Research Paper

Pronator Teres Reflex and the Diagnosis of C6 and C7 Radiculopathy

Arash Babaei-Ghazani[1], Negar Aflakian[1], Hamid Reza Fadavi[2], Ali Babashahi[3], Maziar Azar[3], Fariba Afshari-Azar[3], Hosnieh Soleymanzadeh[1], Mathieu Boudier-Reveret[4], Bina Eftekharsadat[5*]

1. Neuromusculoskeletal Research Center, Department of Physical Medicine and Rehabilitation, Iran University of Medical Sciences, Tehran, Iran.
2. Physical Medicine and Rehabilitation Specialist with Subspecialty in Interventional Pain Management, Clinical Director, Mission Pain and Spine, Mission Viejo, CA, USA.
3. Department of Neurosurgery, School of Medicine, Iran University of Medical Sciences, Tehran, Iran.
4. Department of Physical Medicine and Rehabilitation, University of Montreal Health Centre, Montreal, Canada.
5. Physical Medicine and Rehabilitation Research Center, Department of Physical Medicine and Rehabilitation, Tabriz University of Medical Sciences, Tabriz, Iran.

Use your device to scan and read the article online

Citation Babaei-Ghazani A, Aflakian N, Fadavi HR, Babashahi A, Azar M, Afshari-Azar F, et al. Pronator Teres Reflex and the Diagnosis of C6 and C7 Radiculopathy. Iranian Rehabilitation Journal. 2022; 20(1):73-80. http://dx.doi.org/10.32598/irj.20.1.1510.1

doi http://dx.doi.org/10.32598/irj.20.1.1510.1

Article info:
Received: 16 Jun 2021
Accepted: 29 Dec 2021
Available Online: 01 Jun 2022

Keywords:
Radiculopathy, Pronator teres reflex, Diagnostic value, Sensitivity, Specificity

ABSTRACT

Objectives: Neck roots lesions are among the etiologies of cervical and arm pain. A detailed patient evaluation could assist the diagnosis, reduce imaging requests, and promote the treatment of cervical pain. We tried to estimate the value of pronator teres reflex in C6 and C7 roots irritation.

Methods: The present study comprises 118 participants, including 56 patients with C6 and C7 lesions and 62 normal controls. The reliability and usefulness of this reflex in C6 and C7 roots lesions were compared to positive electromyography and imaging with magnetic resonance.

Results: The sensitivity, specificity, positive predictive value, and negative predictive value for pronator teres reflex were 36.4%, 13.6%, 64.8%, and 4.6%, respectively.

Discussion: This reflex can be considered an additional reflex during the physical examination for C6 and C7 nerve roots injury, but its diagnostic value for C6 and C7 radiculopathy is unreliable to be used for screening purposes.

*** Corresponding Author:**
Bina Eftekharsadat, MD.
Address: *Physical Medicine and Rehabilitation Research Center, Department of Physical Medicine and Rehabilitation, Tabriz University of Medical Sciences, Tabriz, Iran.*
Tel: *+98 (21) 88908519*
E-mail: *binasadat@yahoo.com*

Highlights

● Pronator teres reflex tests the C6 and C7 cervical roots pathway and is recommended in upper limb neurologic examination.

● Compared to MRI and electrodiagnostic studies, pronator teres reflex has lower sensitivity and specificity.

● This reflex could add some information to our physical examination but might not be as important as described previously in daily routine cervical radiculopathy assessments.

Plain Language Summary

Cervical radiculopathy is a common etiology for neck pain radiating to the upper limb. The physical examination will help a physician diagnose or be suspicious of cervical nerve root compression. Physical examination is time-consuming and should be efficient. One of the important parts of physical examination is the muscle stretch reflex performed by a medical hammer. In upper limbs, pronator teres reflex is described as a muscle stretch reflex for evaluating the sixth and seventh cervical roots pathway and is recommended in upper limb neurologic examination. This research was conducted to evaluate the diagnostic value of this reflex. In this study, 118 participants (56 with and 62 without the sixth and seventh cervical roots radiculopathy) were recruited. The diagnostic value of this upper limb reflex (pronator teres reflex) was compared with positive electromyography and magnetic resonance imaging. The sensitivity, specificity, positive predictive value, and negative predictive value for pronator teres reflex were 36.4%, 13.6%, 64.8%, and 4.6%, respectively. Although this reflex can be considered an adjunct reflex during the physical examination for evaluating the sixth and seventh cervical nerve roots, its diagnostic value for cervical radiculopathy is unreliable.

