PSYCHOLOGY AND EDUCATION (2025) 62(02):
ISSN: 1553-6939

The Importance of Early Cochlear Implantation in the Algerian Clinical Setting

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Received: 10/09/2024 **Published: 18/02/2025**

Abstract:

The study, conducted over 18 months, aimed to compare the linguistic achievement of children who received cochlear implants before and after the age of 4. The results revealed statistically significant differences at the significance level of (0.01) between the mean scores of pre-operative cochlear implant evaluation and the mean scores of evaluation 18 months post-operation, in favor of children who benefited from cochlear implantation before the age of 4.

Keywords: Deafness in Algerian children; Early cochlear implantation; Diagnosis of deafness; Speech therapy management of deafness; Electronic cochlea.

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1Introduction:

Cochlear implantation has become a well-established procedure worldwide as a preferred method to assist children with profound deafness. This electro-acoustic device aims to restore hearing function by providing auditory stimulation, allowing children to hear speech sounds during the critical period of language acquisition. Without hearing, a child cannot develop language, social skills, or learning abilities. Hearing enables individuals to enjoy music, interact with the surrounding world of sounds, and respond to warning sounds such as traffic or alarms, ensuring safety in daily situations. Children who grow up with sound have better educational opportunities, and good hearing is essential for professional success later in life. Hearing means social, intellectual, and linguistic independence.

The first five years of life are the most critical for auditory development. Children who do not receive auditory stimulation during this crucial period will face difficulties in learning to speak. The brain's ability to process sound and develop spoken language declines after this critical period, up to around seven years of age, after which language learning becomes more challenging.

Parents are usually the first to notice hearing impairments. The earlier hearing loss is addressed, the better the chances of avoiding delays in speech and language development. Early intervention increases the likelihood of the child acquiring normal speech and language skills.

Common signs of hearing loss in children include:

- Lack of response to loud sounds.
- Inability to locate the source of sound.
- Initial babbling that stops shortly after.
- Failure to develop babbling into understandable speech.
- Lack of response to sounds, especially when not wearing a hearing aid.
- Inability to follow instructions or misunderstanding directions.

To mitigate the challenges of deafness, children with profound hearing loss can benefit from cochlear implants. While this procedure has gained popularity recently, it has raised several questions, such as whether it is suitable for children over four years old. This question prompted us to explore this topic to determine whether cochlear implantation allows these children to develop individual language skills that enable communication with others or if it is better for them to learn sign language directly. Field observations have shown that some children who received cochlear implants and underwent four years of speech therapy failed to acquire basic language skills for communication, missing the opportunity to learn sign language. By the age of ten, these children were unable to understand either spoken language or sign language. This reality led us to investigate whether it is appropriate for children over four years old to receive cochlear implants.

One study that examined language acquisition in children with cochlear implants was conducted by Marie-Thérèse Le Normand (2004). This study aimed to examine the components of lexical and grammatical development to better

understand the mechanisms of auditory-verbal plasticity. Over three years, Le Normand followed 50 children with profound genetic deafness who were implanted between 21 and 78 months. Their progress was compared to a sample of 181 children aged 2 to 4 years. The study concluded that age plays a significant role in the development of individual vocabulary in these children. The younger the age at implantation, the better the outcomes.

The goal of this study is to compare two groups of children: the first group received cochlear implants before the age of four, while the second group received implants after the age of four. The comparison is based on the same auditory assessment conducted before the surgery and 18 months after the surgery for both groups. This is to confirm that children who received the implant before the age of four develop better language skills than those who received it after the age of four. This study, which lasted over 18 months, intentionally selected ten cases that received the same rehabilitation program, in the same location, and by the same speech therapist. The study sample is divided into two experimental groups, with the independent variable being the rehabilitation program. After the experimental period, the researcher re-measures the dependent variable, and the difference in measurement is considered evidence that age plays a role in the improvement or deterioration of results.

The study's problem revolves around answering the following questions:

- Are there differences in language acquisition 18 months after the surgery between the group that received cochlear implants before the age of four and the group that received them after the age of four?

Hypotheses:

- There are statistically significant differences 18 months after the surgery between the mean ranks of the two groups in language acquisition, favoring the group that received cochlear implants before the age of four.

