The Role of Weight-Bearing Computed Tomography Scan in Hallux Valgus

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Introduction

Hyperpronation of the 1st metatarsal in hallux valgus (HV) is poorly understood by conventional weightbearing radiography and is not always linked to the tibial sesamoid position.[1,2] We aimed to evaluate this parameter using weightbearing computed tomography (WBCT) and to understand its association with other standard measurements.

Methods

Retrospective evaluation of WBCT and weightbearing radiographs (WBXR) was performed for 20 patients with hallux valgus (HV) feet and 20 controls with no such deformity. Axial CT images of both groups were compared for 1st metatarsal pronation angle (α angle) and tibial sesamoid subluxation (TSS) grades (Figure 1). The hallux valgus angle (HVA), first-second intermetatarsal angle (IMA), 1st metatarsal-medial cuneiform angle (MMCA), Meary's angle, and calcaneal pitch (CP) angle of the study and control groups were compared on both WBXR and the corresponding 2D images of WBCT. All the measurements were independently studied by a dedicated musculoskeletal radiology fellow. All statistical analyses were performed in R v3.5.2.[3] Mean comparisons were made using either t-test (for normally distributed data) or Wilcox rank-sum test (for non-normal data and for subluxation grade). Univariate analysis was performed using Fisher's test. Receiver operating characteristic (ROC) curves were fit to data using the "pROC" package.[4] Example "optimal" ROC thresholds were calculated using Youden's J statistic.[5]

Results

The HV group demonstrated significantly higher values for TSS grade ($p < 0.001$) but not for α angle ($p = 0.19$) compared to controls (Table 1). Likewise, significantly elevated HVA and IMA were noted in the HV group on both imaging modalities while no such differences were observed for the CP angle and Meary's angle. On the other hand, higher MMCA in the study group was evident only on WBXR ($p = 0.009$) but not WBCT ($p = 0.076$).

Among all, the receiver operating characteristic (ROC) curves demonstrated the greatest area under curve (AUC) for HVA followed by IMA (Table 2). The a angle performed just within the range of a chance (AUC 0.64, 95% CI: 0.49 to 0.66). The Pearson's correlations of the α angle, in the HV group, revealed no significant linear relationship with TSS grades, IMA and MMCA, and only a moderate positive correlation was identified between α angle and HVA as per the WBXR ($r = 0.38$, $p = 0.014$) but not by the WBCT images ($p = 0.084$).

Discussion

The existing methods to assess sesamoid position using weightbearing AP radiograph have been found to be unreliable as they fail to capture the rotational component of HV deformity.[6-9] Previous studies utilizing true full WBCT have shown a tendency of the first metatarsal to pronate during weightbearing with a mean pronation angle of eight degrees in patients with HV, though this difference was not always statistcailly significant.[10] In our study, similar full weightbearing was practiced while taking the CT images, and we obtained a mean α angle of 18.2 degrees in the HV study group,

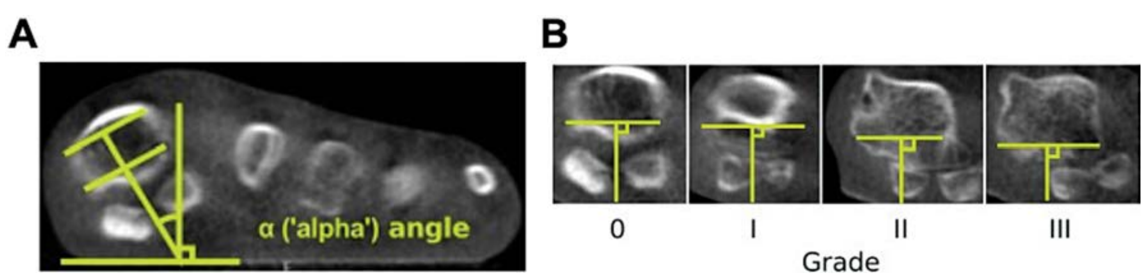

Figure 1. Parameters assessed by musculoskeletal radiologist. **(A)** Measurement of alpha angle in using weightbearing computed tomography (WBCT). **(B)** Measurement of sesamoid grade based on the location of the medial sesamoid with respect to the intersesamoid ridge. WBCT images of the hallux of the left foot are shown.

Table 1. Comparison of radiographic (XR) and computed tomography (CT) parameters in individuals without hallux valgus versus patients with known hallux valgus. P values shown were obtained by t-test, except where * indicates the use of Wilcox test for data with a non-normal distribution.

