasound can be successfully used to detect the presence of persistent median artery. Ultrasonography represents a non-invasive modality that can be used to consistently and accurately visualize the complex anatomy of the forearm.¹⁶ Based on the high prevalence of patent persistent median arteries observed in the current study, the use of ultrasound prior to pediatric hand and/or upper extremity medical procedures should be considered to better understand existing arterial anatomical variants and thus, to augment existing pre-procedural planning strategies.

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Figure 1. Forearm data collection points

Prior to the exam, the forearm was divided into the five levels described above.

Figure 2. Ultrasound detection of PMA

B-mode Ultrasound of a PMA, midforearm with and without color-flow doppler.

Figure 3. Probability of a Persistent Median Artery in a Given Limb Based on Age
Estimates of limb specific probability by are adjusted for correlation due to inclusion of multiple limbs as well as race

Figure 4. Intra operative finding of PMA

This was an incidental finding on a 17 year old patient with perilunate dislocation.

Table 1**Subject Diagnoses**

	N	%
Congenital/Syndromic/ Neuromuscular Condition		
Trigger Thumb	22	51.2%
Syndactyly	8	18.6%
Polydactyly	4	9.3%
Cerebral Palsy	2	4.7%
Arthrogryposis	1	2.3%
Congenital Hyperextension of MP Joint	1	2.3%
TBI	1	2.3%
Clubfoot	1	2.3%
Contracture Secondary to Vascular Malformation	1	2.3%
Radial Club Hand	1	2.3%
Fraser Syndrome	1	2.3%
Traumatic/Acquired Condition		
Upper Extremity Fracture	49	53.3%
Ganglion Cyst	21	22.8%
Laceration	5	5.4%
Foreign Body	2	2.2%
Lipoma	2	2.2%
Mallet Finger	2	2.2%
Scar Revision	2	2.2%
Amputation Due to Trauma	1	1.1%
Boutonniere Deformity	1	1.1%
Burn	1	1.1%
Intra-Osseous Inclusion Cyst	1	1.1%
Knee Injury	1	1.1%
Out-Toeing	1	1.1%
Soft-Tissue Mass	1	1.1%
Foot Sprain	1	1.1%
Tendon Rupture	1	1.1%

Table 2

Subject Demographics and Clinical Characteristics

	Persistent Median Artery Present in One or Both Limbs		Persistent Median Artery Absent from Both Limbs		P value
	N	%	N	%	
Gender					
Male	20	26.7%	55	73.3%	>0.9999
Female	16	26.7%	44	73.3%	
Race					
White	27	24.3%	84	75.7%	0.1168
African-American	7	53.6%	6	46.2%	
Asian	1	25.0%	3	75.0%	
Other/ More than one race	1	14.3%	6	85.7%	
Ethnicity					
Non-Hispanic	29	31.5%	63	68.5%	0.0936
Hispanic	7	16.3%	36	83.7%	
Hand Dominance					
Right	20	21.3%	74	78.7%	0.0707
Left	10	40.0%	15	60.0%	
Ambidextrous	6	46.2%	7	53.6%	
Unknown	0	0.0%	3	100.0%	
Diagnosis					
Trauma/Acquired	22	23.91%	70	76.1%	0.3032
Congenital/Syndromic/Neuromuscular	14	32.56%	29	67.4%	
Treatment					
Surgical	30	29.13%	73	70.8%	0.2463
Non-Surgical	6	18.75%	26	81.3%	

Table 3

Persistent Median Artery Frequency and Age by Regression Level

	N	%*	Median Age	Interquartile Range
Elbow Crease to Forearm-Midpoint	11	4.1%	6.0	5–14
Forearm-Midpoint to Wrist Crease	29	10.7%	11.0	5–15
Wrist Crease	16	5.9%	8.3	3–13

* Crude/Unadjusted Limb Specific Prevalence Estimate