Activity of the f wave as a clinical diagnosis in thoracic-outlet syndrome

F wave in thoracic-outlet syndrome

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***Abstract*— Thoracic outlet syndrome comprises a series of signs and symptoms that depend on the structure that is involved (artery, vein, or nerve) which becomes highly disabling. The objective was to find the relationship between clinical, surgical and neurophysiological findings, specifically of the F wave, in surgical treatment. The study was retrolective, descriptive. A review of the files of the National Institute of Rehabilitation LGII was carried out, from January 1, 2017 to April 30, 2019 that included the clinical diagnosis of thoracic outlet syndrome. The results showed the relationship between the initial persistence, maneuvers, post-maneuvers and the quantitative parameters of the persistence and latency of the F wave of the median and ulnar nerve with the electrophysiological diagnosis, with a 90% positive late response in patients with Thoracic outlet syndrome by clinical criteria. An increase in the percentage of the quantitative parameters of the persistence and latency of the F wave was found. Therefore, we conclude that there is a significant relationship between the results of the F wave with the diagnosis of thoracic outlet syndrome confirmed by surgical procedure.**

Keywords: ***Thoracic outlet syndrome, Dynamic F wave, Electrophysiology, surgical procedure.***

I.- INTRODUCTION

Thoracic-Outlet Syndrome (TOS) since its description by Peet in 1956 continues to cause great controversy in current medical practice and is probably one of the longest and most controversial diagnoses [1]. There is no clear definition or a consistent disease chart, it is considered a morphodynamic disorder of the so-called cervico-axillary canal [2]. In clinical practice, a wide variety of symptoms and complaints are described that have their possible cause in a compression of vascular or nervous structures in the upper thoracic opening, the literature defines it as the set of symptoms related to compression or irritation of: brachial plexus trunks (neurogenic); the vein and / or the subclavian (vascular) artery, compromised structures in the outflow defiles of the thoracic cage, as a result of congenital or acquired changes in bone or soft tissue [3].

Of the subtypes, the neurogenic type is by far the most common form, accounting for more than 95% of all TOS patients, the venous type occurs between 2% and 3%, while the arterial type comprises less 1% of patients [4,5]. Most patients with TOS are between 20 and 50 years of age, less than 5% are adolescents, while 10% are older than 50 years, some type of thoracic outlet syndrome is rarely observed in patients older than 65 years, as well as in pediatric patients. 70% are women, however, there is no explanation for the female predominance [6,7]. Electrodiagnostic techniques are important to examine the degree of neurogenic involvement and to localize the site of injury [8]. These techniques have made promising advances in recent years, such as sensory conduction of the medial antebrachial cutaneous nerve, late responses of the F wave performing dynamic maneuvers, somatosensory evoked potentials, and the triple stimulation technique. However, there is still controversy about the effectiveness of the diagnosis with the use of these tests [9,10]. Imaging studies that include ultrasound, MRI, or CT angiography can show pathology in severe cases, but the sensitivity of such tests is low in the early stages [11]. On the other hand, the dynamic use of electrodiagnosis allows us to do it in a logical and reproducible way. In each case, the electrodiagnostic test is an extension of the physical examination, a numerical representation of a physical finding, or a provocative maneuver that is associated with the condition we are focusing on. The key to using nerve conduction studies in this way is to determine by physical examination, which nerve pathways may be involved, it is an opportunity to graduate the "neurogenic thoracic outlet syndrome" to a different entity [8,12,13].

Dynamic F-wave study is a relatively easy, non-invasive and well-tolerated technique that can provide additional diagnostic value in the early stages of thoracic outlet syndrome [14]. Therefore, the objective of the present study is to evaluate the activity in the persistence and latency of the F wave on the clinical, neurophysiological and surgical findings of patients with thoracic outlet syndrome.

II.- MATERIAL AND METHODS

An observational, cross-sectional, retroelective study was carried out. Through the review of files from the National Institute of Rehabilitation LGII, in a period from January 1, 2017 to April 30, 2019, with the clinical diagnosis of thoracic outlet syndrome. Of the records that met the inclusion criteria, such as electrophysiological studies that include the evaluation of the dynamic F wave performed in the evening shift of the electrodiagnostic department of the INRLGII, with a report of surgical intervention with a pre-surgical diagnosis of thoracic outlet syndrome and studies Electrophysiological performed before the surgical intervention in the record. A non-probabilistic sample was carried out for convenience. The request was filled out to the computer service to obtain the database of clinical records with a diagnosis of thoracic outlet corresponding to the period January 1, 2017 to April 30, 2019. The confidential letter was made in order to corroborate the commitment of ethics when using the information in the files. Once the database was obtained, the files that met the inclusion criteria were reviewed, the files that met the aforementioned elimination criteria were eliminated.

