AIM OF THE WORK

The aim of the work is to develop a comprehensive, valid and reliable protocol for evaluation of Arabic speaking patients with acquired apraxia of speech in order to detect the diagnostic features of this ailment for planning the proper management and differentiating it from other disorders.

SUBJECTS

This study was conducted on:

- Fifty six adult patients with expressive aphasia and /or dysarthria who attended the unit of phoniatrics, ENT department, Alexandria University to detect any apraxic elements by the proposed protocol.
- One hundred healthy adult subjects as a control group were evaluated by the proposed protocol of apraxia assessment to determine the validity and reliability of the test. These subjects had no history of language or speech disorders and no history of neurological insults.
- A pilot study was conducted on twenty healthy individuals and fifteen patients with expressive aphasia and or dysarthria to modify the proposed protocol of apraxia assessment.

Selection criteria for the patients group:

- Adults of both sexes aged 18 years and above with expressive aphasia and or dysarthria.
- History of speech and or language affection starting after incidence of neurological insult.

Selection criteria for the control group:

- Adults of both sexes aged 18 years and above.
- Absence of previous history of neurological insults, speech and or language deterioration.
- No evidence of current communicative difficulty.

Exclusion criteria:

Patients with communication problem due to sensory deficits (hearing or visual impairment), psychiatric disorder and receptive aphasia were excluded.

METHODS

Each subject was subjected to the apraxia evaluation protocol which consists of three procedures to detect the presence of apraxia of speech, aphasia and dysarthria and to determine the type of dysarthria and dysphasia if present.

This protocol consisted of:

• Elementary diagnostic procedures:

- Complete history taking (personal data–complaint and analysis of symptoms–history of present illness-past history of similar episodes and relevant diseases).

- Complete clinical examination including general examination, ENT examination and complete neurological examination.

• Clinical diagnostic aids:

- Auditory perceptual assessment was done in order to assess the patient speech and voice characteristics to detect any abnormalities and to determine the presence of dysphasic, dysarthric, and or apraxic characteristics. The patients group was subdivided into apraxic patients and non apraxic patients (patients with dysarthria and or aphasia without apraxia) according to presence or absence of these apraxic characteristics which include:
  - Effortful trial and error groping with attempts at self correction.
  - Visible/audible searching.
  - Marked difficulty initiating speech.
  - Errors are highly inconsistent.
  - Abnormal prosodic features (including equalized and difficult varying stress, restricted or altered pitch ,durational and loudness contour and slow rate)
  - Awareness of errors and inability to correct them.
  - Fewer errors with automatic speech than volitional speech.
  - Errors increase as phonemic sequence increases.
  - Phonemic anticipatory errors.
  - Phonemic perseverative errors.
  - Phonemic transposition errors.
  - Phonemic voicing errors.
  - Phonemic vowel errors.
  - Intrudes schwa sound between syllables or in consonant clusters.[11]

- Formal testing:

  a. Detection of any associated dysphasia element and diagnose its type by Modified scoring system for testing language disability in dysphasic patients.[56]
  b. Arabic articulation test to detect any pattern of misarticulation.[75]
  c. Apraxia Battery for adult II was applied after translation and modifications which was based on the results of pilot study. Validity and reliability of the test was assessed. [5]

- Evaluation of cognitive and perceptual abilities using :

  a. Stanford Binet intelligent scale: To assess intelligence quotient.[76]
  b. Test of non verbal intelligence (TONI)[77]
  c. Taylor test of anxiety: To detect any elements of anxiety.

- Visualization and documentation of the glottis and velopharyngeal valve using Kaypentax fibroptic naso-pharyngo-laryngoscopy model RLS 9100 B.

• Additional instrumental tools:

- Acoustic analysis (MDVP): Using Kay CSL model 4500. The patient sits comfortably infront of the microphone 10 cm distance and the patient asked to say /a/ to obtain perturbation measures as jitter and shimmer percent.

- Spectral analysis of patient speech: Using Kay CSL model 4500. The patient sits comfortably infront of the microphone 10 cm distance repeating after the examiner the word /teen/ and the sentence /wald beyakl tofaha/. The data obtained by visual calculations, the following data were studied:

  - Voice onset time is measured for the plosives /t/ in /teen/.
  - Vowel duration for the vowel in /teen/
  - Syllable duration for the syllable /t e/ in /teen/
  - Sentence duration.

- Nasometric analysis: Using Kay Nasometer II model 6450 to record nasalance score of oral sentence /ali rah jel ʕb kura/ and nasal sentence /mama betnayem manal/.

- Aerodynamic measures: It was done using the voice function analyzer Aerophone II model 6800 to obtain the following data:

  - Vital capacity: by asking the patient to take deep breath and then give maximum expiration into the mouth piece.
  - Mean flow rate: it is measured by asking the patient to say /ipipi/into the mask with a tiny tube in the patient mouth connected to pressure transducer.

- Brain imaging (CT – MRI) to detect the possible etiological factors and to determine the site of the lesion.

Control group was also evaluated by the above protocol to yield cutoff scores and to test the validity of the test and its ability to differentiate between those with normal speech and apraxic patients. The control group was also used to obtain normative data for acoustic analysis, spectral analysis, nasometric and aerodynamic measures to be compared with the results of apraxic patients.

An informed consent was taken from all participants in the study.

Test materials

Apraxia Battery for Adults II consists of examiner record form and a picture book containing pictures for subtest four and five, and action picture for spontaneous speech and the reading passage for subtest six.

Test description

Apraxia Battery for Adults - second edition (ABA II) was designed to verify the presence of apraxia in adult patients and to estimate the severity of the disorder. [5]

It consists of six subtests which are:

Subtest 1: Diadochokinetic Rate.

This measures volitional control over the articulators.
In this item the examinee repeats one, two and three – syllable combinations as quickly as possible within a given time limit.

Subtest 2: Increasing word length (part A, B)

This measures the ability to sequence the correct number of syllables in the proper order. The examinee repeats similar words that increase in number of syllables.

Subtest 3: Limb apraxia and oral apraxia.

This subtest measures the ability to produce a movement based on an oral direction. It consists of two parts:

In part A, limb apraxia, the examiner gives the examinee 10 oral directions requiring the use of the arms and hands (e.g. make a fist)

In part B, oral apraxia, the examiner gives the examinee 10 oral directions for volitional manipulation of the oral structures (e.g. stick out your tongue)

Subtest 4: Latency time and utterance time for polysyllabic words.

This measures the amount of time it takes to begin initiation of a word and the amount of time it takes to produce the word once initiation begins. The examinee is asked to name 10 objects presented in picture form. The examiner uses only the utterance time score to determine the severity of apraxia.

Subtest 5: Repeated trials.

