ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA MAKALESİ

Diagnostic Value of Pronator Quadratus Muscle Thickness Measured by Ultrasonography in Predicting Occult Wrist Fractures

Ultrasonografi ile Ölçülen Pronator Kuadratus Kası Kalınlığının Okült Bilek Kırıklarını Öngörmede Tanısal Değeri

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ABSTRACT

Aim: The aim of this study was to investigate the predictive power of pronator quadratus (PQ) muscle thickness, which is measured by focused ultrasonography, in patients applied to the emergency department (ED) with wrist trauma and without bone pathology detected in plain radiography.

Material and Methods: This prospective study was conducted in a tertiary ED. All patients' measurements of the PQ muscle thickness in the longitudinal and transverse planes on both hand sides were performed by emergency medicine residents. For the diagnosis of an occult distal radius fracture and occult wrist injury, orthopedics and traumatology specialist's opinion, which was decided as a result of the outpatient follow-up and additional examinations was used as reference.

Results: No statistically significant difference was found between the PQ muscle thickness of 32 patients without occult wrist injury and 15 patients with occult injury and 6 patients with occult distal radius fracture. Also, no statistically significant difference was found between the PQ muscle thickness difference of the traumatic and non-traumatic sides.

Conclusions: Sonographic measurement of PQ muscle thickness may not an effective method to detect occult distal radius fracture and other occult wrist injuries.

Keywords: Wrist injuries, radius fractures, occult fractures, diagnostic ultrasound

ÖZ

Amaç: Bu çalışmanın amacı, acil servise el bileği travması ile başvuran ve direk grafide kemik patolojisi saptanmayan hastalarda odaklanmış ultrasonografi ile ölçülen pronator kuadratus (PQ) kas kalınlığının prediktif gücünün araştırılmasıdır.

Gereç ve Yöntemler: Bu prospektif çalışma üçüncü basamak bir acil serviste yürütülmüştür. Hastaların her iki taraftaki longitudinal ve transvers düzlemlerde tüm PQ kas kalınlığı ölçümleri acil tıp asistanları tarafından yapıldı. Gizli distal radius kırığı ve gizli el bileği yaralanmaları tanısı için ayaktan takip ve ek tetkikler sonucunda karar veren ortopedi ve travmatoloji uzman görüşü referans alındı.

Bulgular: Gizli bilek yaralanması olmayan 32 hasta ile gizli yaralanması olan 15 hastanın ve gizli distal radius kırığı olan 6 hastanın PQ kas kalınlıkları arasında istatistiksel olarak anlamlı bir fark bulunmadı. Ayrıca travmatik ve travmatik olmayan tarafların PQ kas kalınlık farkı arasında istatistiksel olarak anlamlı bir fark bulunmadı.

Sonuç: PQ kas kalınlığının sonografik ölçümü, gizli distal radius kırığını ve diğer gizli el bileği yaralanmalarını saptamak için etkili bir yöntem olmayabilir.

Anahtar Kelimeler: El bileği yaralanmaları, radius kırıkları, gizli kırıklar, tanısal ultrason

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Introduction

Wrist injuries constitute approximately 20% of the emergency department (ED) admissions due to trauma (1). The wrist has an anatomically and functionally complex structure. Therefore, plain radiographs are insufficient to exclude all injuries alone (2). However, it is important to recognize occult distal radius fractures since they can cause high morbidity. Magnetic resonance imaging (MRI) is the gold standard diagnostic method to detect occult wrist injuries. However, due to being expensive and time consuming, its use in ED is limited.

Pronator quadratus (PQ) muscle is one of the deep flexor compartment muscles of the distal forearm. It is a flat, quadrangular shaped muscle extended from ulna to the radius with a thin adipose tissue cover. This adipose tissue can see as a slightly convex thin radiolucent line parallel to the distal radius in lateral radiographs (3). Hemorrhage into the PQ muscle due to wrist trauma may cause this fat pad to be displaced or disrupted in the lateral radiographs of the wrist. This image, known as PQ fat pad sign (FPS) was reported to have high sensitivity and specificity in wrist fractures (4-6). However, the studies carried out in the following years pointed out otherwise (7-10). Recently, point-of-care ultrasound has been reported to have a high sensitivity for the fracture identification and muscle injuries, but the use of sonographic measurement of PQ muscle thickness for the diagnosis of occult distal radius fractures has not been extensively studied.