Every scientific study characterized by objectivity must rely on a methodological and logical approach. In this research, we chose a quasi-experimental method, which aims to verify cause-and-effect relationships by randomly dividing a number of individuals into groups where one or more independent variables are manipulated, and the effect on the dependent variable(s) is studied. This method involves creating specific experimental conditions by controlling the independent variable(s) in terms of quantity or quality to observe their effect on the dependent variable. Additionally, we used a comparative descriptive approach to compare the experimental and control groups in pre-test results to ensure that improvement is not due to other variables, such as regular academic progress. This study evaluates ten subjects, five of whom underwent surgery before the age of four, and five who received cochlear implants after the age of four.

To avoid interference and influence on variables, we selected ten cases that meet the following criteria:

- The subject must not have stopped attending auditory rehabilitation sessions.
- The deaf subject must not suffer from accompanying disorders to avoid their impact on the study results. To ensure these conditions, we relied on clinical interviews and the subject's medical records. At the University Hospital of Blida, before the surgery, each candidate undergoes an auditory assessment consisting of 07 consonants, 28 vowels, 28 words, and 10 sentences arranged in order of difficulty from easiest to most complex. Every six months, the same consonants, vowels, words, and sentences are reassessed, yielding specific results. For consonants, the result is out of 7, for vowels out of 28, for words out of 28, and for sentences out of 10. During this study, we examined the results before the surgery and compared them to the results obtained 18 months after the external device was fitted.

For each child, the following information was considered: cause of deafness (genetic or acquired), age at implantation, presence of other deaf individuals in the family, and residual hearing. As mentioned earlier, the study sample consists of ten cases of both genders, divided into two groups. The first group consists of five children who underwent surgery before the age of four, while the second group consists of five children who received cochlear implants after the age of four, as shown in the following tables:

Table 1: Characteristics of the first group of the study sample who underwent surgery before the age of four (Group 1).

Case	Gender	Date of Birth	Cause of Deafness	Date of Implantation	Residual Hearing
1	Male	June 2010	Genetic	March 2012	-
2	Female	August 2005	Genetic	November 2009	+
3	Female	July 2005	Genetic	December 2009	+
4	Male	September 2006	Genetic	December 2010	-
5	Female	May 2005	Acquired	July 2009	+

Table 2: Characteristics of the second group of the study sample who underwent surgery after the age of four (Group 2).

Case	Gender	Date of Birth	Cause of Deafness	Date of Implantation	Residual Hearing
6	Male	July 2002	Genetic	March 2009	+
7	Female	October 2004	Genetic	March 2011	+
8	Female	August 2006	Acquired	June 2012	+

9	Female	June 2003	Genetic	July 2012	-
10	Male	April 2004	Acquired	June 2012	+

2. The Importance of Early Intervention

Hearing Screening Tests:

When a hearing specialist suspects that a newborn has hearing loss, they choose a method suitable for the child's age. These methods objectively measure the child's hearing ability and do not require active participation from the child. These quick and simple tests are painless and are performed while the child is asleep. Among the most commonly used tests is the Otoacoustic Emissions (OAE) test, which examines the function of the hair cells in the cochlea. A device is placed in the child's ear, emitting clicking sounds. When the cochlea receives these sounds, it produces an echo that the device captures.

After this procedure, the specialist reviews the audiogram, a graph used to document the child's hearing ability. This test shows the degree and type of hearing loss in each ear. Determining the hearing threshold (the softest sound the child can hear) is essential because it indicates the sound level, measured in decibels (dB). Frequency is measured in Hertz (Hz), from low pitch on the left side to high pitch on the right side of the graph. The average range of normal hearing is between 10-20 dB. If the hearing threshold is above this range, the individual is considered to have hearing loss. For example, a person with a 40 dB hearing loss may not hear normal speech

and may require the speaker to shout or speak loudly to be heard. There are several degrees of hearing loss: 20-40 dB is considered mild, 40-70 dB is moderate, 70-90 dB is severe, and 90-120 dB is profound. The speech therapist must be familiar with the details of the audiogram to detect any changes in hearing ability without delay.