This subtest measures change in production of words over successive trials. The examinee is asked to repeat 10 polysyllabic words (e.g. telephone) three times each.

Subtest 6: Inventory of articulation characteristics of apraxia.

The examinee engages in three types of speech behaviors: Spontaneous speech, reading and automatic speech. This subtest measures the presence of apraxic speech behaviors in each of these types of speech. This subtest is used for treatment purposes only.

The administration time of ABA II is about 20 minutes. Some examinees may respond slowly and require considerably more than 20 minutes completing the battery of six subtests. The responses are timed only on subtest 1: Diadochokinetic Rate and subtest 4: Latency Time and Utterance Time for Polysyllabic words. For the remainder, the examinee can be given as much time to complete the test as the examiner considers desirable and feasible.

In scoring of the test, the ABA results are recorded as raw scores except for subtest 6 (inventory of articulation characteristics of apraxia) which is used for treatment purposes only.

Modifications of Apraxia Battery for Adults II:

The original ABA II is not suitable to be applied to Arabic speaking patients due to lingual and cultural differences. So it has been subjected to translation and modification to suit the Egyptian culture and environment and to overcome the differences in the language structure between English and Arabic language. These modifications were done based on the results of pilot study. It was done on twenty control and fifteen patients to check the suitability and clarity of the test materials for Arabic speaking subjects.

Most changes were done in the word lists of subtest 2 (Increasing word length A, B). They were changed to more suitable Arabic words which are progressively increasing in the number of syllables. Word lists and pictures of subtest 4 and 5 (utterance time for polysyllabic words and repeated trials) were changed to more suitable Arabic multisyllabic words. In subtest 6 (inventory of articulation characteristics of apraxia), the reading passage was changed to a more clear one showed a lot of prosodic variations. Direct linguistic translation was avoided because of the difference in the critical phonemic structure between English and Arabic language with taking in consideration the complexity and increased syllables in the test items to be more suitable and easily elicit the apraxic speech behaviors.

These modifications considered the original aim and the level of difficulty of the modified item, and these will be demonstrated in appendix (1 and 2).

Statistical analysis of the data

After data were collected it was revised, coded and fed to statistical software IBM SPSS version 20. The given graphs were constructed using Microsoft excel software. All statistical analysis was done using two tailed tests and alpha error of 0.05. The following statistical tests were used:

A. Descriptive statistics: It included the mean with standard deviation and percent to describe the scale and categorical data, respectively while median was used for skewed data.

B. Analysis of numerical data:

a. **One Way ANOVA**: It is a parametric statistical test that used to compare the means for quantitative data of more than two independent groups which follow a normal distribution.

b. **Man Whitney test:** A procedure compares ranks (medians) for two independent groups of cases. Ideally, for this test, the subjects should be randomly assigned to two groups. It is like t-test but with skewed data.

C. Analysis of categorical data: Using Mont Carlo exact test and Fishers exact test. They are alternatives for the Pearson's chi square test if there were many small expected values.

D. Correlation analysis: Correlation is used to test the nature and strength of relation between two quantitative / ordinal variables. The spearman correlation co efficient (rho) is expressed as the Pearson co efficient. The sign of the co efficient indicates the nature of relation (positive / negative) while the value indicates the strength of relation as follow: Weak correlation for rho less than 0.25, intermediate correlation for rho of value between 0.25-0.74 and strong correlation for values between 0.75-0.99.

E. Reliability analysis: Alpha Cronbach's was calculated for each scale to test for the internal consistency of the scale items which ranged from 0.746 - 0.937. If Alpha Cronbach's is $0.7 \leq \alpha < 0.8$, this means acceptable inter correlation. When it is $0.8 \leq \alpha < 0.9$, this means good inter correlation. If it is ≥ 0.9, this means excellent inter correlation.

F. ROC curve: ROC curve is a graphical plot that illustrates the performance of a binary classifier system (Apraxic and non Apraxic) or (case and normal) as its discrimination threshold is varied. The curve is created by plotting the true positive rate against the false positive rate at various threshold settings. Area under curve is a method to test whether the used test is discriminatory or not (if area >0.5).

RESULTS

This study was conducted at the Unit of Phoniatrics, Faculty of Medicine, Alexandria Main University Hospitals, through the period between April 2013 and October 2014.

The results of the present study will be presented in the following order:

1. Pilot study.

2. Demographic Data of the studied groups:
   - Age.
   - Gender.
   - Educational level.
   - Handedness.

3. Characters of the patients group:
   - Diagnosis of the patient's condition.
   - Presence of speech apraxia.
   - Duration of the condition in months.
   - Cause of the neurological insult.
   - Determination of the site of the lesion.
   - Description of clinical features of patients with AOS.

4. Performance of the apraxic patient group on psychometric tests, fibroptic naso-pharyngo-laryngoscopy, MDVP, nasometer, CSL and aerodynamics studies.

5. Test result analysis.

   - Reliability.
   - Validity.
   - Comparison between performance of the Egyptian sample and English sample on ABA II.
   - Sensitivity and specificity.

1. Pilot study:

A pilot study was conducted on twenty healthy individual and fifteen patients with expressive aphasia and or dysarthria with ages from 18 to 76 years, they were randomly chosen.

The test was applied on them after translation and modification to check clarity and suitability of the materials used, and to check the pattern and order of presentation of the test items.

2. Demographic distribution of the studied groups:

The subjects in this study were divided into two groups: 100 normal controls and 56 aphasic (expressive affection) and or dysarthric patients.

The following table illustrates apraxia of speech distribution among the patient group depending on the presence of apraxic features in the patient's speech. It shows that apraxic patients constituted 37.5 % (21 cases) of the patient group while non apraxic patients constituted 62.5 % (35 cases).

Table (2): Apraxia of speech distribution among the patient group (n= 56).

Apraxia of speech	Number	Percent (%)
None apraxic patients	35	62.5%
Apraxic patients	21	37.5%

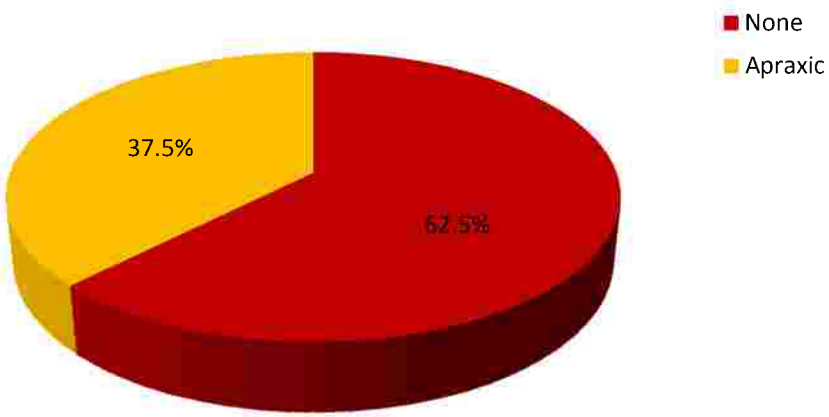

Figure (1): Apraxia of speech distribution among the patient group.

