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Surgical aspects of paediatric cochlear implantation

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Abstract

Cochlear implantation in the paediatric population is now an accepted method of rehabilitating profoundly or totally deaf children. The problems of cochlear implantation in children with other significant medical problems are examined. A retrospective review of the records of the first 45 children implanted at our centre was carried out. The review focused on surgical factors and outcome in addition to variations in technique which have occurred since the programme began. Congenital hearing loss was the most common indication for implantation. Fifteen children (33 per cent) had other medical problems. Three cases of flap breakdown (two occurring after direct trauma to the package bed) and one case of a misplaced electrode requiring re-implantation accounted for the only major complications to date. Minor complications included hypertrophic scar formation and post-operative wound infection. All children were using their implants at the time of this review, but two have subsequently been explanted. Cochlear implantation of children with multiple medical problems requires acceptance of a slightly higher risk of complications.

Key words: Cochlea; Cochlear implant, complications; Child

Introduction

Since 1992, children with profound or total deafness have undergone cochlear implantation at Great Ormond Street Hospital (GOSH). As cochlear implant programmes accrue increasing numbers of children, surgical factors relating to outcome can be analysed. Such retrospective assessment allows advancement of surgical technique in concert with advances in neurophysiology and programming. Examination of our experience with cochlear implants in children with multiple handicaps will help us to define the contribution of these handicaps to technical outcome after cochlear implant surgery. This report summarizes our experience and outlines the development of our current surgical approach to paediatric cochlear implantation.

Methods

A retrospective review of the case notes of all children who received a cochlear implant from October 1992 until December 1995 was carried out. Forty-five children had a cochlear implant inserted during this period. Two principal surgeons carried out all of the operations using a standard technique and the small differences in their techniques are briefly described. The Nucleus mini-22 cochlear implant is currently the only implant used in our programme.

Our standard technique begins with an extended endaural incision (Lenhardt and Hirshorn, 1986) and elevation of a full-thickness scalp flap. Flap thinning has not been necessary in any case. A cortical mastoidectomy is then performed and the middle ear is entered via a posterior tympanotomy. The site for the receiver package is marked out on the bone and a well for the package is drilled, usually down to dura, keeping the anterior edge of this package bed high to prevent migration of the package anteriorly into the mastoid cavity. A cochleostomy is then fashioned just antero-inferior to the round window and the implant electrode is inserted. The electrode lead is fixed with cement to the posterior canal wall close to the edge of the posterior tympanotomy, and with a dacron tie to the superior edge of the mastoid cavity: the package is then tied down to the skull with a prolene suture. Minor differences in technique between the two implanting surgeons have evolved since the programme began without negative impact on the outcome for the patients. Description of three of these technical differences will serve to highlight the variety of methods that are available for implanting paediatric cochleas.

The first difference is in the incision used. Both use the Lenhardt (1986) incision but one surgeon prefers

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TABLE I
NUMBER OF CHILDREN IMPLANTED PER YEAR, MEAN AGE (IN YEARS) AND RATIOS OF GENDER AND EAR OF IMPLANTATION

Year	Number implanted	Mean age in years	Male : Female	Right : Left
1992	4	8.1 ± 3.5		
1993	9	6.3 ± 3.4		
1994	18	6.1 ± 2.9		
1995	14	5.6 ± 3.4		
Total	45	6.2 ± 3.2	18 : 27	30 : 15

to extend the incision into the canal to a level approximately 4 mm lateral to the tympanic membrane. This extension allows the tympanic membrane to be clearly seen by rotating the patient's head towards the surgeon during the operation to allow visual determination of the level of the tympanic annulus when the posterior tympanotomy is being formed. The second difference is that one surgeon removes the incus before fashioning the posterior tympanotomy in continuity with the fossa incudis. This allows for a full view of the facial nerve throughout its course in the middle ear and mastoid during development of the posterior tympanotomy. The third difference is the type of cement used to secure the electrode to the posterior canal wall. One surgeon used Ionos (sterile glass ionomer cement) and the other Ketac (non-sterile glass ionomer dental cement). We have had no problems associated with either of these agents in our series, but Ionos is no longer available.

