

Libyan cochlear implant programme: achievements, difficulties, and future goals

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Cochlear implantation has become established worldwide as a safe and effective method of auditory rehabilitation of selected severely and profound deaf children and adults. Over 100,000 patients have received cochlear implants worldwide with the paediatric population proving to be the main beneficiaries. The Libyan cochlear implant programme was set up in 2004. Data relating to the patients who received cochlear implantation at Tripoli Medical Centre between October 2007 and February 2010 were analysed. Implant operations were performed on 37 patients. All patients received Med-El SONATA_{TI}¹⁰⁰ devices. Thirty-four (91.9%) of these patients were children, whilst three (8.1%) were adults. Combined, congenital hearing loss (56.8%) and perinatal/neonatal (29.7%) were the two main aetiological factors in children. Seventeen patients (45.9%) had a positive family history of deafness. Sixteen patients (43.2%) were born to blood-related parents. The overall rate of minor and major complications was 16.2%, which is comparable to previous studies.

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Cochlear implantation (CI) has become established worldwide as a safe and effective intervention for auditory rehabilitation of selected severely and profound deaf children and adults with sensorineural hearing loss (1, 2). Cochlear implantation allows the implant beneficiary to reintegrate with the hearing world (3). Its value, safety, and dependability are well documented (1). It is estimated that over 100,000 patients have received cochlear implants worldwide with the paediatric population proving to be the main beneficiaries from this prosthesis (1, 3). Studies have revealed that the majority of CI users, affected by pre- or post-lingual deafness, acquire considerable benefit from this intervention (4). Cochlear implantation is currently the only means of restoring a sufficient level of hearing in patients with severe to profound hearing impairment that are not remedied by conventional methods such as hearing aids (5). All these factors make cochlear implantation arguably the most successful neural prosthesis in the history of medicine.

The aim of a cochlear implant is to replace a non-functional inner ear hair cell transducer system by converting mechanical sound energy into electrical signals that can be delivered to the cochlear nerve in profoundly deaf patients (6). The cochlear implant device

is comprised of a number of components that include (5): a microphone, which picks up acoustic information and converts them into electrical signals; an externally worn speech device that processes the signal according to a predefined strategy; and a surgically implanted electrode array that is in the cochlea near the auditory nerve. Essentially, the aim of a cochlear implant is to provide direct stimulation of the spiral ganglion cells of the cochlear nerve bypassing the damaged hair cells (6).

Libya is a developing North African country with an estimated population of 5,323,991 (7). Tripoli is the capital city of Libya situated on the northwest coastline of the country. Tripoli Medical Centre (TMC) is a public hospital with about 1,450 beds, 1,000 physicians, and approximately 3,000 employees. The hospital provides its services to a significant proportion of the population. In addition to the inhabitants of Tripoli, patients from across Libya present to TMC due to its level of expertise, facilities, and provision of care. Tripoli Medical Centre is the sole institution in Libya that installs cochlear implants.

The Libyan cochlear implant programme (LCIP) was set up in 2004. Prior to the development of the programme, patients predominantly travelled to Europe as well as neighbouring Arab countries such as Egypt and

Jordan for cochlear implantation. However, due to substantial financial implications of medical care and travelling among many other factors, very few patients could afford the costs of surgery, aftercare, and rehabilitation.

Tripoli Medical Centre is recognised as the official cochlear implant centre. However, other ENT departments in Libya have offered this procedure mainly to be carried out by visiting surgeons from across the world. Data relating to these procedures and patient profiles of those implanted outside TMC, although very few, are unfortunately unknown and have not been included in this report. The aim of this report is to describe the experiences and progress of the cochlear implant in Libya.

Methods

Data relating to patients who received cochlear implantation between October 2007 and February 2010 were studied. Implant operations were performed on 37 patients. Patient records available at the time of the study includes age of patient at implantation, year of implantation, place of birth, diagnosis leading to hearing loss, perinatal, neonatal and medical history, pre-operative investigations (Computed Tomography [CT] and Magnetic Resonance Imaging [MRI]), pre-operative audiometry tests, and any post-operative complications. The LCIP currently accepts the minimum age for implantation of 2 years for anatomical reasons.