The demographic distribution of the studied sample:

I. Age:

The age in the control and patient group ranged from 18 – 76 years, they were classified into two groups:

I. From 18 to 45 years.

II. Above 46 years.

Statistically, no significant difference between patients (both apraxic and non apraxic) and control group was found (p – value = 0.779).

Table (3): Age distribution among the three groups.

Demographic data	Patients(n=56)				Normal(n=100)		*p*
	Apraxic(n=21)		Non-Apraxic(n=35)				
	No	%	No	%	No	%	
Age							
▪ 18-45	9	42.9	12	34.3	40	40.0	0.779
▪ 46-76	12	57.1	23	65.7	60	60.0	
Min- Max.	18.0-76.0		24.0- 66.0		23.0 - 68.0		
Mean ± SD	47.5 ± 15.7		48.7 ± 12.5		48.0 ± 13.5		

P value based on Mont Carlo exact probability

II. Gender:

- Males group constituted 12 individuals (57.1 %) of apraxic patients, 27 individuals (77.1%) of non apraxic patients and 55 individuals (55%) of the control group.
- Females constituted 9 individuals (42.9 %) of apraxic patients, 8 individuals (22.9 %) of non apraxic patients and 45 individuals (45 %) of the controls.

By testing the difference in gender distribution between the groups, p value = 0.067 which is statistically insignificant.

Table (4): Gender distribution among the three groups.

Demographic data	Patients(n=56)				Normal(n=100)		*P*
	Apraxic(n=21)		Non-Apraxic(n=35)				
	No	%	No	%	No	%	
Sex							
▪ Male	12	57.1	27	77.1	55	55.0	0.067
▪ Female	9	42.9	8	22.9	45	45.0	

P value based on Mont Carlo exact probability

III. Educational level:

The sample represents three groups according to educational level:

- Illiterate group.
- Middle education: from primary school to secondary education.
- High education: university and above.

Illiterate patients constituted 19 % of apraxic patients and 22.9 % of non apraxic patients. Patients with middle education constituted 52.4 % of apraxic patients and 65.7 % of non apraxic patients. Patients with high education constituted 28.6 % of apraxic patients and 11.4% of non apraxic patients.

By testing the difference of results between these two groups, p value = 0.268 which is statistically insignificant.

Table (5): Educational levels among the two groups (apraxic and non apraxic).

Demographic data	Patients(n=56)				*P*
	Apraxic(n=21)		Non-Apraxic(n=35)		
	No	%	No	%	
Educational level					
▪ Illiterate	4	19.0	8	22.9	0.268
▪ Middle	11	52.4	23	65.7	
▪ High	6	28.6	4	11.4	

P value based on Mont Carlo exact probability

IV. Handedness:

Table (6) shows distribution of the patients group according to handedness. Right handed constituted 21 cases (100%) of apraxic cases and 34 cases (97.1%) of non apraxic group.

By testing the difference in handedness distribution between the apraxic and non apraxic groups p value = 0.747 which is statistically insignificant.

Table (6): Distribution of the apraxic and non apraxic group according to handedness

Demographic data	Patients (n=56)				*P*
	Apraxic (n=21)		Non-Apraxic (n=35)		
	No	%	No	%	
Handedness					
▪ Right	21	100.0	34	97.1	0.747
▪ Left	0	0.0	1	2.9	

3. Characters of the patients group:

• Diagnosis of the patient's condition:

Table (7) shows distribution of the patients according to the clinical diagnosis which divided into:

- Expressive aphasia: It constituted 20 patients (35.7 %) of the patient group.
- Dysarthria: It constituted 27 patients (48.3 %) of the patient group.
- Expressive dysphasia and spastic dysarthria: It constituted 5 patients (8.9 %) of the patient group.
- Expressive dysphasia and UMN dysarthria: It constituted 4 patients (7.1%) of the patient group.

Table (7): Distribution of the patients (n=56) according to the clinical diagnosis.

Diagnosis	**Number**	**percent**
Expressive aphasia	20	35.7 %
Dysarthria:	27	48.3 %
- Spastic dysarthria	13	23.2%
- UMN dysarthria	11	19.6 %
- Mixed dysarthria	1	1.8 %
- Ataxic dysarthria	1	1.8 %
- Flaccid dysarthria	1	1.8 %
Expressive dysphasia and spastic dysarthria	5	8.9 %
Expressive dysphasia and UMN dysarthria	4	7.1 %

Table (8) shows the distribution of AOS among the patients group. Thirteen apraxic patients (61.9 %) had expressive aphasia. Four apraxic patients (19 %) had expressive aphasia and spastic dysarthria while only two apraxic patients (9.5 %) had spastic dysarthria. So expressive aphasia (either isolated or associated with dysarthria) was present in 18 patients (85.7 %) of apraxic patients. Dysarthria (either isolated or associated with expressive aphasia) was present in 8 patients (38%) of apraxic patients.

Table (8): Distribution of the apraxic and non apraxic patients according to the diagnosis.

Diagnosis	None apraxic(n=35)		Apraxic(n=21)	
	No	%	No	%
Expressive aphasia	7	20	13	61.9
Spastic dysarthria	11	31.4	2	9.5
UMN dysarthria	10	28.5	1	4.8
Mixed dysarthria	1	2.9	0	0.0
Ataxic dysarthria	1	2.9	0	0.0
Flaccid dysarthria	1	2.9	0	0.0
Expressive dysphasia and spastic dysarthria	1	2.9	4	19
Expressive dysphasia and UMN dysarthria	3	8.5	1	4.8

- **Duration of the condition in months.**

Duration of the disease ranged from 2 months to 30 months with a mean of 6 months.

- **Cause of the neurological insult.**

Table (9) shows distribution of the patients according to the cause of the neurological insult. The cause divided into:

- Vascular: It constituted 82.2% of the cause; it is either brain hemorrhage or non hemorrhagic infarction (thromboembolic).
- Trauma: Head trauma (falling from height) constituted 5.4 % of the causes.
- Multiple sclerosis: It constituted 7.1% of the causes.
- Others as brain tumors (1.8 %), motor neuron disease (1.8 %) and brain infection (1.8 %).

While the cause among the patients with AOS divided into:

- Vascular: It constituted 90.4% of the cause; it is either brain hemorrhage or non hemorrhagic infarction.
- Other causes as head trauma (4.8 %) and brain infection (4.8 %).

Table (9): Distribution of the patients according to the cause.