In both surgical techniques, small details in perioperative care have varied over the course of the series. These small alterations will be discussed more formally in the results section.

Results

Forty-five children have undergone cochlear implantation at GOSH during the study period. Their demographics are summarized in Table I. The modal age at implantation of our patients was four years (mean = 6.2 yrs) with an age range of 1.6 to 13.3 years. The presumed causes of deafness in these children are outlined in Table II. All of the children with post-meningitic deafness had vestibular deficits in addition to 17 of the children with congenital deafness. The two children with CHARGE association had absent semicircular canals. Many children (33 per cent) had other handicaps, and the hearing loss often formed part of a recognized syndrome (Table III). Postural instability coexisted with hearing loss and vestibular abnormality in one child with cerebral palsy and in another with Still's disease. The children in our series have been implanted for between 0.3 and 3.6 years (mean = 1.6 years). At the time of this review, all children were using their implants, but two have subsequently been explanted.

TABLE II
AETIOLOGY OF HEARING LOSS AND ASSOCIATED DEFICITS AFFECTING POSTURAL STABILITY

Congenital deafness	36
plus vestibular deficit	17
plus CHARGE	2
plus cerebral palsy	2
plus visual deficit	2
Post-meningitic deafness	9
plus vestibular deficit	9
plus cerebral palsy	1
plus visual deficit	1

Throughout the series the surgical technique has evolved as experience has increased. A few of these developments merit specific mention. The use of antibiotics was not routine throughout the period of review as, on the advice of our microbiology department, there was a period during which no antibiotic prophylaxis was administered (five children). Since the middle of 1994, a standard regime of piperacillin, tazobactam and amikacin has been administered intravenously for 24 hours followed by seven days of oral Augmentin, on the recommendation of our microbiology department as a result of the increased Gram negative bacterial resistance which had been identified at our hospital. It must be emphasized that this is not advocated as a standard regime.

The use of drains has also been variable with use now being determined by the amount of fluid collecting during closure. The use of a drain was documented in 27 patients, removal on the second post-operative day being the norm. A modified Stenver's radiograph is performed post-operatively to check the electrode position. Prolene sutures have been used to secure the receiver/stimulator package in all but six patients. With the aim of minimizing the profile of the receiver/stimulator on the skull, the package is routinely bent by both surgeons as described by Hoffman and Cohen (1993).

TABLE III
ASSOCIATED MEDICAL PROBLEMS IN CANDIDATES FOR COCHLEAR IMPLANTATION

Epilepsy	1
Asthma	1
Johanson-Bizzard syndrome	1
Unilateral blindness	1
Goldenhar's syndrome	1
Hirschsprung's disease	1
Usher's syndrome	1
Still's disease	1
Intra-ventricular haemorrhage, ileal perforation, jaundice, cerebral palsy	1
CHARGE association	2
Waardenburg's syndrome	1
Branchio-oculo-facial syndrome	1
Hydrocephalus with ventriculo-peritoneal shunt	1
Total	15 (33%)

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TABLE IV
COMPLICATIONS

	Number	Re-operation required	Re-implantation required
Intraoperative complication			
TM perforation	2		
Minor post-operation complication			
Hypertrophic scar	3	2–1 operation 1–2 operations	
Wound infection	5	1 – drained on ward	
Incision ulcer	2		
VII weak/OME	1	Grommets inserted	
Major post-operation complication			
Flap breakdown	3	1–1 operation 1–2 operations* 1–3 operations*	
Electrode misplaced	1	1 operation	Yes

*Explantation occurred after original submission of the manuscript. Both children are currently scheduled for reimplantation.

In all but six children, all of the 22 active electrodes were inserted into the cochlea. In the remaining children, insertion was terminated when resistance sufficient to bow the electrode was met (Hoffman and Cohen, 1993). The number of active electrodes left outside the cochlea ranged from one to 11 for these six children. In all patients, the cochleostomy was closed using a small piece of temporalis muscle. There were two perilymphatic gushers encountered but both stopped with plugging of the cochleostomy.