1. Introduction

Cervical radiculopathy usually presents with pain and or sensory-motor impairment secondary to the inflammation of or pressure on the cervical nerve roots [1-4]. Patient complaints may include pain, paresthesia, burning sensation, muscle weakness, and amyotrophy. Facet joint spondylosis and intervertebral hernia are the two most common causes of cervical nerve root compression [5]. Timely recognition and diagnosis of cervical radiculopathy may expedite the treatment and recovery of the symptoms leading to a faster recovery.

Cervical radiculopathies have an annual incidence of 107.3 and 63.5 per 100000 among men and women, respectively [1]. Peak incidence occurs between the ages of 50 and 54 [1]. The most frequently involved cervical roots are C7, C6, and C8. Assessment may reveal sensory impairment and motor dysfunction along with the territory of the involved nerve roots. Diagnostic tests include imaging and electrophysiological studies [6].

Muscle Stretch Reflex (MSR) assessment may play a principle role in diagnosing cervical roots lesions. Attenuation of MSR is commonly correlated with pathology observed during surgeries [7]. MSR examination in the upper limb usually includes evaluation of biceps, brachioradialis, and triceps reflexes. When the elbow is semi-flexed, and the forearm semi-pronated, the Pronator Teres (PT) reflex can be evaluated with a brief strike of a medical reflex hammer at the distal forearm. The muscle involved in this reflex is the pronator teres [8, 9].

Electrodiagnostic Studies (EDS) indicate that denervation of pronator teres is one of the most common findings in C6 radiculopathy. It is also commonly seen in C7 radiculopathy [10].

Biceps and brachioradialis reflexes help to evaluate the integrity of both C5 and C6 nerve roots without discriminating between the two roots. Pronator teres reflex may play a role in differentiating C6 root involvement from the C5.

Because of the high prevalence of radiculopathy in patients over 50, the high cost of imaging studies, and the necessity for accurate diagnosis of cervical radiculopathy, we aimed to evaluate the diagnostic value of pronator teres reflex for C6 and C7 radiculopathy. We stipulated that if there is a relationship between the two, pronator teres reflex can play a role in screening patients with signs of radiculopathy.

2. Materials and Methods:

In an observational study, we conducted a descriptive-analytic cross-sectional diagnostic evaluation on 118 consecutive individuals referred to the physical medicine and rehabilitation (PM&R) clinic of Iran University of Medical Sciences (Rasool Akram Hospital), Tehran City, Iran, from 2018 to 2020. This study was accepted and approved by the Ethics Committee of the Iran University of Medical Sciences, and informed consent was obtained from all participants.

The criteria for diagnosis of cervical radiculopathy were based on the North American Spine Society [11] and a previously published article [12]. These criteria included a history of neck pain, duration of symptoms between one month and one year, numbness and or pain in the upper limb, and or emergence of symptoms by the change in the neck position, abnormal sensory examination in a dermatomal pattern, abnormal motor examination in a myotomal distribution, and or abnormal muscle stretch reflex (deep tendon reflexes).

We excluded all participants with a previous history of treated cervical disk herniation, fracture in upper limbs or cervical spine, history of a traumatic brain lesion or cerebrovascular accident, diabetes, rheumatologic disease, and neuropathies.

Participants underwent electrodiagnostic studies (EDS) and magnetic resonance imaging (MRI) to determine the diagnosis of C6 and or C7 root lesions. Subjects in the control group did not have any symptoms described in these criteria and therefore ruled out the possibility of cervical radiculopathy.