Surgical approach

From the outset of the programme, the classical surgical technique for cochlear implantation has been used on all patients. The main steps in this approach include a post-auricular 'C' shaped incision usually made 1 cm from the planned site of the receiver (Fig. 1). The pericranium is raised with the skin flap in order to maintain good vascular supply, as mentioned in previous studies (4). Afterwards, a cortical mastoidectomy is performed and a bed (bony well) is drilled for the receiver-stimulator unit (8). Posterior tympanotomy is then carried out, followed by cochleostomy, which has been enthusiastically adopted by cochlear implant surgeons as it provides good access to the round window and promontory (9). Care and precision is taken not to mistake hypotympanic cells for the round window niche in order to correctly insert the electrode array in the scala tympani, in order to prevent what is considered an unacceptable complication (4). The duration of this operation usually lasts up to 2 hours. All paediatric patients were given intra- and post-operative prophylactic antibiotics (ceftriaxone) against meningitis.



Fig. 1. Post-auricular incision performed with a view of the cochlear implant (Courtesy of Dr Anwer Esriti).

Results

Since 2007, a total of 37 implantations have been performed through the LCIP. Four of these operations (10.8%) were performed in 2007, 12 (32.4%) in 2008, 19 (51.4%) in 2009, and 2 (5.4%) up until February 2010. All patients received MED-EL SONATA^{TI}100 devices. Post-operative switch on was performed 4 weeks post-implantation. Each patient taking part in the LCIP was given a specialist auditory and communication skills training that was incorporated in their rehabilitation programme at TMC.

Thirty-four (91.9%) of these patients were children (male, 19; female, 15). Three adults (8.1%) were installed with implants, of which two were male and one female. Thirty-two (86.5%) patients received implants in their right ear, whilst five (13.5%) patients were implanted in their left ear. Seventeen (45.9%) patients received cochlear implants before the age of five. Of this subgroup, nine (52.9%) were male and eight (47.1%) were female. The mean age of paediatric patients taking part in the programme was 3.4 years (Fig. 2).

The study revealed that 21 (56.8%) patients presented with congenital hearing loss as the primary aetiology of their deafness (Table 1). Other aetiologies included meningitis, progressive disease, and perinatal/neonatal (including prematurity, pre-eclampsia, birth asphyxia, meconium aspiration, and febrile convulsions). Thirty-five patients (94.6%) presenting to the programme were

Table 1. Aetiology of hearing loss

Aetiology	No. (%)
Congenital	21 (56.8%)
Progressive	3 (8.1%)
Meningitis	2 (5.4%)
Perinatal/neonatal	11 (29.7%)

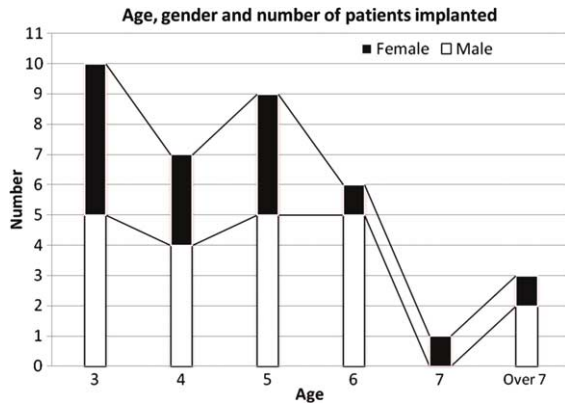


Fig. 2. Age and gender of patient at implantation.

diagnosed with sensorineural hearing loss (SNHL). Two patients (5.4%) that were diagnosed with auditory neuropathy were referred for cochlear implantation and will be discussed further on in this study.