Complications occurred in 17 children in this series (Table IV). Three children had more than one complication. Intra-operative complications occurred in two children (four per cent). In both of these children a small tympanic membrane tear was identified and repaired immediately and no further treatment was required. The post-operative complications were sub-divided by severity.

Complications were classified as minor if no revision surgery was required or if such surgery did not threaten the implant. Strict criteria for inclusion of complications were applied. Any child who required wound appraisal was considered to have a wound infection. Based on this criterion 24 per cent of our children had minor complications. Only one child's wound had to be drained; the remainder settled with antibiotics. Specific complications are shown in Table IV.

Of the children with multiple complications, one child had a minor wound infection and pain over the implant which resolved contemporaneously with resolution of the infection. Another had a minor wound infection and facial nerve stimulation with initial activation of the electrodes (this resolved with programming modification). The third child developed a hypertrophic scar in the incision and post-operatively had had a small haematoma under the flap.

Major complications were those which both threatened the implant and required re-operation. There were three cases of flap breakdown and one of electrode misplacement. The misplaced electrode was diagnosed radiographically and the child subsequently re-implanted. Post-operative imaging showed that the electrode ran into a bone hook (Hoffman and Cohen, 1993) at the entry into the cochlea and was deflected up into the vestibule. At re-operation, the cochleostomy was enlarged anteriorly and the bone hook drilled away, permitting an uneventful re-insertion.

In the children with flap breakdown, two have subsequently required explantation and both of these had suffered direct trauma to the implant site (six and eight months post-implantation). One, a child with severe cerebral palsy, has only now at age 4.5 years learned to walk without support. He fell on the implant site in the playground and lacerated the skin over the implant site. Another, a seven-year-old with severe rheumatic joint disease is also posturally unstable. She fell heavily against a chest of drawers with a corner impacting on the package site. The third child with flap breakdown had a dehiscence at the posterior aspect of the incision which was extending at the time the decision was made to recover the package. Two of these children have had their packages resited at the time of recovering and all three children had rotation flaps to cover the defects over the package sites. There have been no cases of device failure or perilymph fistula and no cases of facial nerve paresis arising from the surgical procedure.

Discussion

Our knowledge of surgical complications following cochlear implant surgery is based on the experience of several large centres whose experience is considerable (Webb *et al.*, 1991; Cohen and Hoffman, 1993). The demand for cochlear implantation is projected to increase (O'Donoghue *et al.*, 1995) and as a result, a number of other centres will be required to develop cochlear implant programmes. These new, smaller programmes will need realistic measures of surgical outcome to which they can compare their own performance rather than using the established benchmarks developed at the larger institutions. Our careful and critical analysis of the first 45 implants in our moderately-sized teaching programme would lead us to conclude that beginning

an implant programme, especially with inclusion of multiply handicapped children, is a demanding task.

Cohen and his co-workers (1988) commented that there was 'very little written regarding risks and complications' and went on to a discussion of complications based on a questionnaire sent to 152 surgeons. The report identified 55 complications occurring in 459 procedures with an overall complication rate of 11.8 per cent. A single life-threatening complication was described, a case of meningitis. Major complications, those requiring revision surgery, occurred in 4.8 per cent of cases and were mostly related to flap breakdown or improper electrode insertion. Minor complications occurred in seven per cent. Importantly, the concept of the learning curve was introduced with respect to flap complications as 80 per cent occurred within the first three procedures performed by individual surgeons. The importance of proper training, meticulous technique and attention to detail were identified as major factors in limiting complications.

The most common major complication occurring after cochlear implantation is flap breakdown; the reported incidence varies from 0.6 to 7.7 per cent (Cohen, 1989; Wang *et al.*, 1990; Webb *et al.*, 1991; Lloyd *et al.*, 1995). We report a 6.8 per cent major flap complication rate. The first flap breakdown in our series occurred within a surgeon's first eight patients which would fall into the area under the learning curve. This child had a revision flap placed to cover his still-functioning receiver-stimulator. The flap healed well and there has been no reason to remove his cochlear implant. The other two cases of flap failure resulted from falls with consequent direct trauma to the implant site in children with significant handicaps directly affecting their postural stability. Both children have continued to use their functioning device until eventual explantation.