- *Statistic analysis*

Means and standard deviations, frequencies and percentages were determined. The chi-square test, the agreement (kappa), Student's t test and ANOVA were applied. Statistical analysis was performed with the SPSS v19 program. A value of p <0.05 was taken as statistical significance

III.- RESULTS

394 records of patients who were evaluated in the rehabilitation and hand orthopedics consultation were reviewed, of which 45 had the clinical diagnosis of Thoracic Outlet Syndrome and 10 met the inclusion criteria.

The mean age was 36.2 ± 17.22 years, the youngest patient was 18 years old and the oldest 60 years old. 100% (10 cases) were women. The most frequently affected side was the right in 70% (7/10 cases) and 30% was the left side. 100% of the patients had a clinical diagnosis, 9 out of 10 were diagnosed by electromyography and surgically, while only half had an ultrasound diagnosis.

Taking surgical management as the gold standard, it was observed that the clinical diagnosis had 90% of true positives (9/10 cases) and 10% (1/10 cases) of false positives, the ultrasound diagnosis had 50% of true positives (5/10 cases), 0% false positives, 40% (4/10 cases) false negatives and 10% (1/10 cases) true negatives, electrodiagnosis had 80% (8/10 cases)) of true positives, 10% (1/10 cases) of false positives and 10% (1/10 cases) of false negatives without presenting true negative cases.

Table 1 shows the relationship between the surgical finding and the different diagnostic methods used to identify TOS. A greater agreement was observed with the clinical diagnosis and surgical findings, followed by electrodiagnosis and lastly ultrasound. In ultrasound findings, the most frequent diagnosis was the presence of accessory scalene in 40%, followed by arterial compression in 20%, and the rest were negative results.

Table 1. Relationship between the surgical finding and diagnostic methods

Kappa = 0.2		Surgical Findings		
		Positive (n=9)	**Negative (n=1)**	Total (N=10)
DIAGNOSTIC METHOD	Positive clinical	100% (9)	100% (1)	(10)
	Positive ultrasound	55.5% (5)	0	(5)
	Positive electrodiagnosis	88.8% (8)	100% (1)	(9)

Table 2 shows the relationship between the initial latency, maneuvers and post-maneuvers of the median and ulnar nerve with the surgical diagnosis, evaluated in patients with TOS by clinical criteria.

Table 2. Relationship between the difference in latencies of the median and ulnar nerve F wave with the Surgical Diagnosis

	Surgical Diagnosis		
Late answer F	**Positive (n=9)**	**Negative (n=1)**	**P**
Median nerve Latency ms			
Initial (Ms)	25.15 ± 1.91	21.7	0.12
Maneuvers	25.33 ± 1.5	26	0.68
Postmaneuvers	25.52 ± 1.4	29.3	**0.03***
Ulnar nerve Latency ms			
Initial (Ms)	24.7 ± 1.7	23.5	0.52
Maneuvers	28.15 ± 8.3	25	0.72
Postmaneuvers	28.56 ± 8	25	0.68

Table 3 shows the relationship between the initial persistence, maneuvers and post-maneuvers of the median and ulnar nerve with the surgical diagnosis, evaluated in patients with TOS by clinical criteria.

Table 3. Relationship between the difference in persistence of the median and ulnar nerve F wave with the Surgical Diagnosis

	Surgical Diagnosis		
Late answer F	**Positive (n=9)**	**Negative (n=1)**	**P**
Median nerve Persistence%			
Initial (Ms)	78.89 ± 15.35	75	0.81
Maneuvers	60.56 ± 27.62	64	0.90
Postmaneuvers	74.11 ± 16.38	69	0.77
Ulnar nerve Persistence%			
Initial (Ms)	79.76 ± 17.88	62.5	0.38
Maneuvers	59.22 ± 20.76	54	0.81
Postmaneuvers	68.77 ± 18.99	56.2	0.54

Table 4 shows the relationship between the initial latency, maneuvers and post-maneuvers of the median and ulnar nerve with the electrophysiological diagnosis, evaluated in patients with TOS by clinical criteria.