Three patients taking part in the programme were adults. One patient had a cerebrovascular accident that led to deterioration in hearing and as a result was installed with a cochlear implant. This patient unfortunately died a number of months after being implanted, the cause of which was not linked to the surgery. The other two patients had progressive aetiologies causing their profound hearing loss. Both remaining adult patients underwent intensive auditory post-implantation and have since integrated well into society and are content with the results of the implant. Both patients have reported no complications.

Records of each patient hearing thresholds were also reviewed (Fig. 3). As classified by the WHO, all patients were identified as having profound hearing impairment (81 dB or greater in better ear). Eighteen patients (48.7%)

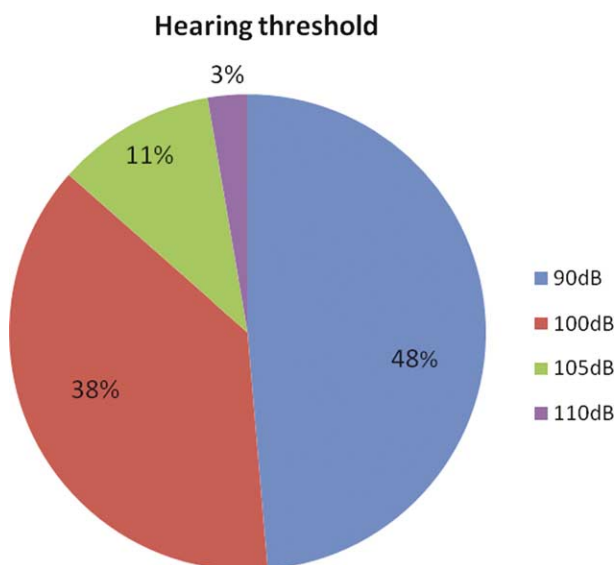


Fig. 3. Pre-operative hearing thresholds.

were recorded having an ABR up to 90 dB, 14 (37.8%) with ABR of up to 100 dB, 4 (10.8%) up to 105 dB, and 1 patient with an ABR of up to 110 dB (Fig. 3). Three post-lingual patients, all of whom were adults, were tested by tympanometry. Two patient's otoacoustic emissions were identified, in addition to their abnormal ABR and hence were given a diagnosis of auditory neuropathy.

Data collected in this study also includes the hometown of each patient. Fourteen patients (37.8%) presented from Tripoli; four patients (10.8%) each from Benghazi and Al-Zawya; two patients (5.4%) each from Al-Bayda, Kikla, Ghriyan, Misrata and Subrata; and a patient (2.7%) each from Al-Azizia, Ghat, Al-Zahra, Mselata, and Zletan. The hypothesis of geographical factors influencing deafness will be reviewed in the discussion section of this paper.

Seventeen patients (45.9%) had a positive history of deafness in the family (a first degree relative suffering from deafness). Sixteen patients (43.2%) had blood-related parents, 13 had parents whom were first degree cousins (35.1%), 1 patient (2.7%) whose parents were second degree cousins, and 2 patients (5.4%) whom parents were third degree cousins. Twenty-one patients (56.8%) had parents whom were not related (Table 2).

Of the 17 patients with a family history of deafness, 11 patients (64.7%) had parents related to the first degree, 2 (11.8%) with third degree related parents, and 4 patients (23.5%) with parents not blood related. While in comparison, patients with a negative family history of deafness, 2 patients (10%) had parents related to the first degree, 1 (5%) with second degree related parents, and 17 patients (85%) with parents not blood related.

Cochlear implantation has been recognised as a safe intervention (1, 3). However, as with any type of surgery, it possesses the risk of minor and major complications (2). A major complication is defined as one leading to explantation or re-implantation, death of a patient, or stay in hospital in excess of 1 week. A minor complication is defined as self-limiting or improves with conservative management (2, 3).

The overall incidence of post-operative complications was 16.2%. There were minor complications in three patients (8.1%), all of whom had a haematoma surrounding the implant occurring within the first week of surgery.

