P970051

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administration
9200 Corporate Boulevard
Rockville MD 20850

Ronald E. West
President
Cochlear Corporation
61 Inverness Drive East
Suite 200
Englewood, CO 80112

JUN 25 1998

Re: P970051
Nucleus 24 Cochlear Implant System
Filed: November 3, 1997
Amended: January 28 and April 8, 1998

Dear Mr. West:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its review of your premarket approval application (PMA) for the Nucleus 24 Cochlear Implant System.

The Nucleus 24 Cochlear Implant is intended to restore a level of auditory sensation to adults and children via electrical stimulation of the auditory nerve.

1. Postlinguistically Deafened Adults

The Nucleus 24 Cochlear Implant System, hereinafter referred to as the Nuclear 24, is intended for use in individuals 18 years of age or older who have bilateral, postlinguistic, sensorineural hearing impairment and obtain limited benefit from appropriate binaural hearing aids. These individuals typically have moderate-to-profound hearing loss in the low frequencies and profound (90 dB HL) hearing loss in the mid-to-high speech frequencies. Limited benefit from amplification is defined by test scores of 40% correct or less in the best-aided listening condition on tape recorded tests of open-set sentence recognition.

2. Prelinguistically and Perilinguistically Deafened Adults

The Nucleus 24 is intended for use in prelinguistically and perilinguistically deafened individuals, 18 years of age or older, who have profound sensorineural deafness and do not benefit from appropriate hearing aids.

3. Children

The Nucleus 24 is intended for use in children 18 months through 17 years of age who have bilateral profound sensorineural deafness and demonstrate little or no benefit from appropriate binaural hearing aids. In younger children, little or no aided benefit is defined as lack of progress in the development of simple auditory skills in conjunction with appropriate amplification and participation in intensive aural habilitation over a three-to-six-month period. In older children, lack of aided benefit is defined as < 20% correct on the open-set Multi-syllabic Lexical Neighborhood Test (MLNT) or Lexical Neighborhood Test (LNT), depending upon the child's cognitive and linguistic skills. A three-to-six-month hearing aid trial is required for children without previous aided experience.

We are pleased to inform you that the PMA is approved subject to the conditions described below and in the "Conditions of Approval" (enclosed). You may begin commercial distribution of the device upon receipt of this letter.

The sale, distribution, and use of this device are restricted to prescription use in accordance with 21 CFR 801.109 within the meaning of section 520(e) of the Federal Food, Drug, and Cosmetic Act (the act) under the authority of section 515(d)(1)(B)(ii) of the act. FDA has also determined that, to ensure the safe and effective use of the device, the device is further restricted within the meaning of section 520(e) under the authority of section 515(d)(1)(B)(ii) insofar as the sale, distribution, and use must not violate sections 502(q) and (r) of the act.

In addition to the post-approval requirements in the enclosure, the annual post-approval reports must include the results and analyses of the two post-approval studies described below. The studies are designed to provide long-term data demonstrating the safety and effectiveness of the Nucleus 24 Cochlear Implant System in children implanted between 18 months and five years of age. Device effectiveness will be directly assessed using age-appropriate measures of auditory speech perception. Receptive and expressive language skills, which are secondary or indirect benefits of cochlear implantation, also will be evaluated over time using a commonly applied assessment tool.

1. The existing investigational protocol will be continued for three years from the date of this approval in the first 100 children implanted between 18 months and up to five years of age as a part of the clinical trial. Post-operative evaluations will be conducted at three, six, and twelve month intervals, and annually thereafter. Evaluation measures will include the following:

   - Electrical Threshold and Maximum Comfort Level Measurements
   - Aided Sound Field Detection Thresholds
   - Meaningful Auditory Integration Scale (MAIS)
   - Early Speech Perception Battery (Low Verbal or Standard Version as appropriate)

  - Pattern Perception
  - Spondee Identification
  - Monosyllable Identification
- GASP Words
- Multi-syllable Lexical Neighborhood Test (MLNT)

2. Expressive and receptive language competency for children implanted between 18 months and up to five years of age will be assessed annually using the Reynell Developmental Language Scales (RDLS). The study will be conducted for five years for children implanted at three investigational sites: New York University Medical Center; Manhattan Eye, Ear, and Throat Hospital; and Indiana University Medical Center. The RDLS instrument will be administered in the language modality used by the child (e.g., spoken English, signed English, Cued Speech, etc.) and results obtained for the receptive and expressive scales will be converted to age-equivalent scores. The RDLS has been normed on hearing children and is commonly used to evaluate developing language constructs in hearing-impaired children who are as young as 18 months of age.

Expiration dating for this device has been established and approved at 24 months.

CDRH will notify the public of its decision to approve your PMA by making available a summary of the safety and effectiveness data upon which the approval is based. The information can be found on the FDA CDRH Internet Home Page located at http://www.fda.gov/cdrh/pmapage.html. Written requests for this information can also be made to the Dockets Management Branch (HFA-305), Food and Drug Administration, 12420 Parklawn Dr., rm. 1-23, Rockville, MD 20857. The written request should include the PMA number or docket number. Within 30 days from the date that this information is placed on the Internet, any interested person may seek review of this decision by requesting an opportunity for administrative review, either through a hearing or review by an independent advisory committee, under section 515(g) of the Federal Food, Drug, and Cosmetic Act (the act).