Often, parents feel alone in facing the challenges that arise with their child. Therefore, the speech therapist tries to provide support by informing them about all available resources to offer realistic solutions. For parents to make informed decisions, they must have a comprehensive understanding of their child's condition. Cochlear implantation is one solution for profound deafness. This electronic device is surgically implanted under the skin behind the ear and surrounds the damaged hair cells in the inner ear to stimulate the cochlea. Early intervention is crucial, allowing necessary steps to be taken without delay to help the child during this critical period of language learning. The fetus can hear sounds from inside and outside the mother's body from the 24th week of pregnancy, as the inner ear is fully developed.

During the first few months, children develop phonological awareness, acquiring an understanding of various sounds around them. This allows them to distinguish between human speech and other environmental sounds. Hearing and interacting with others are essential for the child to acquire language. The first two years are critical, and children cannot develop speech skills on their own after this critical period.

Parents must be aware that the younger the child is when receiving a cochlear implant (in cases of profound deafness),

the easier it will be for them to acquire spoken language. During this critical period, the brain is much more capable of processing new information than in older children. Therefore, it is important and necessary to provide children with hearing devices as early as possible so they can develop spoken language quickly and catch up with their peers who were born with normal hearing.

Among the conditions for receiving a cochlear implant is that the child must have severe to profound sensorineural hearing loss. Individuals with this type of hearing loss do not benefit from conventional hearing aids (the benefit is minimal or nonexistent). The cochlear implant delivers sound signals directly to the auditory nerve without passing through the outer and middle ear.

The device consists of two parts: an internal part surgically placed under the skin at the level of the cochlea. These electronic components and electrode array are connected to the auditory nerve (Cranial Nerve VIII). The external part is worn behind the ear and consists of a control unit, a battery pack, and a transmitter that directs information through the skin to the internal part.

This device converts sounds into electrical pulses in the form of codes. These electrical pulses stimulate the nerve fibers in the cochlea, and the auditory nerve sends signals to the brain, where they are translated into sounds. This continuous and immediate process allows the perception of sounds as they are produced.

The benefits are numerous, as it allows for understanding speech, speaking more clearly, using the phone, listening to music, communicating with the environment, and enjoying the world of sounds in all its aspects. It is important to know that results vary depending on several factors, such as the degree and duration of hearing loss, cochlear anatomy, and the type and quality of care received.

Steps to Receive a Cochlear Implant:
A team of specialists determines whether the child is a candidate for cochlear implantation. To receive the electronic device, the child must have profound sensorineural hearing loss in both ears. Additionally, the child must have partially or not benefited from electronic hearing aids. There must be no medical reasons preventing the child from undergoing surgery (anesthesia, auditory nerve integrity, etc.). Appropriate speech therapy must be provided, with strong parental motivation to participate in the rehabilitation process.

Children are not candidates for cochlear implantation in the following cases:

- If the child benefits significantly from conventional hearing aids, this is likely the better solution.
- If the cause of hearing loss is elsewhere than the inner ear, there may be a more effective alternative.
- If the cochlea does not allow proper electrode placement or if the auditory nerve is absent, there may be a more effective alternative.
- It is important that the child receives family support and participates in rehabilitation.

If the medical team deems the child eligible for cochlear implantation, the child receives the electronic device. The procedures can be summarized in the following steps:

1. **Evaluation:** To determine eligibility, the child undergoes a series of medical tests to assess if they are a candidate. These tests relate to ear anatomy and include medical, auditory, and radiological (X-ray) evaluations. The speech therapist ensures that the child and parents are motivated to take this step. If positive, the speech therapist assesses the child using an auditory assessment.
2. **Surgery:** The surgical procedure usually takes one to three hours and is performed under general anesthesia. The risks are low and similar to other ear surgeries. Children typically wake up and recover the next day, and the hospital stay can range from one to several days depending on the child's personal needs.
3. **Initial Fitting of the External Device:** About four weeks after implantation, the child receives their sound processor (external part). The sound processor is programmed or fitted individually by an audiologist or other professional (programmer). This program includes settings for speech and noise. Initially, frequent programming sessions are required to gradually fine-tune the settings. Often, the device is set to a low volume to allow the child to adjust to the world of sounds, and the volume is gradually increased to provide appropriate hearing.

4. **Rehabilitation:** The electronic device offers a great opportunity for children with hearing loss. Sounds may be confusing and noisy at first, so training with a speech therapist is essential to understand sounds and develop listening and speaking skills.