Table 2. Consanguinity, family history, and parent blood relation

Family history	Consanguinity			
	1st degree	2nd degree	3rd degree	None
+ve (n = 17)	11 (64.7%)	0 (0%)	2 (11.8%)	4 (23.5%)
-ve (n = 20)	2 (10%)	1 (5%)	0 (0%)	17 (85%)
Total (n = 37)	13 (35.1%)	1 (2.7%)	2 (5.4%)	21 (56.8%)

In two of these patients, their haematomas resolved spontaneously, while the third patient had his haematoma aspirated and all recovered without incidence. Two patients (5.4%) included in the study were re-implanted due to damaged implants that were performed in 2004. During the programme, only one patient (2.7%) developed CSF gusher, which is considered a major complication (Table 3). This complication was managed by operating on the patient again and occluding the Eustachian tube and the cochleostomy site. After this intervention, the patient recovered well.

Two patients were installed with cochlear implants in spite of their diagnosis of auditory neuropathy. This phenomenon is a sensorineural hearing disorder distinguished by an abnormal/absent ABR in spite of a present otoacoustic emission (10, 11). The matter of installing cochlear implants in patients with auditory neuropathy is still a contentious one and is currently being hotly debated. However, there are promising signs as demonstrated by a previous study (12), which suggests that the outcome of implanting patients with auditory neuropathy does not differ drastically from their paediatric counterparts with sensorineural hearing loss. Previous studies hypothesise that the cochlear implant is able to overcome the theory of principal desynchronisation as thought with auditory neuropathy (12).

Discussion

Previous data (3) has reported cases of meningitis post-implantation. As a result, all paediatric patients were given intra- and post-operative ceftriaxone. Post-operative meningitis was not observed in any of the LCIP patients. The majority of implanted patients were children (91.9%) and their mean age at implantation was 3.4 years. There were 56.8% patients that presented with congenital hearing loss, which is comparable to other reports (3). The incidence of sensorineural hearing loss among children in Libya until today is still unknown and requires further research.

Until now, there has been no study identifying geography as a cause or an influence on the aetiology of deafness. The remote location of some patients and the distances travelled by these patients to reach Tripoli is remarkable. One of the main criteria in selecting patients for the LCIP was their commitment to rehabilitation post-operatively.

Table 3. Number of complications

Complications	No. (%)
None	31 (83.3%)
Haematoma	3 (8.1%)
Re-implantation	2 (5.4%)
CSF gusher	1 (2.7%)

Due to financial implications associated with developing a cochlear implant programme in a developing country, post-operative hearing testing was very limited. Currently, a post-operative x-ray is performed to identify the location of the implant as well. Ideally, the assessment of speech and language development post-implantation include hearing threshold levels, measured by pure tone audiograms as well as listening progress profiles. However, due to a lack of funds, politics and the LCIP being a relatively new cochlear programme, these forms of monitoring after implantation were neither available nor correctly recorded to be added to this study.

A number of studies have shown that excellent results are feasible as well as achievable in pre-lingual patients when a cochlear implant is received before the age of three without surgical complications or functional tuning difficulties (3, 6, 8). The desired aim of the LCIP, as well as other cochlear programmes, is to implant younger pre-lingual children as soon as possible, eventually even during the first year of life from a neuro-developmental point of view (6). In reality this concept, however, is dependent on a number of factors for it to succeed in Libya.

Initially, early identification of high risk patients is necessary, particularly patients with a positive family history. Extensive media coverage of the programme on local television has encouragingly raised awareness and provided great exposure to the public about hearing loss and the cochlear implant programme among the general public. This issue has so far been dealt with well in Libya, ever since the introduction of the LCIP.

Firstly, this has led to earlier presentation of patients with a complaint of hearing loss. Secondly, this has lowered the thresholds of families in coming forward with their children with delayed hearing development. Thirdly, it has given members of the multi-disciplinary team an opportunity to intervene at an earlier stage and offer their services and recommend rehabilitation sooner than what was previously possible.