Table 4. Relationship between the differences in latencies of the median and ulnar nerve F wave with the electrophysiological diagnosis

	Diagnóstico Electrofisiológico		
Late answer F	**Positive (n=9)**	**Negative (n=1)**	**P**
Median nerve Latency ms			
Initial (Ms)	24.91 ± 2.21	23.9	0.67
Maneuvers	25.34 ± 1.50	25.9	0.73
Postmaneuvers	26 ± 1.89	25	0.62
Ulnar nerve Latency ms			
Initial (Ms)	24.47 ± 1.72	25.5	0.58
Maneuvers	27.8 ± 8.39	28.2	0.96
Postmaneuvers	28.23 ± 8.13	28	0.97

Table 5 shows the relationship between the initial persistence, maneuvers and post-maneuvers of the median and ulnar nerve with the electrophysiological diagnosis, evaluated in patients with TOS by clinical criteria.

Tabla 5. Relationship between median and ulnar nerve F wave persistence differences with electrophysiological diagnosis

	Electrophysiological diagnosis		
Late answer F	**Positive (n=9)**	**Negative (n=1)**	**P**
Median nerve Persistence%			
Initial (Ms)	78.89 ± 15.35	75	0.81
Maneuvers	58.67 ± 26.72	81	0.45
Postmaneuvers	73 ± 16.34	79	0.73
Ulnar nerve Persistence%			
Initial (Ms)	81.05 ± 15.63	50	0.09
Maneuvers	59.67 ± 20.57	50	0.66
Postmaneuvers	69.46 ± 18.32	50	0.34

IV.- DISCUSSION

In the present study, the relationship between clinical, surgical and neurophysiological findings, specifically of the F wave, in patients with the clinical diagnosis of thoracic outlet syndrome (TOS) was analyzed, the average age of 36.2 years, as well as the under the age of 18 and over 60, agrees with that reported in the literature, where the majority of patients with TOS are between 20 and 50 years of age, less than 5% are adolescents, while 10% are older age 50 years, some type of thoracic outlet syndrome is rarely seen in patients older than 65 years, as well as in pediatric patients [6,7].

In the present study, the relationship between clinical, surgical and neurophysiological findings, specifically of the F wave, in patients with the clinical diagnosis of thoracic outlet syndrome (TOS) was analyzed, the average age of 36.2 years, as well as the under the age of 18 and over 60, agrees with that reported in the literature, where the majority of patients with TOS are between 20 and 50 years of age, less than 5% are adolescents, while 10% are older age 50, some type of thoracic outlet syndrome is rarely seen in patients older than 65 years, as well as in pediatric patients. Akkus et al., (2018), mention that their study is the first report that compares surgical results using electrodiagnostic tests and clinical symptoms (QuickDASH score) in patients with NTOS (Neurogenic Thoracic Outlet Syndrome) [15]. If we take this point of view into account, the results shown in this work indicate that it is a pioneer in Mexico, by making a relationship between clinical, surgical and neurophysiological findings, specifically of the F wave. Among the most relevant is the finding of 100% of clinical concordance, with 90% of the patients diagnosed by electromyography and surgically, while only half were diagnosed by ultrasound. Taking surgical management as the gold standard, it was observed that the clinical diagnosis presented 90% of true positives, in contrast to the electrodiagnosis that showed 80% of true positives. As we have already pointed out in the background, electrodiagnostic techniques are important to examine the degree of neurogenic involvement and localization of the injury site, but there is controversy over the diagnostic value of these tests [16].

Despite the fact that more relevance has been given to surgical findings and diagnostic techniques such as magnetic resonance imaging and ultrasound [17,18]. Electromyography has made promising advances in recent years, as shown by our results regarding the late responses of Wave F. Where the relationship between the surgical finding and the different diagnostic methods used to identify TOS, showed greater concordance with clinical diagnosis and surgical findings, followed by electrodiagnosis and finally ultrasound. In relation to this point, we found in the literature that the use of the routine study of the F wave and the somatosensory evoked potential has limited value. Imaging studies, including ultrasound, MRI, or CT angiography can show pathology in severe cases, but the sensitivity of such tests is low in the early stages [18].

Furthermore, Cuevas-Trisan and Cruz-Jiménez (2003) reported that F wave results can aid in early diagnosis [9]. This makes examination of F wave latencies a useful tool for assessing brachial plexus pathology [19]. This is where we can talk about the importance of electrodiagnosis, since it gives us high reliability in terms of its correlation with surgical findings, which is corroborated by our results on the relationship between the surgical finding and the clinical diagnosis, which was 10 and 20% respectively, while the relationship with ultrasound diagnosis was 10%. On the other hand, the relationship between the surgical finding and the finding of positive cases for ultrasound, evaluated in patients with clinical symptoms of TOS was not significant.