Failure to comply with the conditions of approval invalidates this approval order. Commercial distribution of a device that is not in compliance with these conditions is a violation of the act.

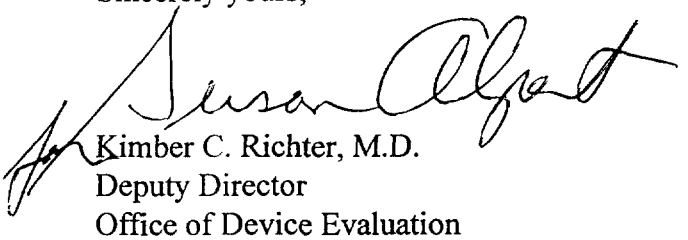
You are reminded that, as soon as possible and before commercial distribution of your device, you must submit an amendment to this PMA submission with copies of all approved labeling in final printed form.

All required documents should be submitted in triplicate, unless otherwise specified, to the address below and should reference the above PMA number to facilitate processing.

PMA Document Mail Center (HFZ-401)
Center for Devices and Radiological Health
Food and Drug Administration
9200 Corporate Blvd.
Rockville, Maryland 20850

If you have any questions concerning this approval order, please contact J. E. Warren at (301) 594- 2080.

Sincerely yours,



Kimber C. Richter, M.D.
Deputy Director
Office of Device Evaluation
Center for Devices and
Radiological Health

Enclosure
Conditions of Approval

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Issued: 3-4-98

CONDITIONS OF APPROVAL

APPROVED LABELING. As soon as possible, and before commercial distribution of your device, submit three copies of an amendment to this PMA submission with copies of all approved labeling in final printed form to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration (FDA), 9200 Corporate Blvd., Rockville, Maryland 20850.

ADVERTISEMENT. No advertisement or other descriptive printed material issued by the applicant or private label distributor with respect to this device shall recommend or imply that the device may be used for any use that is not included in the FDA approved labeling for the device. If the FDA approval order has restricted the sale, distribution and use of the device to prescription use in accordance with 21 CFR 801.109 and specified that this restriction is being imposed in accordance with the provisions of section 520(e) of the act under the authority of section 515(d)(1)(B)(ii) of the act, all advertisements and other descriptive printed material issued by the applicant or distributor with respect to the device shall include a brief statement of the intended uses of the device and relevant warnings, precautions, side effects and contraindications.

PREMARKET APPROVAL APPLICATION (PMA) SUPPLEMENT. Before making any change affecting the safety or effectiveness of the device, submit a PMA supplement for review and approval by FDA unless the change is of a type for which a "Special PMA Supplement-Changes Being Effected" is permitted under 21 CFR 814.39(d) or an alternate submission is permitted in accordance with 21 CFR 814.39(e). A PMA supplement or alternate submission shall comply with applicable requirements under 21 CFR 814.39 of the final rule for Premarket Approval of Medical Devices.

All situations which require a PMA supplement cannot be briefly summarized, please consult the PMA regulation for further guidance. The guidance provided below is only for several key instances.

A PMA supplement must be submitted when unanticipated adverse effects, increases in the incidence of anticipated adverse effects, or device failures necessitate a labeling, manufacturing, or device modification.

A PMA supplement must be submitted if the device is to be modified and the modified device should be subjected to animal or laboratory or clinical testing designed to determine if the modified device remains safe and effective.

A "Special PMA Supplement - Changes Being Effected" is limited to the labeling, quality control and manufacturing process changes specified under 21 CFR 814.39(d)(2). It allows for the addition of, but not the replacement of previously approved, quality control specifications and test methods. These changes may be implemented before FDA approval upon acknowledgment by FDA that the submission is being processed as a "Special PMA Supplement - Changes Being Effected." This acknowledgment is in addition to that issued by the PMA Document Mail Center for all PMA supplements submitted. This procedure is not applicable to changes in device design, composition, specifications, circuitry, software or energy source.

Alternate submissions permitted under 21 CFR 814.39(e) apply to changes that otherwise require approval of a PMA supplement before implementation of the change and include the use of a 30-day PMA supplement or annual postapproval report. FDA must have previously indicated in an advisory opinion to the affected industry or in correspondence with the applicant that the alternate submission is permitted for the change. Before such can occur, FDA and the PMA applicant(s) involved must agree upon any needed testing protocol, test results, reporting format, information to be reported, and the alternate submission to be used.