Cause	The patient group (n=56)		Apraxic patients (n=21)	
	No	Percent	No	Percent
Non hemorrhagic infarction	44	78.6	18	85.7
Brain hemorrhage	2	3.6	1	4.8
Multiple sclerosis	4	7.1	0	0.0
Trauma	3	5.4	1	4.8
Tumor	1	1.8	0	0.0
Motor neuron disease	1	1.8	0	0.0
Infection	1	1.8	1	4.8

- **Determination of the site of the lesion**

CT and MRI showed the different locations of the neurological insult that caused AOS. It revealed that left inferior frontal gyrus (Broca's area) alone constituted the most frequent site affected which represents 42.9 % among the apraxic patients. This can be explained in the following table.

Table (10): Site of lesion in apraxic patients (n=21).

Site of lesion	Number	Percent
Left inferior frontal gyrus	9	42.9 %
Left temproparietal region	4	19 %
Left frontoparietal (insula) and left temproparietal region	3	14 %
Left parietal lobe	3	14 %
Left frontoparietal (insula) cortical and subcortical and basal ganglia	1	4.8 %
Left inferior frontal gyrus and frontopariatal area(insula)	1	4.8 %

- **Description of clinical features of patients with AOS.**

Diagnosis of AOS depends on the presence of various speech behaviors. These apraxic features can be summarized in the following table.

Table (11): Description of clinical features of patients with AOS.

Speech behaviors	Patients with AOS (n=21)	
	N0	Percent (%)
Effortful trial and error groping with attempts at self correction.	19	90 %
Visible/audible searching.	20	95 %
Errors are highly inconsistent.	20	95 %
Marked difficulty initiating speech.	19	90 %
Abnormal prosodic features (including equalized and difficult varying stress, restricted or altered pitch ,durational and loudness contour and slow rate)	18	85 %
Awareness of errors and inability to correct them.	18	85 %
Fewer errors with automatic speech than volitional speech.	19	90 %
Errors increase as phonemic sequence increases.	19	90 %
Phonemic anticipatory errors.	4	19 %
Phonemic perseverative errors.	5	23 %
Phonemic transposition errors.	13	61 %
Phonemic voicing errors.	3	14 %
Phonemic vowel errors.	2	9 %
Intrudes schwa sound between syllables or in consonant clusters.	6	28 %

From Wambaugh et al (2006) [11]

4. Performance of the apraxic patient group on psychometric tests, fibroptic naso-pharyngo-laryngoscopy, MDVP, aerodynamics, nasometer and CSL studies:

▪ Performance of the patient group on psychometric tests.

Tables (12, 13, 14) show distribution of the patients according to the psychometric results which included:

- Stanford Binet scale: This included verbal, abstract and general IQ.
- TONI. - Taylor test of Anxiety.

By testing the difference in psychometric results between the apraxic and non apraxic groups, p value was statistically insignificant. There was no difference in performance on these psychometric tests between the two groups. It was found that verbal I Q was markedly affected especially among the apraxic patients (no one had average or below average verbal IQ while 23.8 % of apraxic patients were non testable).

Table (12): Distribution of the patients group according to Stanford Binet results.

IQ	None apraxic(n=35)		Apraxic(n=21)		P
	No	%	No	%	
Verbal IQ					
▪ Average	4	11.4	0	0.0	
▪ Below average	3	8.6	0	0.0	
▪ Slow learner	6	17.1	2	9.5	0.102
▪ Mild	14	40.0	8	38.1	
▪ Moderate	3	8.6	1	4.8	
▪ Severe	2	5.7	5	23.8	
▪ Non testable	3	8.6	5	23.8	
Abstract IQ					
▪ Average	1	2.9	2	9.5	
▪ Below average	8	22.9	5	23.8	
▪ Slow learner	15	42.9	9	42.9	0.715
▪ Mild	11	31.4	5	23.8	
▪ Moderate	-	-	-	-	
▪ Severe	-	-	-	-	
General IQ					
▪ Average	1	2.9	1	4.8	
▪ Below average	4	11.4	3	14.3	
▪ Slow learner	13	37.1	4	19.0	
▪ Mild	16	45.7	11	52.4	0.584
▪ Moderate	1	2.9	2	9.5	
▪ Severe	-	-	-	-	

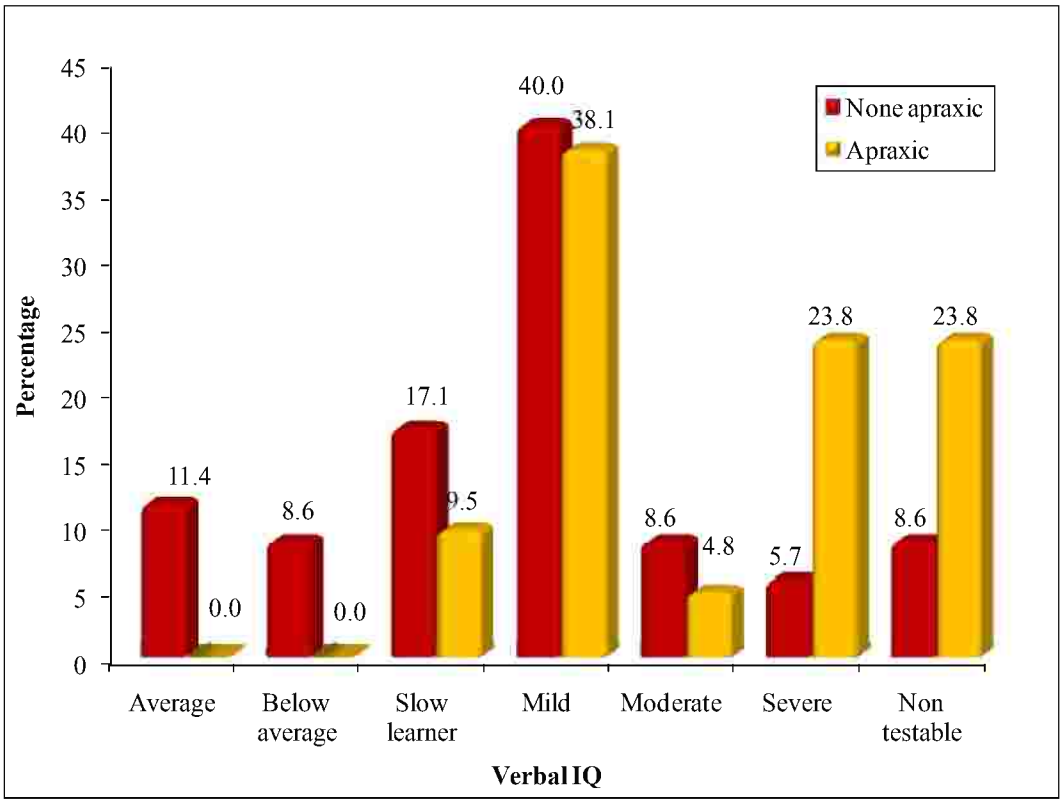

Figure (2): Distribution of the patients group according to Stanford Binet results