The aim of this study was to investigate the ability to predict of occult distal radius injury with PQ muscle thickness sonographic measurement in patients admitted to the ED with wrist trauma and without fracture in plain radiographs.

Material and Methods

This prospective study was conducted between 01.04.2018 and 30.10.2018 in an urban ED with an annual adult admission rate of nearly 170,000. Ethical approval was obtained prior to the study from the local ethics committee (No:16/11.12.2017), and patient consent was obtained to participate in the study.

All patients older than 18 years with wrist trauma and who were considered to have normal radiographs and require short arm splint or elastic bandage due to edema, pain and limitation of motion were to be a candidate in the study. Among these candidates, those who applied during the hours when the sonographers were available were included in the study.

Patients with an open wound or bilateral injury, a history of forearm splint within past six months, with muscle strength disorder (stroke, etc.), history of wrist surgery, previous wrist fracture, an ipsilateral dialysis fistula on the upper extremity, a trauma occurred more than 48 hours who refused to participate in the study and patients with no radiography or sonography due to any reason were excluded from the study. In addition, patients who did not go to the outpatient clinic for follow up and whose final decision was not made by the orthopedic physician were excluded from the study.

Patients and their x-rays were evaluated by emergency medicine attending physicians working in the trauma unit. Sonographic imaging was performed by one of the 4 sonographers participating in the study to those with normal x-rays. Demographic data, the patients' work (overwork with hand or not), hand dominance, trauma side, the mechanism and time of the injury, physical examination findings, immobilization method and sonographic measurement were recorded. Sonographic measurements of the patients were performed by sonographers who were blinded to the physical examination findings and other data of the patients. Sonographic examinations were performed by four volunteer emergency medicine residents (EMRs) who third years of the education. Two-day theoretical and practical ultrasonography training on PQ thickness measurement was given to four EMRs by an emergency medicine attending physician experienced in musculoskeletal ultrasonography.

Sonographic examinations were performed with a 12 MHz linear probe (Philips ClearVue 550 Ultrasound system, The Netherlands.). Measurements were performed as described by Sato et al., while patients' wrists were 5-10 degrees of extension, at full supination, and elbow was on 90 degrees of flexion. Thickness measurements of the PQ muscle in the longitudinal plane were performed from the flexor carpi radialis tendon level, and measurements in the transverse plane were performed from the thickest part of the muscle (11) (Figure 1).

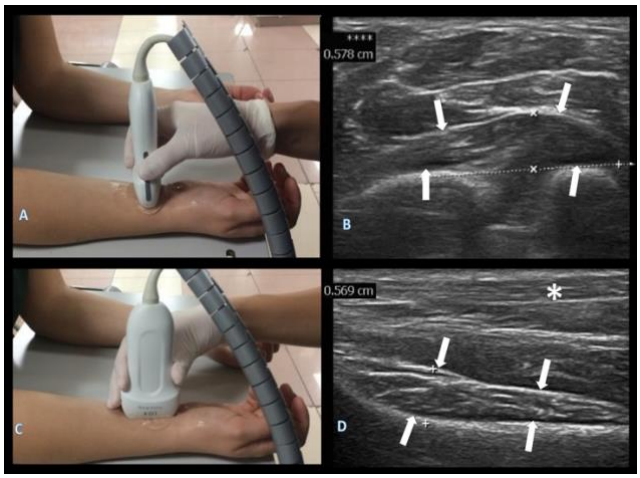

Figure 1. Probe position (A and C) and sonographic images (B and D) of pronator quadratus muscle thickness measurements in longitudinal and transverse planes.
asterisk: flexor carpi radialis tendon

All patients included in the study were referred to the same orthopedics and traumatology specialist for control examination within a week who was blinded to the PQ

muscle measurements performed in the ED. Orthopedic physician was free for perform any imaging examination and follow up time so, his opinion was accepted as the gold standard for the final diagnosis of the patients. The diagnostic value of PQ muscle thickness was analyzed for distal radius fracture and all other occult injuries -all fractures (carpal fractures and distal radius fractures), ligament injuries, joint effusions, cartilage injury- from the patients included in the study.