		Normal		Hallux Valgus		95% CI			P
		Mean	*(SD)*	*Mean*	*(SD)*				
α angle (deg)	CT	14.7	(7.8)	18.2	(9)	(−1.8	-	8.8)	0.19
TSS (grade)	CT	0	(0.2)	2	(1.1)	(1.4	-	2.4)	< 0.001*
HVA (deg)	*CT*	11.6	(3.8)	30	(7.4)	(14.6	-	22.2)	< 0.001
	XR	8.9	(5.2)	25.7	(7.1)	(12.8	-	20.7)	< 0.001
1-2 IMA (deg)	*CT*	10.3	(2.2)	14.9	(4.2)	(2.4	-	6.7)	< 0.001
	XR	8.2	(2.4)	11.7	(3.9)	(1.5	-	5.6)	0.003*
Meary's angle (deg)	*CT*	6.8	(5)	9.1	(8.2)	(−2	-	6.7)	0.449*
	XR	4.5	(3.5)	8.8	(7.8)	(0.4	-	8.3)	0.066*
Calcaneal pitch angle (deg)	*CT*	16.7	(7.2)	17.4	(5.1)	(−3.2	-	4.7)	0.718
	XR	16.5	(7.2)	17.2	(7.2)	(−3.9	-	5.3)	0.765
MMCA (deg)	*CT*	0.8	(0.7)	2.4	(2.7)	(0.3	-	2.9)	0.076*
	XR	0.6	(0.5)	2.5	(2.5)	(0.6	-	3)	0.009*

Table 2. Receiver operating characteristic (ROC) models were created using populations with and without a diagnosis of hallux valgus. The area under curve (AUC) value for each parameter is shown, describing how well each parameter can predict a diagnosis of hallux valgus. AUC values greater than 0.5 indicate that a parameter will predict hallux valgus better than a simple "coin flip". Optimal "threshold" values (obtained using Youden's J statistic) for each parameter are also shown, along with threshold-specific specificity and sensitivity.

	Threshold (deg)	Specificity (%)	Sensitivity (%)	AUC			
		(for predicting hallux valgus)		*AUC*	*95% CI*		
Hallux valgus (CT)	18.4	95	100	1	(0.98	-	1)
Hallux valgus (XR)	14.2	86	100	0.98	(0.94	-	0.98)
1st-2nd IMT (CT)	13.7	95	90	0.83	(0.87	-	0.94)
1st-2nd IMT (XR)	9.4	95	65	0.78	(0.7	-	0.83)
MMCA(XR)	2	76	75	0.74	(0.63	-	0.78)
Meary' s (XR)	1.9	100	45	0.67	(0.58	-	0.74)
MMCA(CT)	2.5	40	90	0.66	(0.5	-	0.67)
Alpha (CT)	19.2	100	40	0.64	(0.49	-	0.66)
Meary's(CT)	6.7	81	55	0.57	(0.46	-	0.64)
Calcaneal pitch (CT)	14.3	57	60	0.54	(0.39	-	0.57)
Calcaneal pitch (XR)	15.1	43	80	0.52	(0.36	-	0.54)

which was also not significantly different from controls. Moreover, nine out of 20 feet in the control group had an abnormal α angle greater than 16 degrees, suggesting that hyperpronation may be observed in non-HV feet as well. Also, the α angle performed just within the range of a simple coin flip (AUC 0.64) when measured in the ROC model, indicating its poor diagnostic ability in the diagnosis of HV deformity

There are a few limitations to this retrospective study.

First, a small sample size of study and control groups (N = 20, in each). Recruitment of larger numbers could affect the results as one might expect the normal group to trend to more normal α angle values. Secondly, the WBCT images in the control population were obtained for indications unrelated to HV condition (e.g. ankle arthritis).

Conclusions

In conclusion, our study showed that the α angle—a measure of abnormal hyperpronation of the first metatarsal —is an independent factor that may co-exist with other parameters in HV, but in isolation has limited diagnostic utility. "Abnormal" α angles may even be observed in individuals without HV deformity. An increase in the HVA, IMA, MMCA or TSS grade is not necessarily associated with a similar increase in the α angle and hence, the severity of HV deformity may not be judged on this parameter alone. The WBCT is a reliable method to assess hyperpronation and guide physicians during surgical management.

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