Neonatal screening of hearing loss until now has yet to be formally initiated in Libya. The matter of screening is multi-factorial and is dependent on a number of issues. Firstly, government funding and backing is required to set up a successful screening process. Secondly, a more intensive and interactive campaigning with the general population about hearing loss are needed for quicker presentation. Hopefully, this will eventually take in the form of genetic counselling of blood-related parents and families with positive histories of hearing impairment.

As prevention is better than cure, it is a timely opportunity for the obstetrics and neonatal services in Libya to be reviewed. Perinatal and neonatal causes of hearing loss appear to be prevalent in this study for some reason or another. Eleven patients (29.7%) had history relating to conditions such as birth asphyxia, meconium

aspiration, and febrile convulsions. Future research and review of these services in Libya may help tackle what may possibly be avoidable causes of hearing loss.

Inherited causes of hearing impairment are an important cause of severe and profound hearing loss (13). Previous studies (14, 15) have revealed that 70% of cases of severe hearing loss were the result of consanguineous marriages (1). This study identified 16 patients (43.2%) that were born to blood-related parents. Seventeen patients (45.9%) had a positive family history of deafness.

Eleven of the 17 (64.7%) had parents blood related to the first degree (Table 4). Although, perhaps not common in the West, the practice of consanguineous marriages is prevalent and frequent practice in many countries across the world, especially in the Middle East and parts of Asia for a number of social and cultural circumstances (1, 3, 14, 15). This custom makes tackling the topic of hearing loss a bit harder. In spite of this, certain steps could be taken in view of preventing hearing loss as much as possible. Schemes such as health education, genetic

Table 4. Patient demographics

Patient	Age	Sex	Ear	DOI	Aetiology	FHx	Consanguinity
1	3	F	R	07/10/07	Premature	+	Third
2	4	M	R	15/10/07	Pre-eclampsia	+	
3	4	M	R	07/10/07	MA and FC	—	Second
4	52	M	R	15/10/07	Progressive	—	
5	4	F	R	20/01/08	Congenital	—	
6	7	F	R	31/01/08	Congenital	+	First
7	3	M	R	03/02/08	BA and MA	—	
8	3	M	R	03/02/08	Congenital	—	First
9	5	F	R	09/03/08	Congenital	—	
10	5	M	R	23/03/08	Congenital	—	
11	3	M	R	06/04/08	Congenital	—	
12	6	F	R	08/04/08	Congenital	+	First
13	30	F	L	04/05/08	Progressive	—	
14	4	M	R	11/05/08	Congenital	—	
15	5	M	R	28/12/08	Congenital	+	
16	5	F	R	22/01/09	Congenital	+	
17	6	M	L	08/02/09	Congenital	+	First
18	5	F	L	09/02/08	FC	+	First
19	5	M	R	10/02/09	FC	—	
20	6	M	R	01/03/09	Congenital	—	
21	5	M	R	11/03/09	BA	—	
22 ^a	5	M	R	22/03/09	Congenital	—	First
23	4	M	R	22/03/09	Meningitis	+	First
24	3	M	R	12/04/09	BA and FC	—	
25	3	F	R	19/04/09	Premature	—	
26	3	F	R	10/05/09	Meningitis	—	
27	6	M	R	31/05/09	Congenital	—	
28	4	F	R	14/06/09	Congenital	—	
29	4	F	R	17/06/09	FC	—	
30	6	M	R	21/06/09	Congenital	+	First
31	3	F	L	02/09/09	MA	+	Third
32	3	F	R	06/09/09	Congenital	+	First
33	3	M	R	09/09/09	Congenital	+	First
34 ^a	6	M	R	13/09/09	Congenital	+	First
35	32	M	L	02/12/09	Progressive	+	
36	5	F	R	27/01/10	Congenital	+	First
37	5	F	R	07/02/10	Congenital	—	First

^adiagnosed with auditory neuropathy.

Note: FHx, family history; DOI, date of implantation; R, right; L, left; BA, birth asphyxia; MA, meconium aspiration; FC, febrile convulsions.

counselling, adequate perinatal and neonatal care, immunisation programmes and screening will all synergistically benefit the citizens of Libya and its health service in treating those with a hearing impairment.