Sonographers performed measurements on five healthy volunteers before carrying out the study. Measurements were made in the transfers and longitudinal planes by the sonographer from both sides of the volunteer. It was found that there was a perfect agreement between the measurements [intraclass correlation coefficient= 0.875 (95% confidence interval: 0.825-0.911)].

The sample size was calculated using OpenEpi software (v3.01) [12]. When the PQ muscle thickness of 6.2 ± 1.5 mm in cases with fracture, 4.5 ± 1.2 mm in cases without fracture and occult fracture prevalence was taken as 20% [11]. It was found that 42 cases with an 80% power and 95% confidence level were the minimum sample size for the study. An additional 10% error margin was for any potential error. According to those calculations the decision was made to include 47 participants in the study.

The data were recorded in different forms during the ED and outpatient control stages. SPSS 22.0 was used to record and analyze all research data. Qualitative data were expressed as frequencies and rates, while quantitative data were expressed as median, interquartile range, and minimum-maximum values since the research data did not conform to the normal distribution. Mann Whitney U test was used in the quantitative data analysis. All analyzes were performed in a 95% confidence interval. A p-value of less than 0.05 was considered significant.

Results

This study was conducted with 47 patients who came to outpatient clinic follow-up. The patient flow diagram is shown in Figure 2.

Demographic information of the patients was presented in Table 1. The median time between the injury and admission to the ED was 9 (IQR: 12, min.:0- max: 48) hours. All patients, except 2 (4.3%) patients who were not accept, were undergoing an immobilization method that were 27 (57.4%) short arm volar splints, 18 (38.3%) elastic bandages. All patients who were evaluated in the outpatient clinic, were underwent any imaging examination which were 14 plain radiography, 13 MRI, 2 computed tomography (CT) and 1 electromyography at the discretion of the orthopedics and traumatology specialist. 17 of the patients were not underwent any imaging examination in addition to first radiography in the ED.

Female (n; %)	25 (53.2)
Age (median years, IQR, min-max)	34 (20, 18 – 68)
Right-handed (n; %)	42 (89.4)
Job requiring physical strength (n; %)	29 (61.7)
Right wrist trauma (n; %)	18 (38.3)
Falls on to an outstretched hand (n; %)	19 (40.4)
Occult wrist injuries (n; %)	15 (32)
Ligament injuries and joint effusions	7 (47)
Distal radius fractures	6 (40)
Carpal bone fractures	2 (13)

Table 1. Demographic information of the patients

No statistically significant difference was found between the PQ muscle thickness of 32 patients without occult wrist injury and 15 patients with occult injury and 6 patients with occult distal radius fracture (Table 2). Also, no statistically significant difference was found between the PQ muscle thickness difference of the traumatic and non-traumatic sides (Table 3).

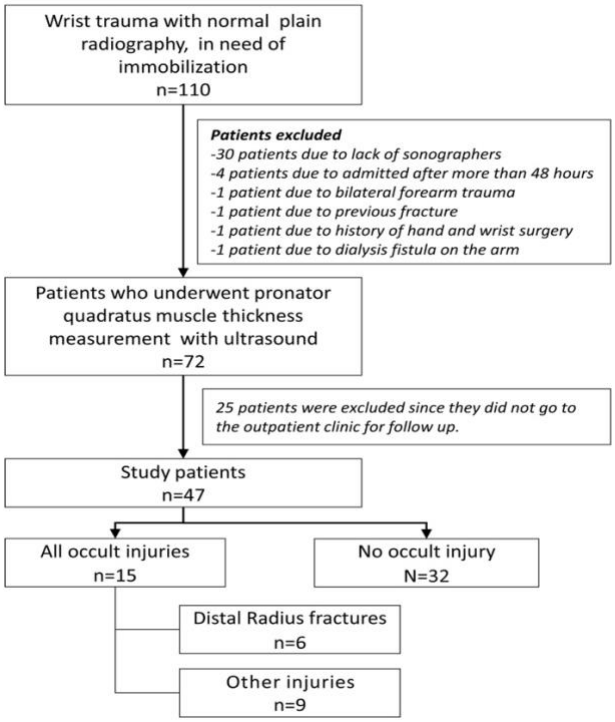

Figure 2. The patient flow diagram

Discussion

In this study, we measured the PQ muscle thickness with ultrasonography for the detection of occult distal radius fracture in patients with normal radiography presenting to the ED with wrist trauma. No statistically significant difference was found between the PQ muscle thickness measurements performed in the longitudinal and transverse planes of patients with and without occult distal radius fracture.