The study participants comprised 56 individuals with C6 and C7 radiculopathy (Group 1) and 62 subjects without radiculopathy (Group 2). Group 2 participants were among the referral patients to the PM&R clinic without symptoms of cervical radiculopathy (lumbosacral radiculopathy or lower limb pain). The diagnostic value of the PT reflex was compared to positive EDS findings in evaluating the possibility of C6 and C7 cervical roots lesions.

Our data collection tool included a checklist and field-collecting method using MRI, physical examination, and EDS. The study variables comprised weight, height, body mass index, gender, age, clinical symptoms, upper limb muscle stretch reflexes, MRI, and EDS results. All physical examinations were performed with experienced PM&R specialists. For each participant, all physical examinations (including MSR) and EDS evaluations were performed on the same day. First physical examination and then EDS was performed.

Pronator teres reflex was examined in all participants with or without signs and symptoms of cervical radiculopathy. To evaluate the pronator teres reflex, the forearm was placed in the neutral position, such that the elbow joint was bent about 90° and the forearm was in semi-pronation. The reflex was then triggered by striking the volar portion of the distal forearm (radius side) using a medical reflex hammer. Following this strike that generates a supination force, a motion response occurs in the form of pronation, which is usually visible to the examiner [13].

Biceps reflex was evaluated with the arm in a neutral, relaxed posture; the elbow joint was bent at about 90° with the forearm in full supination. The reflex was then triggered by tapping on the distal biceps tendon in the cubital fossa using a reflex hammer. Brachioradialis reflex was evaluated with the elbow joint at 90° flexion and the forearm in mid-pronation. This reflex was triggered by tapping over the distal brachioradialis tendon at the distal forearm. Triceps reflex was evaluated with the arm in relaxed abduction and internal rotation, and the elbow joint was flexed about 90° with the examiner holding the participant's arm with another hand. The reflex was then triggered by striking the distal triceps tendon using a reflex hammer [13].

The forearm pronation force was evaluated by placing the forearm in complete pronation. The evaluator attempted to supinate the forearm by exerting force on the distal portion of the forearm. The pronator teres force was evaluated in the elbow joint at 90° flexion. The shoulder abduction force was tested with the shoulder joint in 90° abduction and attempting to perform arm adduction by applying force to the distal arm. Elbow flexion force was evaluated with the elbow at 90° flexion. The practitioner attempted to extend the elbow, inserting force into the distal forearm. Elbow extension force was evaluated with the flexed elbow and applying force to the distal forearm attempting to flex the elbow against the subject's resistance. Wrist extension force was evaluated with the wrist in full extension, and the evaluator attempted to make a wrist flexion by applying force over the dorsal hand [13].

For sensory examination, we considered the lateral side of the mid-arm for C5, the palmar side of the thumb for C6, and the palmar side of the middle finger for the C7 root.

Table 1. Baseline characteristics in both groups

Variables \ Groups	Mean±SD		P (Baseline Comparison)
	With C6-C7 Radiculopathy (1)	Without Radiculopathy (2)	
Age (Y)	50.46±10.73	47.23±11.26	0.113
Wight (Kg)	75.86±12.1	73.32±13.21	0.281
Height (cm)	166.39±6.57	164.55±8.26	0.174
BMI (kg/m^2)	27.42±4.38	27.18±5.15	0.780
Female, No.(%)	33(58.9%)	40(64.5%)	0.573*

BMI: body mass index. *The Fisher exact test.

Iranian Rehabilitation Journal

A positive Spurling test was considered to reproduce radicular symptoms in upper limbs with passive neck lateral flexion and inserting a compression force to the head.

A positive relief test was considered as reduction or relief of ipsilateral radicular symptoms by abducting the ipsilateral arm actively and putting the hand on the head.