Although all patients benefited greatly from their implants, it is difficult to compare these results to other studies, without the use of pure tone audiograms and listening profiles. As a number of patients travel vast distances to present to TMC, outreach programmes could be offered and set up in a number of cities across Libya in order to assess patients locally and intervene sooner. Future research is required to identify the genetic causes of hearing loss particularly in consanguineous marriages and in those with a positive family history of hearing impairment. Additionally, an appraisal of the perinatal and neonatal services in Libya is needed to review the high numbers of perinatal and neonatal conditions leading to impaired hearing.

Conclusion

The LCIP has proved to be a successful rehabilitative intervention for children and adults in the country so far. Further government funding is required to continue the progress already made and provide the means to improve the existing programme. Future initiatives such as health education, genetic counselling, adequate perinatal and neonatal care, immunisation programmes, and screening will all go a long way in preventing deafness, identify those at risk, and allow earlier intervention of people affected by a hearing impairment in Libya.

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References

1. Khan MI, Mukhtar N, Saeed SR, Ramsden RT. The Pakistan (Lahore) cochlear implant programme: issues relating to implantation in a developing country. *J Laryngol Otol.* 2007; 121: 745–50.
2. Collins MM, Hawthorne MH, el-Hmd K. Cochlear implantation in a district general hospital: problems and complications in the first five years. *J Laryngol Otol.* 1997; 111: 325–32.
3. Al-Muhaimeed HS, Al-Anazy F, Attallah MS, Hamed O. Cochlear implantation at King Abdulaziz University Hospital, Riyadh, Saudi Arabia: a 12-year experience. *J Laryngol Otol.* 2009; 123: e20.
4. Makhdoum MJ, Snik AF, van den Broek P. Cochlear implantation: a review of the literature and the Nijmegen results. *J Laryngol Otol.* 1997; 111: 1008–17.
5. Shah JP, Patel SG. *Operative techniques otolaryngology head and neck surgery.* 3rd ed. Maryland Heights, MO: Mosby; 2003.
6. Kandogan T, Levent O, Gurol G. Complications of paediatric cochlear implantation: experience in Izmir. *J Laryngol Otol.* 2005; 119: 606–10.
7. Great Socialist People's Libyan Arab Jamahiriya, Libyan Health Information Centre. Available from: www.health.gov.ly [cited 15 February 2010].
8. Hehar SS, Nikolopoulos TP, Gibbin KP, O'Donoghue GM. Surgery and functional outcomes in deaf children receiving cochlear implants before age 2 years. *Arch Otolaryngol Head Neck Surg.* 2002; 128: 11–4.
9. Kronenberg J, Migirov L, Dagan T. Suprameatal approach: new surgical approach for cochlear implantation. *J Laryngol Otol.* 2001; 115: 283–5.
10. Dowley AC, Whitehouse WP, Mason SM, Cope Y, Grant J, Gibbin KP. Auditory neuropathy: unexpectedly common in a screened newborn population. *Dev Med Child Neurol.* 2009; 51: 642–6.
11. Madden C, Rutter M, Hilbert L, Greinwald JH Jr, Choo DI. Clinical and audiological features in auditory neuropathy. *Arch Otolaryngol Head Neck Surg.* 2002; 128: 1026–30.
12. Buss E, Labadie RF, Brown CJ, Gross AJ, Grose JH, Pillsbury HC. Outcome of cochlear implantation in paediatric auditory neuropathy. *Otol Neurotol.* 2002; 23: 328–32.
13. WHO 2006. Deafness and hearing impairment. WHO Fact Sheet No. 300. Geneva: World Health Organisation.
14. Singh AP, Chandra MR, Dayal D, Chandra R, Bhushan V. Prevalence of deafness in a rural population of Lucknow district. *Indian J Public Health.* 1980; 24: 23–31.
15. Elahi MM, Elahi F, Elahi A, Elahi SB. Paediatric hearing loss in rural Pakistan. *J Otolaryngol.* 1998; 27: 348–53.

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