We have attempted to minimize further flap complications by altering our surgical technique in the following manner. The anterior edge of the package is felt to be the point at which maximum pressure is placed on a child's thin overlying skin. In children the depth of the cortical bone is less than in adults and the well for the receiver package has to be drilled down to the level of the dura in almost every case. Under the anterior edge, there is often a suture line posterior to the sigmoid sinus which, if not carefully drilled out, will support the package, causing it to protrude above the level of the surrounding cortex even when the rest of the well is down to exposed dura. We now pay specific attention to drilling of the package bed in this area, and place the prolene tie-over suture across the anterior part of the package to prevent it lifting out of the well. Furthermore the package is now routinely bent to allow it to fit more closely to the contour of a child's skull (Hoffman and Cohen, 1993). The flap design itself cannot be held to blame for any failures as it is used successfully in other large implant programmes without significant problems (Webb *et al.*, 1991).

In our three cases of flap breakdown the implant was resited but not removed. The possibility of the implant becoming an infected foreign body was considered in all cases (Hoffman and Cohen, 1993) but prophylactic antibiotics were administered to the patients and the wounds vigorously cleansed. The sites settled quickly in all cases after fresh tissue was brought in to close the wounds and infected tissue removed.

Facial nerve injury has been documented during cochlear implantation (Cohen and Hoffman, 1991) but has not occurred in our series. One patient suffered a mild partial facial nerve paresis six months post-operatively which was concurrent with an episode of otitis media with effusion. Both conditions recovered rapidly after grommets were inserted. It is likely that in obtaining surgical exposure for implantation the facial nerve became exposed at some point along its course and was more susceptible to the effects of otitis media.

The cochleostomy is the least familiar part of cochlear implantation even for a surgeon with considerable experience of conventional otologic procedures (Hoffman and Cohen, 1993). It is therefore understandable that improper electrode placement has been reported to occur with an incidence between one and two per cent. In the present series, one child had the electrode array initially placed in the vestibule despite the fact that the cochleostomy was fashioned without incident and the scala tympani visualized.

There were three patients with hypertrophic scar formation in their incisions and although this had no effect on the implant, it has required a number of operative procedures to control. Hypertrophic scarring is most troublesome when the anterior portion of the incision including the endaural component is involved. In all cases, intralesional steroid (triamcinolone 4 mg/ml) was tried initially but in each case resection of the scar was ultimately required to resolve the problem.

The number of complications in this series can be attributed to two important factors. The first relates to the timing of the complications in the series and the observation that the complication rate declines as experience is gained within an implant team (Summerfield and Marshall, 1995). Development of a new implant programme requires establishment of new surgical and nursing protocols which are based, at the outset, on those of existing programmes which may differ in various respects. Our complication rate is decreasing with time and this underscores the importance of the learning period in development of an implant programme. We feel that reporting our initial experience is important so that new programmes are able to evaluate themselves in comparison with other developing programmes as well as with fully mature programmes.

Another factor which contributed to the complication rate is the inclusion of a number of children who might be considered unsuitable for implantation at other centres owing to their other handicaps. Our programme has been developed especially to accom-

modate such children even though at the outset we anticipated that this would have implications for surgical and post-operative success. Despite this we have 43 children with functioning implants to date who are in a position to benefit from their implants. We are currently considering the use of head protection in implanted children with postural instability to reduce the risk of direct trauma to the implant site.

Summary

Critical evaluation of paediatric cochlear implantation is required to establish realistic outcome goals for new programmes wishing to offer this service. In addition, the higher complication rate in the multiply-handicapped child must be appreciated and not used to refuse such children access to a technology which should optimize their potential. Careful attention to detail, both surgical and actuarial, is vital as we strive to improve the outcome of implantation programmes and to offer the opportunity of implantation to an increasing number of deaf children.

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