Table (13): Distribution of the patients group according to TONI results:

TONI	None apraxic(n=35)		Apraxic(n=21)		P
	No	%	No	%	
▪ Average	0	0.0	2	9.5	
▪ Below average	8	22.9	4	19.0	0.316
▪ Slow learner	17	48.6	10	47.6	
▪ Mild	10	28.6	5	23.8	
▪ Moderate	-	-	-	-	
▪ Severe	-	-	-	-	

P value based on Mont Carlo exact probability

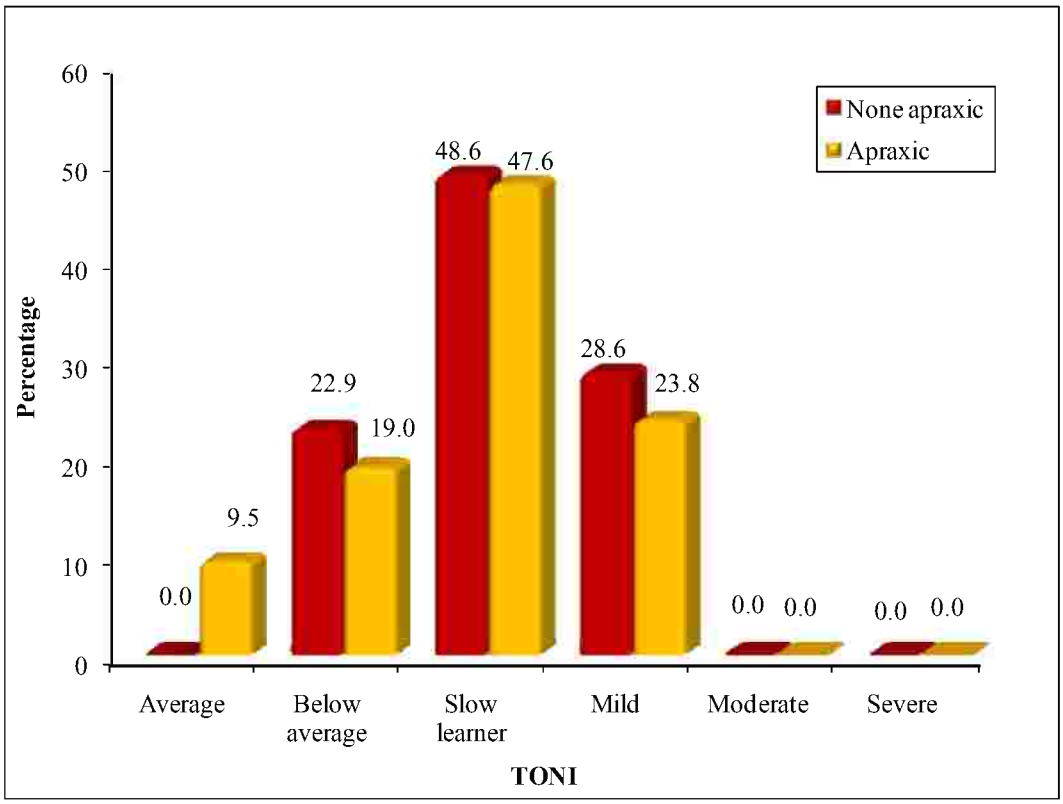

Figure (3): Distribution of the patients group according to TONI results

Evaluation of the patients with Taylor test of anxiety revealed that 52.4 % of apraxic patients showed no anxiety while 23.8 % of these patients had severe degree of anxiety.

Table (14): Distribution of the patients group according to Taylor test of anxiety results

Taylor test of anxiety	Patients(n=56)				*P*
	None(n=35)		Apraxic(n=21)		
	No	%	No	%	
No anxiety	13	37.1	11	52.4	0.441
Mild	10	28.6	3	14.3	
Moderate	6	17.1	2	9.5	
Severe	6	17.1	5	23.8	

P value based on Mont Carlo exact probability

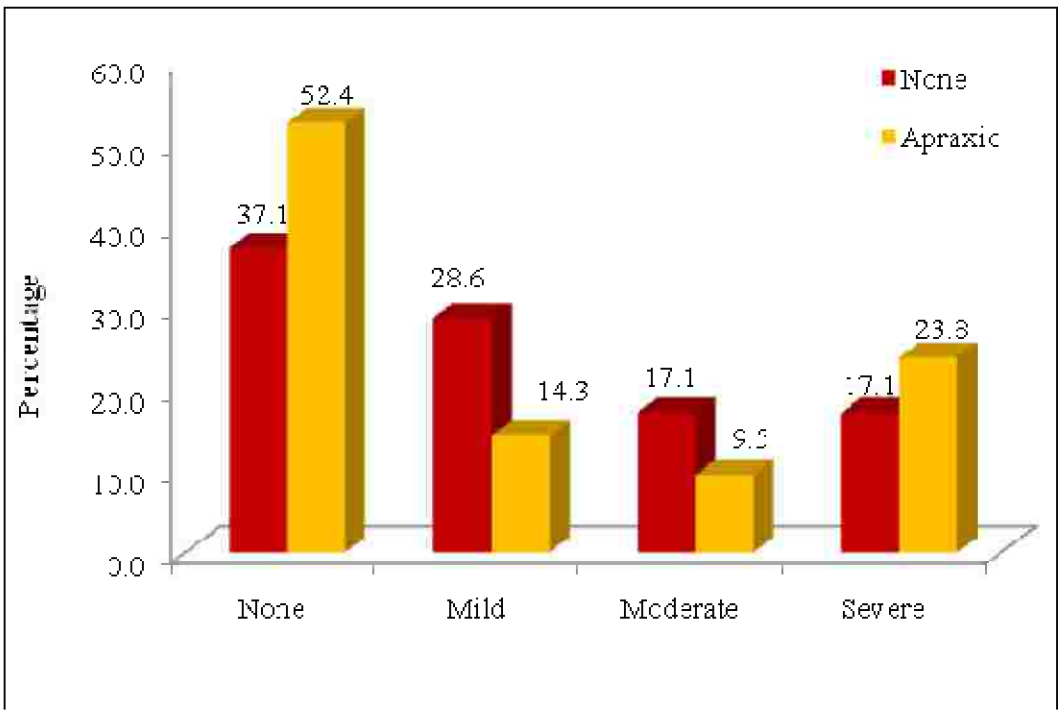

Figure (4): Distribution of the patients group according to Taylor test of anxiety results.