Standard EDS was performed for bilateral upper limbs and both groups with an experienced PM&R specialist in a university-based hospital. For EDS, Both Electromyography (EMG) and Nerve Conduction Studies (NCS) were performed. We measured the Compound Motor Action Potential (CMAP) and Sensory Nerve Action Potential (SNAP) of the median and ulnar nerves. Electromyography of the biceps brachii, deltoid, flexor carpi radialis, pronator teres, abductor pollicis brevis, and extensor digitorum communis muscles was also conducted. All EDS measurements were done using a Synergy NCS EMG EP IOM instrument (The USA) after clinical examination by the physiatrist, who was blinded to the groups. The measurements were based on descriptions provided by Dumitru and Amato [14]. All participants in group 1 had an MRI study correlating with EDS findings. In the case of bilateral radiculopathy, the more symptomatic side was included in the analysis.

The obtained data were analyzed by SPSS software, v. 13. Quantitative variables were described as Mean±SD in this study. Qualitative variables (such as numbness, tingling, positive Spurling, relief sign, MRI findings, etc.) were reported by frequency and percentage. For sub-objectives, statistical tests of the Chi-Square test, Fisher exact test, and independent t test were used.

3. Results

Fifty-six participants with C6 and or C7 roots lesions and 62 healthy participants without cervical roots lesions were recruited for this study. Characteristics of subjects are reported in Table 1. There was no statistically significant difference between the two groups regarding height, age, weight, and body mass index (P>0.05).

In group 1 (with radiculopathy), the force of pronation was significantly lower compared with the individuals in group 2 (P=0.002), with a sensitivity of 85.71% (95% CI: 63.66% -96.95%).

In group 1, the biceps reflex was significantly different in comparison with group 2 (P<0.001), and its sensitivity was 100% (95% CI: 71.51%- 100%) (Table 2).

In group 1, the PT reflex (main study goal) was significantly different from group 2 (P<0.001). This reflex was absent in 35.7% of patients with C6 and C7 roots lesions and 3.2% of healthy individuals (P<0.001) (Table 2).

The overall results for sensitivity and specificity of pronator teres reflex were 36.4% (95% CI: 26.87%-46.91%) and 13.6% (95% CI: 2.91%-34.91%) and positive predictive value (PPV) and negative predictive value (NPV) were 64.8% (95% CI: 57.42%-71.56%) and 4.6% (95% CI: 1.67%-12.46%), respectively.

The sensitivity, specificity, and accuracy values between three diagnostic tools for C6-C7 radiculopathy are presented in Table 3 (MRI vs EDS/pronator teres reflex vs EDS/pronator teres reflex vs MRI).

Additionally, the PT reflex had a sensitivity of 65% (95% CI: 40.78%-84.61%) and specificity of 4.69% (95% CI: 0.98%-13.09%) for the detection and confirmation of

Table 2. Comparing history, physical examination, Electrodiagnostic Study (EDS), and Magnetic Resonance Imaging (MRI) findings in Group 1 and Group 2

Variables		No.(%)		P
		1	2	
Numbness		29(51.8)	12(19.4)	<0.001*
Tingling		34(60.7)	15(24.2)	<0.001*
Pain		47(83.0)	0(0)	<0.001*
Weakness		15(26.8)	0(0)	<0.001*
Positive Spurling		20(35.7 %)	0(0)	<0.001*
Relief sign		20(44.6 %)	0(0)	<0.001*
Elbow flexion force	3/5	1(1.8)	0(0)	0.005**
	4/5	8(14.3)	0(0)	
	5/5	47(83.9)	100.0 %	
Pronation force	3/5	0(0%)	0(0)	0.002**
	4/5	8(14.3)	0(0)	
	5/5	48(85.7)	100.0 %	
Wrist extension force	3/5	1(1.8)	0(0)	0.005**
	4/5	8(14.3)	0(0)	
	5/5	47(83.9)	100.0 %	
Biceps reflex	None	1(1.8)	0(0)	<0.001**
	1+	25(44.6)	2(3.2)	
	2+	30(53.6)	60(96.8)	
Triceps reflex	None	2(3.6)	0(0)	<0.001**
	1+	18(32.1)	2(3.2)	
	2+	36(64.3)	60(96.8)	
Brachioradialis reflex	None	1(1.8)	0(0)	<0.001**
	1+	24(42.9)	2(3.2)	
	2+	31(55.3)	60(96.8)	
Pronator Teres reflex	None	20(35.7)	2(3.2)	<0.001**
	1+	0(0)	0(0)	
	2+	36(64.3)	60(96.8)	
MRI findings (In favor of)	C6	23(41.1)	0(0)	<0.001**
	C7	12(21.4)	0(0)	
	C6 & C7	21(37.5)	0(0)	
	None	0(0)	100.0 %	
Stage of disc herniation	Bulging	12(21.4)	0(0)	<0.001**
	Protrusion	36(69.3)	0(0)	
	Extrusion	8(14.3)	0(0)	
EDS findings (In favor of)	C6	20(35.7)	0(0)	0.0001**
	C7	13(23.2 %)	0(0)	
	C6 & C7	21(37.5)	0(0)	
	None	2(3.6)	100.0 %	