Sato et al. measured the PQ muscle thickness of 55 patients with normal radiographs following acute trauma on both longitudinal and transverse planes by ultrasonography [11]. Occult bone injury was detected with MRI in 23 (92.0%) of 25 patients with PQ muscle swelling. In this study, the

difference between PQ muscle thickness measurements on the affected and unaffected side after trauma was 1.7 ± 1.1 mm in the longitudinal plane and 2.0 ± 1.7 mm in the transverse plane. They reported that the sonographic swelling of the PQ muscle as a result of these data may be indicative of occult bone injury in patients with normal plain radiographs and that ultrasonography can be used for the decision of more detailed imaging studies in these patients. However, this study showed only positive predictive value since patients with normal PQ muscle measurements have not been examined by MRI. It was contained bias in the selection of patients undergoing sonography. Also, PQ muscle atrophies, anatomical variants or occupational factors may have affected the results. In our study, the orthopedist's opinion, which was decided as a result of outpatient follow-up and additional examinations was set as the reference standard for occult injuries. No statistically significant difference was found between the PQ muscle thickness of 32 patients without occult wrist injury and 6 patients with occult distal radius fracture. Also, no statistically significant difference was found between the PQ muscle thickness difference of the traumatic and non-traumatic sides However, in our study, the increase of PQ muscle thickness on the trauma side in both groups with and without occult injury suggests that the sonographer may have a bias. On the other hand, all patients had at least one examination finding such as edema, pain and limitation of motion and an immobilization method was applied to all patients except two because of do not accept. Accordingly, it can be thought that all patients have a certain minor soft tissue trauma even if there is no bone fracture and that the PQ muscle thickness on the traumatic side may have increased due to soft tissue trauma.

In another study, a significant difference was detected in the maximum PQ muscle thickness between the dominant and nondominant hands in healthy volunteers [13]. A significant difference was shown in the comparison between males and

		No occult injury (n = 32)		All occult injury (n=15)		Occult distal radius fracture (n=6)		
		Median	**IQR (min-max)**	**Median**	**IQR (min-max)**	**Median**	**IQR (min-max)**	**P value***
Traumatic PQ muscle thickness (mm)	**Longitudinal**	5.38	2.64 (2.9-12.2)	5.0	2.26 (3.37-8.9)			0.681
						5.78	1.88 (4.42-8.90)	0,245
	Transverse	6.58	2.71 (1.32-11.4)	6.87	3.43 (3.97-11.3)			0.749
						7.14	2.21 (5.78-9.80)	0.245

IQR: Interquartile Range, min:minimum, max: maximum, Mann Whitney U test*

Table 2. Pronator quadratus muscle thicknesses of traumatic sides in patients with no occult injury, all occult injury and only occult distal radius fracture.

females, regardless of hand dominance. Also, a significant difference in PQ thickness between dominant and nondominant hands was shown. They reported that gender and hand dominance must be considered in sonographic studies. However, it should be noted that this study was conducted in a small population and mainly in young volunteers with right-hand dominance. We investigated the PQ muscle thickness difference of the traumatic wrist side versus non-traumatic side. But no statistically significant difference was found. The ratio of women and men was close to each other in the patients included in our study. However, 42 (89.4%) of the patients were right-handed, and 18 (38.3%) had right-hand trauma. In our study the median age of the patients was 34 (IQR: 20, min.:18 – max.: 68) years and there were 29 (61.7%) patients who had a job requiring physical strength. Due to patient diversity and anatomical variations, it is difficult to determine the normal and pathological value of PQ muscle thickness. Given all this, sonographic measurements of the PQ muscle may not be an effective method to predict occult injuries.