Early cochlear implantation allows children to receive auditory information during a critical period when the brain is ready to learn language. Children who receive cochlear implants at an early age develop speech almost similar to children with normal hearing. After this theoretical information, we will present and analyze the results in the following section.

3. Analysis of Results

The study's hypothesis states: "There are statistically significant differences between the mean ranks of the group that received cochlear implants before the age of four and the group that received cochlear implants after the age of four, favoring the group that received cochlear implants at an early age." To verify this hypothesis, the researcher used the T-test to determine the direction and significance of the differences between the mean scores of the two groups 18 months after the surgery for each of the four categories (vowels, consonants, words, sentences), comparing them to the results obtained before the surgery.

The results are shown in Tables 3 and 4, which display the means, standard deviations, T-values, and significance of the differences between the scores of the groups that received cochlear implants before and after the age of four (assessment

before the surgery and 18 months after the surgery). The formula used to calculate T for two unrelated samples of equal size is:

$$T=\frac{Md1-Md2}{\sqrt{\frac{Ed1^2+Ed2^2}{(N-1)}}}$$ Where Ed^2 = sum of squared deviations

Md = mean of differences.

Table 3: Shows the means, standard deviations, T-values, and significance of the differences between the scores of the group that received cochlear implants before the age of four (assessment before the surgery and 18 months after the surgery).

	Pre-operative evaluation n = 05		**Evaluation 18 months post-operation n = 05**				
Category	**mean**	**Standard deviation**	**mean**	**Standard deviation**	**T-Value**	**Critical T-Value**	**ignificance Level**
onsonants	1.60	1.51	5.20	0.83	4.17	3.355	.01
Vowels	2.20	2.28	18.80	3.27	8.32	3.355	.01
Words	1.20	1.78	14.80	7.49	3.54	3.355	.01
Sentences	0	0	1.60	1.81	2.64	3.355	.01

Table 4: Shows the means, standard deviations, T-values, and significance of the differences between the scores of the group that received cochlear implants after the age of four (assessment before the surgery and 18 months after the surgery).

	Pre-operative evaluation n = 05		**Evaluation 18 months post-operation n = 05**				
Category	**mean**	**Standard deviation**	**mean**	**Standard deviation**	**T-Value**	**Critical T-Value**	**Significance Level**
Consonants	1.80	1.30	4.80	0.83	2.84	3.355	.01
Vowels	2.40	1.14	10.40	5.02	3.10	3.355	.01
Words	0	0	8.20	4.43	3.70	3.355	.01
Sentences	0	0	0	0	0	3.355	.01

Table (3) shows that when comparing the calculated "t" value with the tabulated "t" value for (vowels, consonants, and words) in both the experimental and control groups, the calculated "t" > the tabulated "t." Therefore, "t" is statistically significant, and it can be concluded that there are statistically significant differences at the significance level of (0.01) between the mean scores of pre-operative cochlear implant evaluation and the mean scores of evaluations 18 months post-operation and after the application of the program, in favor of

the evaluation after 18 months. This indicates an improvement in linguistic achievement and hearing skills. Thus, the validity of the first hypothesis is confirmed. However, for sentences, although the obtained result is better than the group that received the cochlear implant after the age of four, it is not statistically significant. This may be attributed to the auditory age of these children being 18 months, and at this age, a typical child of the same age (i.e., 18 months) cannot repeat sentences they hear without lip-reading.

On the other hand, Table (4) shows that when comparing the calculated "t" value with the tabulated "t" value for (vowels, consonants, and sentences), the calculated "t" < the tabulated "t." Therefore, "t" is not statistically significant, and it can be concluded that there are no statistically significant differences at the significance level of (0.01) between the mean scores of pre-operative cochlear implant evaluation and the mean scores of evaluation 18 months post-operation. However, for words, the result is statistically significant, which may be due to other factors that contributed to the children's development of word recognition skills.

The auditory cortex allows enjoyment of the world of sounds. Since the completion of this part of the brain, newborns can utilize this region to form a linguistic lexicon and begin their language acquisition phase, encompassing its rhythmic, phonological, lexical, and grammatical components. Language acquisition also heavily depends on the biological maturation of the neural region, requiring the proper development of brain areas dedicated to speech. To function

optimally, at least two fundamental conditions must be met: first, there must be brain maturation, i.e., the completion of brain region growth, and second, favorable conditions for language acquisition (linguistic input) must be present. In deaf children, this region is not stimulated, leading to various difficulties in language acquisition.