In the literature, some imaging studies have shown high sensitivity and specificity to establish the diagnosis of thoracic outlet syndrome, it is important to mention that these studies, such as Ultrasound-Doplex, are totally dependent on the ability of the person who performs it, ultrasound, at basic element in

the TOS of vascular origin and can also be applied to the TOS of neurogenic origin, with the benefit over MRI due to its low-cost nature and more readily available [7,20,21].

In contrast, our results showed that the relationship between the initial persistence, maneuvers, post-maneuvers and the quantitative parameters of the persistence and latency of the F wave of the median and ulnar nerve with the electrophysiological diagnosis, there is a 90% positive late response in patients with TOS by clinical criteria. In addition, there is an increase in the percentage of the quantitative parameters of the persistence and latency of the F wave in patients.

This confirms that the dynamic F-wave study is a non-invasive and well-tolerated technique that is relatively easy to perform, which can provide additional diagnostic value in the early stages of thoracic outlet syndrome [14]. Therefore, it is worth conducting an early electrodiagnostic study in the Mexican population that presents the first symptoms of TOS.

Based on the results obtained in the present study, we were able to realize that the treatment strategy for TOS is controversial. Conservative treatment (medical treatment and physical therapy) is performed first, followed by surgical treatment. Some studies reported more clinical improvements with surgical treatments compared with conservatively treated patients [22]. In contrast, other investigators found no significant difference in long-term outcomes between operated and non-operated patients. Decompression of TOS has been reported to arrest progression of intrinsic hand muscle atrophy and sensory impairment, but does not reverse these findings [23].

Among the studies carried out for the diagnosis of TOS is Magnetic Resonance, which becomes a very expensive study for patients, in addition to not giving precise results to diagnose this pathology, which leads us to look for another type of studies to reach the diagnosis, such as electrophysiological studies, specifically the dynamic F wave, which has been proposed as an effective auxiliary diagnostic study, demonstrating that it is highly sensitive to subtle changes in its persistence after performing provocative maneuvers, although conventional neurophysiological studies have been normal [24,25].

Clinicians are often in the situation where they have a strong clinical suspicion, despite the variable sensitivity and specificity of the physical signs of thoracic outlet syndrome, but objective findings (such as routine electrodiagnostic parameters) are completely normal. This is a fairly frequent occurrence, which has made several compensation systems somewhat skeptical about the existence of this clinical entity, coining the term neurogenic thoracic outlet syndrome in dispute [9,14].

The present study provides great evidence on the usefulness of early electrodiagnosis for patients with TOS in relation to ultrasound and other techniques that are still very useful, but with the high cost for the patient over time. Within the perspectives of this work, it is proposed to carry out a broader study of files that have electrophysiological data that include the evaluation of the dynamic F wave, with a report of surgical intervention, with a pre-surgical diagnosis of thoracic outlet syndrome and electrophysiological studies performed before surgery.

V.- CONCLUSION

The female sex predominated in the patients, and it was also observed that there is a significant relationship in the latency of the F wave of the Median and Ulnar nerve with the Surgical Diagnosis in post-maneuvers. Although it was not significant in the other parameters, a trend is observed between the results of Wave F with the diagnosis of thoracic outlet syndrome confirmed by surgical procedure

VI.- ETHICAL RESPONSIBILITIES

Protection of people. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of the data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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Conflict of interest: The authors declare that there is no conflict of interest.

VII.- REFERENCES

[1] RM. Peet, Thoracic outlet syndrome: evaluation of a therapeutic exercise program. In Proc Mayo Clin. 1956;31:281-28.

[2] B. Povlsen, T. Hansson, SD. Povlsen, Treatment for thoracic outlet syndrome. Cochrane Database of Systematic Reviews. 2014;11.

[3] AM. Pérez, JDCI. Alfonso, VR. Vázquez, FL. Hernández, JLG. Roig, Evaluación neurofisiológica del síndrome del desfiladero torácico. Revista Cubana de Medicina Física y Rehabilitación. 2017;8(2):167-177.

[4] JT. Feng, Y. Zhu, XY. Hua, Y. Zhu, YD. Gu, JG. Xu, WD. Xu, Diagnosing neurogenic thoracic outlet syndrome with the triple stimulation technique. Clinical Neurophysiology. 2016;127(1):886-891.

[5] M. Bromberg, Brachial plexus syndromes. Internet Site up to Date. 2015.

[6] G. Vercellio, V. Baraldini, C. Gatti, M. Coletti, L. Cipolat, Thoracic outlet syndrome in paediatrics: clinical presentation, surgical

treatment, and outcome in a series of eight children. Journal of pediatric surgery. 2003;*38*(1):58-61.