- **Performance of the apraxic patient group on fibroptic naso-pharyngo-laryngoscopy:**

The results of fibroptic naso-pharyngo-laryngoscope were insignificant as there were one apraxic patient only had unilateral vocal fold immobility and other one had velopharyngeal incompetence. Both two cases had spastic dysarthria in addition to AOS that can reflect unremarkable effect of AOS on phonation and resonance.

- **Performance of the apraxic patient group on MDVP, nasometer, aerodynamics and CSL studies:**

Table (15) shows distribution of the patients according to the performance on MDVP, nasometer and aerodynamics studies which included:

- Comparison of perturbation of pitch (Jitter percent) and perturbation of loudness (shim percent) between apraxic patients and control group.
- Comparison of nasal and oral sentence scores between apraxic and control.
- Comparison of vital capacity (VC) and mean flow rate (MFR) between apraxic patients and control.

By testing the difference in MDVP, nasometer results and aerodynamics parameters between the apraxic patients and control, p value was statistically significant for jitter percent, shimmer percent and mean flow rate. This result may be due to associated dysarthria that can affect all speech components.

Table (15): Distribution of the apraxic patients according to the performance on MDVP, nasometer and aerodynamics studies:

Item	Apraxic (n=21)		Control (100)		P
	Mean	SD	Mean	SD	
Jitt (%)	1.46	1.11	0.39	0.17	0.001*
Shim (%)	4.16	1.87	0.32	0.15	0.000*
Oral sentence (%)	29.06	14.19	24.68	14.74	0.872
Nasal sentence (%)	60.66	11.10	61.72	7.06	0.141
VC (in Litre)	4.38	2.82	4.61	0.58	0.596
MFR (L/ sec)	0.07	0.05	0.17	0.08	0.012*

P: P value for Mann-Whitney test

* $P < 0.05$ (significant)

Distribution of the patients according to CSL results which included:

- Voice onset time.
- Vowel duration.
- Syllable duration.
- Sentence duration.

By testing the difference in CSL results between the apraxic patients and control group, p value was statistically significant for vowel duration, syllable duration, and sentence duration

Table (16): Distribution of the apraxic patients according to CSL results.

Item	Apraxic(n=21)		Control(n=100)		P
	Mean	SD	Mean	SD	
Voice onset time (sec)	0.104	0.134	0.056	0.021	0.309
Vowel duration (sec)	0.352	0.119	0.195	0.070	0.000*
Syllable duration(sec)	0.468	0.177	0.257	0.077	0.000*
Sentence duration (sec)	2.548	0.618	1.043	0.195	0.000*

P: P value for Mann-Whitney test

* $P < 0.001$ (significant)

5. Test result analysis:

- **Reliability**:

This was tested by internal consistency reliability using reliability coefficient alpha (Cronbach's alpha)

The high values of alpha in all test items (0.746 - 0.937) denote inter correlation between test items.

Table (17): Reliability coefficient (alpha) values of various test items.

Item	α-Cronbach's
Diadochokinetic rate	0.812**
Increasing word length (part A)	0.805**
Increasing word length (part B)	0.830**
Limb Apraxia	0.914***
Oral Apraxia	0.889**
Utterance time for polysyllabic words	0.746*
Repeated trials	0.937***
Inventory of articulation characteristics of Apraxia	0.884**

*Acceptable: $0.7 \leq \alpha < 0.8$
**Good: $0.8 \leq \alpha < 0.9$
***Excellent: $\alpha \geq 0.9$

- **Validity:**

It was measured using content validity, Concurrent validity, group differentiation.

I. **Content validity (expert opinion):** Experts (5 phoniatricians) examined the content validity relying on the concept tested by each subtest and its aim. They checked that the test included all relevant and important items and excluded irrelevant ones.

II. **Concurrent validity:** Correlation matrix between different items of the test was performed and there was significant correlation between test items. The results are shown in table (18)

Table (18): Correlation between different test items.

	Diadochokinetic rate	Increasing word length (part A)	Increasing word length (part B)	Limb Apraxia	Oral Apraxia	utterance time for polysyllabic words	Repeated trials
Diadochokinetic rate	1						
Increasing word length (part A)	-0.509*	1					
Increasing word length (part B)	-0.538*	0.899*	1				
Limb Apraxia	0.332*	-0.274*	-0.241*	1			
Oral Apraxia	0.579*	-0.478*	-0.483*	0.616*	1		
utterance time for polysyllabic words	-0.672*	0.725*	0.764*	-0.313*	-0.602*	1	
Repeated trials	0.619*	-0.713*	-0.674*	0.143	0.449*	-0.681*	1
Inventory of articulation characteristics of Apraxia	-0.628*	0.734*	0.801*	-0.163	-0.476*	0.768*	-0.821*

*: significant correlation co-efficient

III. Group differentiation:

Comparison of the test results between apraxic patient, non apraxic patients (dysarthric or aphasic) and control is showed in table (19).

Statistically significant differences were found using ANOVA test, between scores of all test items among these groups.

Table (19): Comparison of the test results between apraxic patient, non apraxic patients (dysarthric or aphasic) and control.

Test items	Groups								P
	Normal(100)		Apraxia(21)		Aphasia(11)		Dysarthria(24)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Diadochokinetic rate	27.5	3.3	11.9	6.5	21.0	4.9	19.6	5.3	0.000*
Increasing word length (part A)	0.0	0.0	3.0	2.4	0.0	0.0	0.0	0.0	0.000*
Increasing word length (part B)	0.0	0.0	3.4	2.1	0.0	0.0	0.1	0.4	0.000*
Limb Apraxia	49.4	0.8	47.7	3.2	48.6	1.5	49.6	0.8	0.000*
Oral Apraxia	49.8	0.6	45.1	5.2	48.4	1.6	49.1	1.4	0.000*
Utterance time for polysyllabic words	10.0	0.0	41.9	25.6	21.5	16.5	11.1	2.5	0.000*
Repeated trials	30.0	0.0	20.3	7.3	28.9	1.0	28.4	3.1	0.000*
Inventory of articulation characteristics of Apraxia	0.0	0.0	9.9	2.3	0.6	0.5	0.7	0.9	0.000*

P: P value based on One Way ANOVA
* $P < 0.001$ (significant)

Comparison between performance of the Egyptian sample and English sample on ABA II.

Statistically insignificant differences were found between scores of all test items of the Egyptian and English sample, this is shown in table (20). In English sample there were 40 apraxic patients, 7 dysarthric, 5 aphasic and 49 normal individuals.

Table (20): Comparison between performance of the Egyptian sample (Arabic) and English sample on ABA II.