To mitigate these difficulties, children with deafness receive cochlear implants. Cochlear implants can assist this group of children suffering from profound hereditary or acquired deafness. This electronic device stimulates the auditory cortex, and speech therapists provide individualized care tailored to their needs, helping them acquire language in all its components. A child without deafness acquires the primary processes of communication at a non-verbal level (vision, hand gestures, crying, etc.), then gradually transitions to expressing emotions through spontaneous body movements before beginning to speak. Babbling (Le babillage), which appears around 6-7 months, expands the child's vocal repertoire in the pre-linguistic phase to include various sound patterns. Imitative behavior dominates this phase, earning it the name "imitation phase." By the end of the first year, the child begins to produce isolated words, and between 2 and 4 years, they expand their vocabulary. This period is marked by the appropriate use of grammatical categories such as prepositions, pronouns, gender, and pluralization of nouns.

Despite significant individual variation, a typical child (i.e., one without deafness) at around 3 to 3.5 years of age can produce most basic linguistic structures in their native language. However, there is a specific age point beyond which it becomes difficult for a child to speak a language fluently,

which is around age 9. While our brains are inherently programmed to learn languages, this ability does not last until adulthood and does not remain as efficient as it is during the early years of development. A deaf child who receives a cochlear implant may quickly learn isolated words but struggles with controlling the grammatical and syntactic rules of their native language necessary for forming correct sentences.

In practice, there is significant variation among children who receive cochlear implants. Some exhibit linguistic abilities exceeding the average of their non-deaf peers, while others lack language entirely and cannot form even simple sentences, with their linguistic abilities limited to a few basic words, even 36 months post-implantation.

This linguistic impairment can be explained by difficulties in auditory perception due to the child's reduced ability to organize and integrate sensory stimuli received through hearing, making it challenging to process them within the framework of prior experiences. This leads to the disappearance of information, words, or sounds before they are given meaning and cognitive significance. This perceptual difficulty results in challenges in reproducing linguistic components, especially those related to grammatical categories such as prepositions, pronouns, gender, and pluralization of nouns.

For non-deaf children, abundant linguistic input (i.e., auditory materials) forms a solid foundation for building and acquiring grammatical rules. However, a deaf child struggles to access

certain elements of linguistic input because they simply do not receive the same quantity of linguistic input (linguistic input), such as grammatical markers, which are rapid and brief. Deaf children find it difficult to focus on these elements. Even implanted children who significantly develop their linguistic abilities show difficulty in producing grammatical forms, facing issues with gender identification, noun construction, and verb conjugation. (Le Normand, 2004, p. 7)

Language produced in the context of familiar words is generally relatively simple, and a child with a cochlear implant can encode the meaning of such sentences. Conversely, sentences requiring specific analytical processing with functional words like prepositions, pronouns, conjunctions, or gender and number inflections and verb conjugations are more complex for them. Thus, children with cochlear implants face a complex set of sentences to process and find it difficult to analyze and encode them without external assistance, while their peers do not face the same difficulties, as the process of learning grammatical rules in young non-deaf children is automatic.

When observing the speech of a child with a cochlear implant, multiple errors are noted, primarily related to gender, verbal inflections, omission of certain terms, prepositions, and conjunctions. Children with cochlear implants develop an incomplete cognitive linguistic system, especially concerning grammatical rules, where processing is often non-automatic.

4. Conclusion:

It is important to remember that a cochlear implant is a technical tool for a child's hearing, and success depends on many factors. The age of implantation is just one factor influencing the benefits a child receives from a cochlear implant. A rich communication environment, effective sound processor programming, stimulation, rehabilitation, and realistic expectations regarding the cochlear implant are all important factors contributing to the overall success of a deaf child.

Thus, the maximum degree of success depends on a number of factors that cannot be predicted before implantation. For this reason, it is important to have realistic expectations, and the speech therapist is there to help parents make decisions based on realistic goals for each developmental stage the child may go through.