Iranian Rehabilitation Journal

Group 1; with C6-C7 radiculopathy, Group 2 (Control); without radiculopathy. * The Fisher exact test. ** The Chi-square test.

Table 3. Sensitivity, specificity, and accuracy values of the three groups

Variables	Sensitivity		Specificity		Accuracy	
	Value	95% Confidence Interval	Value	95% Confidence Interval	Value	95% Confidence Interval
MRI & EDS	100%	(93.40% -100%)	96.8%	(89.16%-99.62%)	98.3%	(94.01%-99.79%)
PT. Reflex & EDS	36.4%	(26.87%-46.91%)	13.6%	(2.91%-34.91%)	32.2%	(23.9%-41.43%)
PT. Reflex & MRI	37.5%	(27.82%-47.97%)	9.1%	(1.12%-29.16%)	23.2%	(23.9%-41.43%)

PT: pronator teres; MRI: magnetic resonance imaging; EDS: electrodiagnostic study.

Iranian Rehabilitation Journal

C6 root lesion, and its PPV and NPV were 17.57% (95% CI: 13.3%-22.80%) and 30% (95% CI: 10.88%-60.07%) respectively. PT reflex had a sensitivity of 46.1% (95% CI: 19.22%-74.87%) and specificity of 4.69% (95% CI: 0.98%-13.09%) for the detection of C7 root lesion, and its PPV and NPV were 8.96% (95% CI: 5.17%-15.07%) and 30% (95% CI: 11.29%-59.07%) respectively.

4. Discussion

EDS evaluations indicate that pronator teres denervation is one of the most common findings in C6 and C7 radiculopathy [10]. Although previously published literature demonstrated a confusing and conflicting description of the pronator teres reflex, Malanga et al. showed that this reflex presents the pronator teres muscle activity without activating the pronator quadratus [9]. Because of the prevalence of cervical radiculopathy and the importance of early detection of radiculopathy, we evaluated the association between radiculopathy of the sixth and seventh cervical roots with pronator teres reflex.

Our study showed that the pronator teres reflex (compared to EDS) has a sensitivity of 36.4% and a specificity of 13.6% for the diagnosis of C6 and C7 roots involvement, and PPV and NPV were 64.8% and 4.6%, respectively. In our patient population, we found this reflex was absent among 35.7% of patients with C6 and C7 roots lesions and 3.2% of healthy subjects (P<0.001).

In 1945, Wartenberg et al. described the pronator reflex for the first time with a similar technique we used in our study. He thought this reflex was due to the contraction of both pronator teres and pronator quadratus muscles. He also reported that this reflex was necessary for diagnosing the pyramidal tract lesions affecting the upper limb [9]. In 1962, Steegmann et al. demonstrated the pronator reflex in a vertical position of the wrist, tapping on the medial side of the wrist, therefore, stimulating the pronator muscles contraction and pronator reflex [9]. Seven years later, in 1969, DeGowin et al. described the center of this reflex in the cervical C6-C7 region [9].