Test items	Normal		Apraxia		Aphasia		Dysarthria	
	Arabic	*English*	Arabic	*English*	Arabic	*English*	Arabic	*English*
Diadochokinetic rate Mean± SD	27.5±3.3	36.1±10.2	11.9±6.5	9.3±8.6	21.0±4.9	20.8±3.0	19.6±5.3	28.4±9.5
P	0.087		0.271		0.938		0.173	
Increasing word length (partA) Mean± SD	0.0±0.0	0.06±0.24	3.0±2.4	3.9±3.9	0.0±0.0	3.0±3.7	0.0±0.0	0.43±0.79
P	0.365		0.547		0.857		0.528	
Increasing word length (part B) Mean± SD	0.0±0.0	0.14±0.65	3.4±2.1	2.0±3.5	0.0±0.0	0.4±1.5	0.1±0.4	0.83±2.3
P	0.185		0.263		0.475		0.847	
Limb Apraxia Mean± SD	49.4±0.8	49.6±2.1	47.7±3.2	33.7±12.6	48.6±1.5	44.6±12.1	49.6±0.8	46.4±7.2
P	0.658		0.425		0.663		0.783	
Oral Apraxia Mean± SD	49.8±0.6	49.8±1.2	45.1±5.2	32.3±13.3	48.4±1.6	42.0±12.0	49.1±1.4	47.1±4.5
P	0.869		0.478		0.480		0.884	
utterance time for polysyllabic words Mean± SD	10.0±0.0	9.3±5.1	41.9±25.6	53.3±32.2	21.5±16.5	24.6±30.9	11.1±2.5	15.0±8.0
P	0.514		0.385		0.639		0.685	
Repeated trials Mean± SD	30.0±0.0	29.9±0.5	20.3±7.3	14.9±10.5	28.9±1.0	24.0±8.9	28.4±3.1	24.4±5.3
P	0.687		0.518		0.473		0.756	
Inventory of articulation characteristics of Apraxia Mean± SD	0.0±0.0	0.24±0.88	9.9±2.3	10.0±3.5	0.6±0.5	4.3±5.3	0.7±0.9	4.4±4.3
P	0.207		0.886		0.207		0.261	

P: P value based on One Way ANOVA

• Sensitivity and specificity:

The (ROC) curves with the areas under the curves (AUC) and their statistical significance were used as an indicator for scale and subscale performances. Statistically significant AUCs denoted performances better than chance (AUC=0.50). The greater the AUC the better was the performance with a maximum AUC of 1.00 denoting a gold standard like performance.

Identification of the cutoff values for diagnosis was applied just for statistically significant AUCs where the value that maximized both sensitivity and specificity of the scale was chosen. Values above or equal to the identified cutoff values denote being a case. The (ROC) curve was used to obtain cutoff values for the proposed test. The following tables and figures show the ROC curve of various test items.

Table (21): The ROC curve details of the test item 1(Diadochokinetic rate).

Area Under the Curve Test Result Variable(s): Diadochokinetic rate				
Area under the curve	**Standard Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.952	0.016	0.000	0.920	0.984

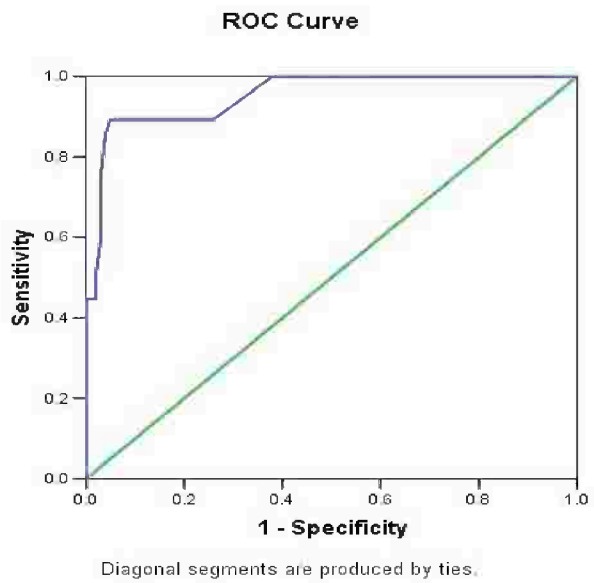

Figure (5): The ROC curves of test item 1(Diadochokinetic rate).

Table (22): The ROC curve details of the test item 2: Increased word length (Part A).

Area Under the Curve Test Result Variable(s): Increasing word length (part A)				
Area	**Standard Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.670	0.049	0.000	0.574	0.765

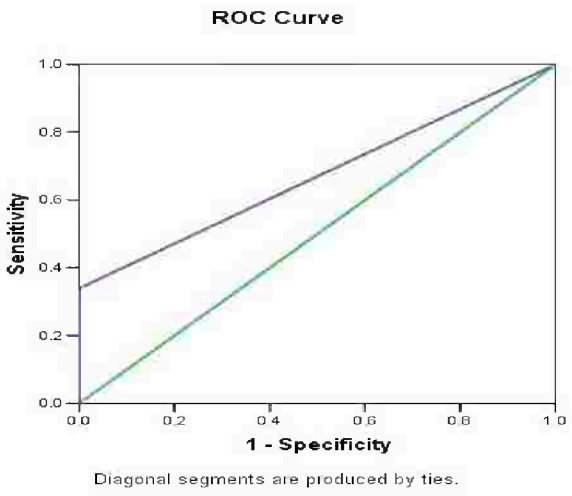

Figure (6): The ROC curves of test item 2: Increased word length (Part A).

Table (23): The ROC curve details of the test item 2: Increased word length (Part B).

Area Under the Curve Test Result Variable(s): Increasing word length (part B)				
Area	**Standard Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.705	0.048	0.000	0.612	0.799

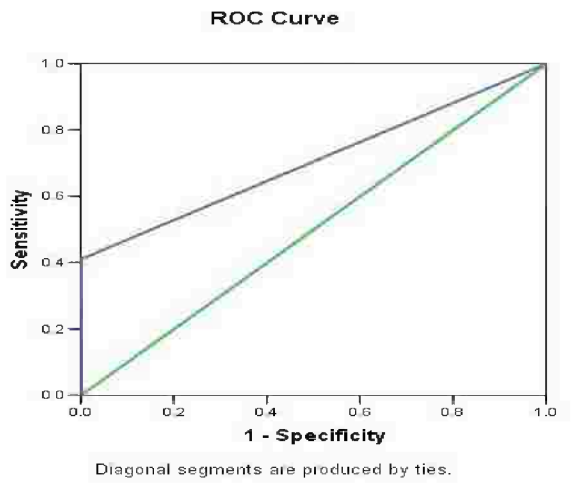

Figure (7): The ROC curves of test item 2: Increased word length (Part B).

Table (24): The ROC curve details of the test item 3: Limb Apraxia.