[7] VR. Salazar, SDPO. Valderrama, MEH. Contreras, BG. Pérez, ADAA. Tristán, MDMG. Méndez, Multidisciplinary management of Paget-Schroetter syndrome. A case series of eight patients. Archivos de Bronconeumología (English Edition). 2015;*51*(8):e41-e43.

[8] T. Smith, W. Trojaborg, Diagnosis of thoracic outlet syndrome: value of sensory and motor conduction studies and quantitative electromyography. Archives of neurology. 1987:*44*(11), 1161-1163.

[9] RL. Cuevas-Trisan, M. Cruz-Jimenez, Provocative F waves may help in the diagnosis of thoracic outlet syndrome: a report of three cases. American journal of physical medicine & rehabilitation. 2003;*82*(9):712-715.

[10] TD. Tolson, "EMG" for thoracic outlet syndrome. Hand clinics. 2004;*20*(1):37-42.

[11] L. Özgönenel, G. Akyüz, B. Özgönenel, T. Adatepe, Provocative F wave in the diagnosis of nonspecific neurogenic-type thoracic outlet syndrome. American journal of physical medicine & rehabilitation. 2012;*91*(4):316-320.

[12] DB. Roos, New concepts of thoracic outlet syndrome that explain etiology, symptoms, diagnosis, and treatment. Vascular Surgery. 1979;13(5):313-321.

[13] LM. Fishman, AN. Wilkins, *Functional electromyography: provocative maneuvers in electrodiagnosis*. Springer Science & Business Media. 2010.

[14] JJ. Luo, F. Bumanlag, Dynamic F-Wave Study Aids In Diagnosis Of Neurogenic Thoracic Outlet Syndrome. SOJ Neurol. 2014;*1*(1):1-3.

[15] M. Akkuş, K. Yağmurlu, M. Özarslan, MYS. Kalani, Surgical outcomes of neurogenic thoracic outlet syndrome based on electrodiagnostic tests and QuickDASH scores. Journal of Clinical Neuroscience. 2018;*58*:75-78.

[16] GM. Franklin, Work-related neurogenic thoracic outlet syndrome: diagnosis and treatment. Physical Medicine and Rehabilitation Clinics. 2015;*26*(3):551-561.

[17] MA. Ferrante, ND. Ferrante, The thoracic outlet syndromes: Part 2. The arterial, venous, neurovascular, and disputed thoracic outlet syndromes. Muscle & nerve. 2017;*56*(4), 663-673.

[18] V. Baute, JA. Strakowski, JW. Reynolds, KR. Karvelas, P. Ehlers, KJ. Brenzy, MS. Cartwright, Neuromuscular ultrasound of the brachial plexus: A standardized approach. Muscle & nerve. 2018;*58*(5):618-624.

[19] SW. Kim, JS. Jeong, BJ. Kim, YH. Choe, YC. Yoon, DH. Sung, Clinical, electrodiagnostic and imaging features of true neurogenic thoracic outlet syndrome: Experience at a tertiary referral center. *Journal of the neurological sciences*. 2019;*404*, 115-123.

[20] CH. Wulff, RW. Gilliatt, F waves in patients with hand wasting caused by a cervical rib and band. Muscle & Nerve: Official Journal of the American Association of Electrodiagnostic Medicine. 1979;*2*(6):452-457.

[21] SJ. Melby, S. Vedantham, VR. Narra, GA. Paletta, L. Khoo-Summers, M. Driskill, RW. Thompson, Comprehensive surgical management of the competitive athlete with effort thrombosis of the subclavian vein (Paget-Schroetter syndrome). Journal of vascular surgery. 2008;*47*(4):809-820.

[22] DA. Axelrod, MC. Proctor, ME. Geisser, RS. Roth, LJ. Greenfield, Outcomes after surgery for thoracic outlet syndrome. Journal of vascular surgery. 2001;*33*(6):1220-1225.

[23] E. Vögelin, L. Haldemann, MA. Constantinescu, A. Gerber, U. Büchler, Long-term outcome analysis of the supraclavicular surgical release for the treatment of thoracic outlet syndrome. Neurosurgery. 2010;*66*(6):1085-1092.

[24] CA. Selmonosky, R. Poblete, El diagnóstico del síndrome del opérculo torácico: Mitos y realidades.Revista chilena de cirugía. 2008;*60*(3):255-261.

[25] R. Thompson, Thoracic outlet syndrome: Neurogenic [Internet]. Ninth Edit. Vol. II, Rutherford's Vascular Surgery and Endovascular Therapy. New York: Elsevier Inc.; 2019