In 1994, Malanga and Denise used surface EMG to show that the pronator reflex results from only pronator teres contraction. They evaluated 10 healthy subjects with surface EMG recording on pronator teres and quadratus muscles. They described a mean reflex response from pronator teres with 9.7±1.8 (Mean±SD) ms latency without any activity of the pronator quadratus. Malanga et al. concluded that the pronator reflex represents C6/C7 roots lesion [9].

Shehab and Butinar evaluated the reliability and reproducibility of the pronator reflex and its latency among 25 healthy participants using surface EMG. In their study, they administered this reflex by hitting the distal volar portion of the forearm (radius) while the elbow was at 90° flexion and the forearm was in a mid-supination/pronation position. This technique led to the pronation of the forearm with a repeatable diphasic response. The mean latency was reported as 15.9±1.3 (Mean±SD) ms with a 95% CI [15]. Compared to our study, they did not evaluate pronator reflex among patients with C6/C7 radiculopathy and did not show the respected sensitivity, specificity, PPV, and NPV.

This study, for the first time, evaluated the specificity and sensitivity of the PT reflex in comparison and combination with electrophysiological and MRI findings for the diagnosis of C6 and C7 roots involvement.

The main limitation of this study is the absence of a gold standard test for the diagnosis of radiculopathy. Although the EDS has high specificity in diagnosing radiculopathy and physiological distortion in root lesions, it is not considered the gold standard. Another limitation of this study is the absence of a multicenter evaluation and testing among different populations.

5. Conclusion

In summary, the results of this study show that the PT reflex can be considered a complementary reflex for evaluating C6 and C7 radiculopathy, keeping in mind that its effect is not as strong as the combination of EDS and imaging findings. Additional studies with larger sample size and greater study power in a multicenter fashion with considering other conflicting variables can increase our knowledge in this field.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. A written consent has been obtained from the subjects. principles of the Helsinki Convention was also observed.

Funding

The paper was extracted from the MD. thesis of the Fariba Afshari-Azar in Department of Physical Medicine and Rehabilitation, Faculty of Medicine. Iran University of Medical Sciences based on the thesis number 2498.

Authors' contributions

Conceptualization: Arash Babaei-Ghazani, Hamid Reza Fadavi, Maziar Azar, Fariba Afshari-Azar, and Bina Eftekharsadat; Methodology: Arash Babaei-Ghazani, Hamid Reza Fadavi, Ali Babashahi, and Mathieu Boudier-Reveret; Software; Negar Aflakian, Maziar Azar, Fariba Afshari-Azar, and Hosnieh Soleymanzadeh; Validation: Arash Babaei-Ghazani, Negar Aflakian, Hosnieh Soleymanzadeh, and Bina Eftekharsadat; Formal Analysis; Arash Babaei-Ghazani, Hamid Reza Fadavi, Maziar Azar, and Hosnieh Soleymanzadeh; Investigation: Arash Babaei-Ghazani, Negar Aflakian, Hosnieh Soleymanzadeh, Mathieu Boudier-Reveret, and Bina Eftekharsadat; Resources; Arash Babaei-Ghazani, Hamid Reza Fadavi, Maziar Azar, Fariba Afshari-Azar, Hosnieh Soleymanzadeh, Bina Eftekharsadat; Data curation: Arash Babaei-Ghazani, Negar Aflakian, Fariba Afshari-Azar, Hosnieh Soleymanzadeh, Bina Eftekharsadat; Writing - original draft: Arash Babaei-Ghazani, Negar Aflakian, Hosnieh Soleymanzadeh, and Bina Eftekharsadat; Writing - review, and editing: Hamid Reza Fadavi, Ali Babashahi, Maziar Azar, Fariba Afshari-Azar, and Mathieu Boudier-Reveret; Supervision: Arash Babaei-Ghazani and Bina Eftekharsadat; Project administration: Babaei-Ghazani, Negar Aflakian, Hamid Reza Fadavi, Hosnieh Soleymanzadeh, and Bina Eftekharsadat.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Carette S, Fehlings MG. Clinical practice. Cervical radiculopathy. The New England Journal of Medicine. 2005; 353(4):392-9. [DOI:10.1056/NEJMcp043887] [PMID]