Area Under the Curve Test Result Variable(s): Limb apraxia				
Area	**Standard Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.567	0.050	0.168	0.468	0.666

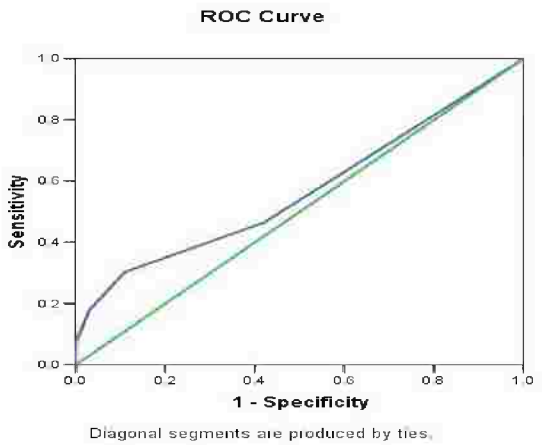

Figure (8): The ROC curves of test item 3: Limb Apraxia.

Table (25): The ROC curve details of the test item 3: Oral Apraxia.

Area Under the Curve Test Result Variable(s): Oral apraxia				
Area	**Standard Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.750	0.044	0.000	0.663	0.837

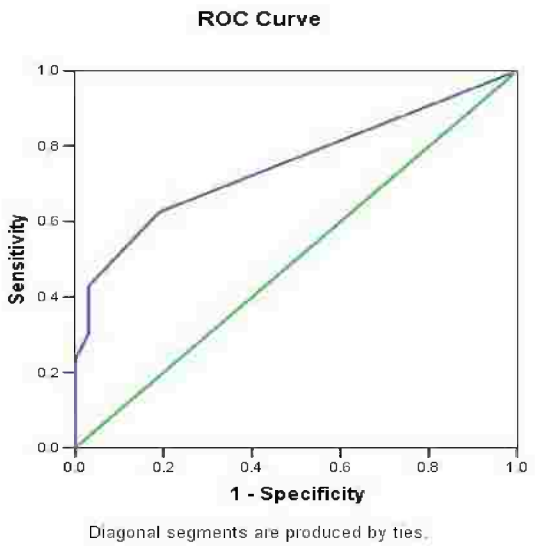

Figure (9): The ROC curves of test item 3: Oral Apraxia.

Table (26): The ROC curve details of the test item 4: Utterance time for polysyllabic words.

Area Under the Curve Test Result Variable(s): utterance time for polysyllabic words				
Area	**Standard. Error**	**Asymptomatic Significance**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.830	0.040	0.000	0.752	0.909

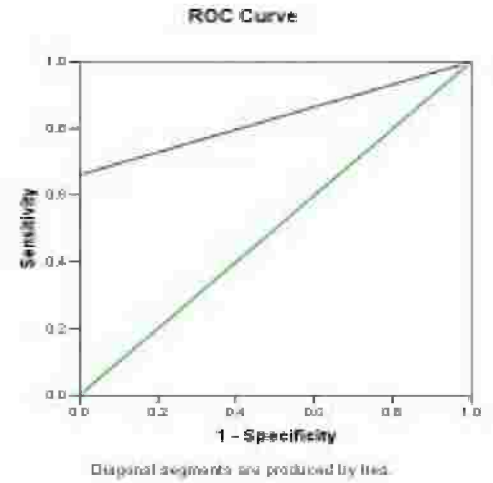

Figure (10): The ROC curve of test item 4: Utterance time for polysyllabic words

Table (27): The ROC curve details of the test item 5: Repeated trials.

Area Under the Curve Test Result Variable(s): Repeated trials				
Area	**Standard. Error**	**Asymptomatic Significance.**	**Asymptomatic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
0.813	0.042	0.000	0.731	0.894

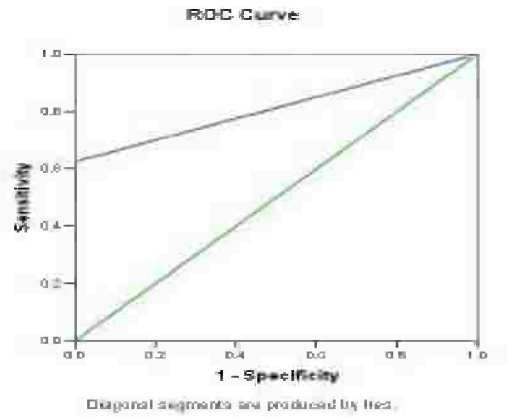

Figure (11): The ROC curves of test item 5: Repeated trials.

Table (28): The ROC curve details of the test item 6: Inventory of articulation characteristics of AOS.

Area Under the Curve Test Result Variable(s): Inventory of articulation characteristics of apraxia				
Area	**Standard. Error**	**Asymptomatic Significance.**	**Asymptomatic 95% Confidence Interval**	
			Lower bond	**upper bond**
0.848	0.038	0.000	0.756	0.958

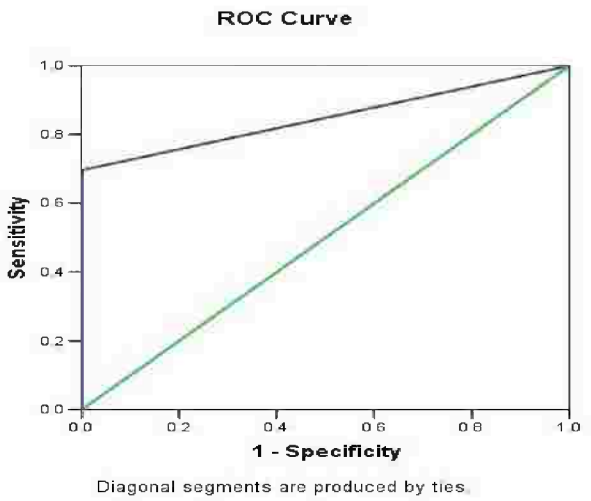

Figure (12): The ROC curves of test item 6: Inventory of articulation characteristics of AOS.

▪ Cut off scores of the test items

Table (29) shows sensitivity, specificity and the cut off scores of the various test items in addition to the cut off scores of the original English version of the test.

Table (29): Sensitivity, specificity and the cut off scores of the various test items.

Test item	Sensitivity %	Specificity %	Cut off (Arabic)	Cut off (English)
Diadochokinetic rate	75 %	97 %	23	26
Increased word length (Part A)	73.4 %	100%	2	1
Increased word length (Part B)	81.1%	100%	2	1
Limb Apraxia	71 %	89%	45	44
Oral apraxia	82.9 %	97%	45	44
Utterance time for polysyllabic words	96 %	100%	15	15
Repeated trials	92.5 %	100%	27	28
Inventory of articulation characteristics of apraxia	70 %	100 %	5	5