In recent years, the PQ FPS in radiography has studied extensively because of its importance for the radiographic diagnosis of wrist fractures [7-10]. The sensitivity of PQ FPS was reported lower in studies which use MRI or CT as a reference than use plain radiography. This result is due to differences in the gold standard diagnostic tests and study population selection. In the study with a high sensitivity, the study population was selected from patients with nondisplaced fractures. in fact, occult fractures were not detected. However, the strength of this study is that the

		No occult injury (n = 32)		All occult injury (n=15)		Occult distal radius fracture (n=6)		
		Median	IQR (min-max)	Median	IQR (min-max)	Median	IQR (min-max)	P value*
Traumatic wrist versus non-traumatic wrist PQ muscle thickness difference (mm)	**Longitudinal**	0.42	1.2 (-0.46 - 5.59)	0.51	2.12 (-2.32 -3.26).			0.624
						0.67	1.79 (-0.35 – 2.07)	0.953
	Transverse	0.61	1.16 (-1.3 - 3.28)	0.27	1.62 (-1.85-7.19)			0.486
						0.93	1.38 (-0.61 – 1.54)	0.830

*IQR: Interquartile Range, min: minimum, max: maximum, * Mann Whitney U test*

Table 3. Pronator quadratus muscle thicknesses difference of traumatic wrist side versus non-traumatic wrist side in patients with no occult injury, all occult injury and only occult distal radius fracture.

Author	Year	Age	Study population	Gold standard test for diagnosis of fracture	Case group (n)	Control group (n)	Frequency of PQ FPS * (%)	Sensitivity for fracture (%)	Specificity for fracture (%)	Classification of patient
Annamalai G et al	2003	N/A	Patients with wrist trauma who had initial radiograph no fracture	MRI	50 patients distal radius fracture	50 patients no fracture	25	26	70	Three groups according to the morphological appearance of PQ muscle. (normal, displaced, absent)
Fallahi F et al.	2012	Over 16 years	Patients with wrist trauma who had initial radiograph no fracture	MRI	28 patients PQ altered	40 patients PQ normal	41	65	69	Four groups according to the morphological appearance of PQ muscle. (normal, raised, obliterated, disrupted)
Sun B et al.	2016	Over 16 years	Patients with undisplaced wrist fracture	Standard plain radiography	106 patients Undisplaced wrist fracture	210 patients Non-traumatic volunteers	N/A	91	84	According to the muscle-to-bone thickness ratio (PQ muscle / distal radius =0.4)
Loesaus J et al.	2017	Over 18 years	Patients with wrist trauma who had initial radiograph no fracture	CT	44 patients distal radius fracture	45 patients no fracture	26	48	96	According to the thickness of the PQ muscle (8mm in females and 9mm in males).

* Frequency of PQ FPS according to the specific classification of the study, MRI: magnetic resonance imaging, CT: Computed tomography, PQ: pronator quadratus

Table 4. Studies investigating the diagnostic value of pronator quadratus (PQ) fat pad sign (FPS) for fracture diagnosis

number of patients is higher than double of the others and the ratio between maximum PQ thickness and the same level of the distal radial thickness (DRT) was used in the diagnosis of fracture [9]. The muscle-to-bone ratio reduces errors that may result from single measurement and the effect of variable factors (such as gender and body size) affecting PQ muscle thickness. The recent studies investigating PQ FPS radiographically are shown in Table 4. In our study, sonographic measurement of PQ muscle thickness was not helpful to diagnose occult distal radius fractures in patients with normal radiography. For the diagnosis of an occult distal radius fracture, orthopedics and traumatology specialist's opinion, which was decided as a result of the outpatient follow-up and additional examinations was used as reference. The sample size was calculated prior to the study but our occult fracture prevalence was lower than we expected.

There were a few limitations of our study. Firstly, the final diagnosis of the patients was not confirmed by MRI. However, the reliability of the final diagnosis made by an orthopedics and traumatology specialist who was free to request an examination is close to the gold standard. The other limitation of our study was sonographic measurements of the PQ muscle made by EMRs have not been validated by an experienced sonographer. Even if EMRs were blinded to physical examination findings, it would not be difficult to predict the traumatic side during sonographic measurements, which may have caused practitioners to take sides.

Conclusion

The frequency of occult wrist injuries is high in patients admitted to the ED with wrist trauma and who have normal radiographic findings with require immobilization physical examination findings. Sonographic measurement of PQ muscle thickness is may not an effective method to detect occult distal radius fractures.

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Authors' Contribution: All authors contrubuted for conception, design of the study, data collection, data analysis, and assembly. The manuscript was written and approved by all authors.

Ethical Statement: Ethical approval for this study was obtained from Health Science University Izmir Tepecik Training and Research Hospital Ethics Committee with the approval number 14/11.12.2017/16

All authors declared that they follow the rules of Research and Publication Ethics.

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