[2] Ellenberg MR, Honet JC, Treanor WJ. Cervical radiculopathy. Archives of Physical Medicine and Rehabilitation. 1994; 75(3):342-52. [DOI:10.1016/0003-9993(94)90040-X]

[3] Fouyas IP, Statham PF, Sandercock PA. Cochrane review on the role of surgery in cervical spondylotic radiculomyelopathy. Spine. 2002; 27(7):736-47. [DOI:10.1097/00007632-200204010-00011] [PMID]

[4] Humphreys SC, Chase J, Patwardhan A, Shuster J, Lomasney L, Hodges SD. Flexion and traction effect on C5-C6 foraminal space. Archives of Physical Medicine and Rehabilitation. 1998; 79(9):1105-9. [DOI:10.1016/S0003-9993(98)90179-4]

[5] Caridi JM, Pumberger M, Hughes AP. Cervical radiculopathy: A review. HSS journal: The Musculoskeletal Journal of Hospital for Special Surgery. 2011; 7(3):265-72. [DOI:10.1007/s11420-011-9218-z] [PMID] [PMCID]

[6] Hakimi K, Spanier D. Electrodiagnosis of cervical radiculopathy. Physical Medicine and Rehabilitation Clinics of North America. 2013; 24(1):1-12. [DOI:10.1016/j.pmr.2012.08.012] [PMID]

[7] Iyer S, Kim HJ. Cervical radiculopathy. Current Reviews in Musculoskeletal Medicine. 2016; 9(3):272-80. [DOI:10.1007/s12178-016-9349-4] [PMID] [PMCID]

[8] Campbell WW, DeJong RN. DeJong's the neurologic examination. Philadelphia: Lippincott Williams & Wilkins; 2005. https://books.google.com/books/about/DeJong_s_the_Neurologic_Examination.html?id=CvgxUpZ7ZfUC

[9] Malanga GA, Campagnolo DI. Clarification of the pronator reflex. American Journal of Physical Medicine & Rehabilitation. 1994; 73(5):338-40. [DOI:10.1097/00002060-199409000-00006] [PMID]

[10] Rainville J, Noto DJ, Jouve C, Jenis L. Assessment of forearm pronation strength in C6 and C7 radiculopathies. Spine. 2007; 32(1):72-5. [DOI:10.1097/01.brs.0000251002.39417.2c] [PMID]

[11] Bono CM, Ghiselli G, Gilbert TJ, Kreiner DS, Reitman C, Summers JT, et al. An evidence-based clinical guideline for the diagnosis and treatment of cervical radiculopathy from degenerative disorders. The Spine Journal: Official Journal of the North American Spine Society. 2011; 11(1):64-72. [DOI:10.1016/j.spinee.2010.10.023] [PMID]

[12] Miller TA, Par1do R, Yaworski R. Clinical utility of reflex studies in assessing cervical radiculopathy. Muscle & Nerve. 1999; 22(8):1075-9. [DOI:10.1002/(SICI)1097-4598(199908)22:83.0.CO;2-U]

[13] Cifu DX. Braddom's physical medicine and rehabilitation E-book. 6th ed. Philadelphia: Elsevier Health Sciences; 2020. https://books.google.com/books/about/Braddom_s_Physical_Medicine_and_Rehabili.html?id=caz0DwAAQBAJ

[14] Dumitru D, Amato AA, Zwarts MJ. Electrodiagnostic Medicine Pitfalls. Electrodiagnostic medicine. 2th ed. Philadelphia: Hanley & Belfus; 2002. [DOI:10.1016/B978-1-56053-433-4.50023-7]

[15] Shehab D, Butinar D. Pronator teres reflex: Reliability and normal value. American Journal of Physical Medicine & Rehabilitation. 1996; 75(5):328-31. [DOI:10.1097/00002060-199609000-00003] [PMID]