A consensus has now been reached that the appropriate age for implantation in young children is two years, or even earlier. In fact, many researchers have begun to accept the idea that early implantation, before 18 months or even 12 months, may allow the emergence of babbling (Le babillage), which appears around 6-7 months, during which the child's vocal repertoire expands in the pre-linguistic phase to include various sound patterns. (Gilles et al., 2002)

Babbling contributes to the emergence and clarity of speech, and early implantation also contributes to high auditory performance. The question that must be asked is: During which age range does the "sensitive period" for language acquisition extend? To perform the procedure during this

phase. Deaf children who receive implants after the age of four do not develop spontaneous language because they have passed the sensitive period for language acquisition. At this late stage, it is not logical to expect them to have perfect language mastery of all language components. Therefore, these children experience slower language acquisition due to the delayed stimulation of the auditory brain region, which must be stimulated during a sensitive period to function optimally, preferably by the age of two.

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6.Appendices:

Table 5: Represents the results of cases in the first group (before surgery and 6 months after surgery).

	Before Surgery				**6 Months After Surgery**			
	Consonants	**Vowels**	**Words**	**Sentences**	**Consonants**	**Vowels**	**Words**	**Sentences**
Case 1	00/07	00/28	00/28	00/10	03/07	08/28	01/28	00/10
Case 2	03/07	05/28	02/28	00/10	03/07	06/28	04/28	00/10
Case 3	03/07	04/28	04/28	00/10	04/07	10/28	10/28	01/10
Case 4	00/07	00/28	00/28	00/10	02/07	03/28	02/28	00/10

Case 5	02/07	02/28	00/28	00/10	03/07	04/28	03/28	00/10

Table 6: Represents the results of cases in the first group (12 and 18 months after surgery).

	12 Months After Surgery				**18 Months After Surgery**			
	Consonants	**Vowels**	**Words**	**Sentences**	**Consonants**	**Vowels**	**Words**	**Sentences**
Case 1	04/07	10/28	04/28	00/10	05/07	15/28	06/28	00/10
Case 2	05/07	15/28	10/28	01/10	06/07	24/28	25/28	03/10
Case 3	05/07	15/28	15/28	02/10	05/07	18/28	17/28	04/10
Case 4	03/07	16/28	05/28	00/10	06/07	18/28	17/28	01/10
Case 5	03/07	16/28	05/28	00/10	04/07	19/28	09/28	00/10

Table 7: Represents the results of cases in the second group (before surgery and 6 months after surgery).

	Before Surgery				6 Months After Surgery			
	Consonants	**Vowels**	**Words**	**Sentences**	**Consonants**	**Vowels**	**Words**	**Sentences**
Case 6	02/07	02/28	00/28	00/10	03/07	05/28	04/28	00/10
Case 7	04/07	04/28	00/28	00/10	04/07	11/28	04/28	00/10
Case 8	01/07	02/28	00/28	00/10	03/07	03/28	00/28	00/10
Case 9	01/07	03/28	00/28	00/10	03/07	05/28	02/28	00/10
Case 10	01/07	01/28	00/28	00/10	03/07	02/28	01/28	00/10

Table 8: Represents the results of cases in the second group (12 and 18 months after surgery).

	12 Months After Surgery				18 Months After Surgery			
	Consonants	**Vowels**	**Words**	**Sentences**	**Consonants**	**Vowels**	**Words**	**Sentences**
Case 6	04/07	07/28	07/28	00/10	04/07	10/28	11/28	00/10
Case 7	04/07	13/28	06/28	00/10	05/07	15/28	10/28	00/10
Case 8	03/07	04/28	01/28	00/10	04/07	06/28	04/28	00/10

Case 9	05/07	15/28	10/28	00/10	06/07	16/28	13/28	00/10
Case 10	04/07	03/28	01/28	00/10	05/07	05/28	03/28	00/10

مصاريف الخدمة

الخدمة	**المستحقات**
الكتابة على الحاسوب	مجانية (ضمن الخدمة)
التدقيق اللغوي في اللغة الأصلية	مجانية (ضمن الخدمة)
عدد الصفحات	25
المستحقات	25*30دج= 7500 دج
المبلغ الإجمالي	**7500 دج (سبعة آلاف وخمسمئة دينار جزائري)**
(مع تحيات فريق العمل، بالتوفيق إن شاء الله)	