POSTAPPROVAL REPORTS. Continued approval of this PMA is contingent upon the submission of postapproval reports required under 21 CFR 814.84 at intervals of 1 year from the date of approval of the original PMA. Postapproval reports for supplements approved under the original PMA, if applicable, are to be included in the next and subsequent annual reports for the original PMA unless specified otherwise in the approval order for the PMA supplement. Two copies identified as "Annual Report" and bearing the applicable PMA reference number are to be submitted to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850. The postapproval report shall indicate the beginning and ending date of the period covered by the report and shall include the following information required by 21 CFR 814.84:

(1) Identification of changes described in 21 CFR 814.39(a) and changes required to be reported to FDA under 21 CFR 814.39(b).

(2) Bibliography and summary of the following information not previously submitted as part of the PMA and that is known to or reasonably should be known to the applicant:

(a) unpublished reports of data from any clinical investigations or nonclinical laboratory studies involving the device or related devices ("related" devices include devices which are the same or substantially similar to the applicant's device); and

(b) reports in the scientific literature concerning the device.

If, after reviewing the bibliography and summary, FDA concludes that agency review of one or more of the above reports is required, the applicant shall submit two copies of each identified report when so notified by FDA.

ADVERSE REACTION AND DEVICE DEFECT REPORTING. As provided by 21 CFR 814.82(a)(9), FDA has determined that in order to provide continued reasonable assurance of the safety and effectiveness of the device, the applicant shall submit 3 copies of a written report identified, as applicable, as an "Adverse Reaction Report" or "Device Defect Report" to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850 within 10 days after the applicant receives or has knowledge of information concerning:

(1) A mix-up of the device or its labeling with another article.

(2) Any adverse reaction, side effect, injury, toxicity, or sensitivity reaction that is attributable to the device and

(a) has not been addressed by the device's labeling or

(b) has been addressed by the device's labeling, but is occurring with unexpected severity or frequency.

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(3)Any significant chemical, physical or other change or deterioration in the device or any failure of the device to meet the specifications established in the approved PMA that could not cause or contribute to death or serious injury but are not correctable by adjustments or other maintenance procedures described in the approved labeling. The report shall include a discussion of the applicant's assessment of the change, deterioration or failure and any proposed or implemented corrective action by the applicant. When such events are correctable by adjustments or other maintenance procedures described in the approved labeling, all such events known to the applicant shall be included in the Annual Report described under "Postapproval Reports" above unless specified otherwise in the conditions of approval to this PMA. This postapproval report shall appropriately categorize these events and include the number of reported and otherwise known instances of each category during the reporting period. Additional information regarding the events discussed above shall be submitted by the applicant when determined by FDA to be necessary to provide continued reasonable assurance of the safety and effectiveness of the device for its intended use.

REPORTING UNDER THE MEDICAL DEVICE REPORTING (MDR) REGULATION. The Medical Device Reporting (MDR) Regulation became effective on December 13, 1984. This regulation was replaced by the reporting requirements of the Safe Medical Devices Act of 1990 which became effective July 31, 1996 and requires that all manufacturers and importers of medical devices, including in vitro diagnostic devices, report to the FDA whenever they receive or otherwise become aware of information, from any source, that reasonably suggests that a device marketed by the manufacturer or importer:

(1)May have caused or contributed to a death or serious injury; or

(2)Has malfunctioned and such device or similar device marketed by the manufacturer or importer would be likely to cause or contribute to a death or serious injury if the malfunction were to recur.

The same events subject to reporting under the MDR Regulation may also be subject to the above "Adverse Reaction and Device Defect Reporting" requirements in the "Conditions of Approval" for this PMA. FDA has determined that such duplicative reporting is unnecessary. Whenever an event involving a device is subject to reporting under both the MDR Regulation and the "Conditions of Approval" for a PMA, the manufacturer shall submit the appropriate reports required by the MDR Regulation within the time frames as identified in 21 CFR 803.10(c) using FDA Form 3500A, i.e., 30 days after becoming aware of a reportable death, serious injury, or malfunction as described in 21 CFR 803.50 and 21 CFR 803.52 and 5 days after becoming aware that a reportable MDR event requires remedial action to prevent an unreasonable risk of substantial harm to the public health. The manufacturer is responsible for submitting a baseline report on FDA Form 3417 for a device when the device model is first reported under 21 CFR 803.50. This baseline report is to include the PMA reference number. Any written report and its envelope is to be specifically identified, e.g., "Manufacturer Report," "5-Day Report," "Baseline Report," etc. Any written report is to be submitted to:

Food and Drug Administration
Center for Devices and Radiological Health
Medical Device Reporting
PO Box 3002
Rockville, Maryland 20847-3002

Copies of the MDR Regulation (FOD # 336&1336)and FDA publications entitled "An Overview of the Medical Device Reporting Regulation" (FOD # 509) and "Medical Device Reporting for Manufacturers" (FOD #987) are available on the CDRH WWW

Home Page. They are also available through CDRH's Fact-On-Demand (F-O-D) at 800-899-0381. Written requests for information can be made by sending a facsimile to CDRH's Division of Small Manufacturers Assistance (DSMA) at 301-443-8818.

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SUMMARY OF SAFETY AND EFFECTIVENESS DATA

I. GENERAL INFORMATION:

Device Generic Name: Cochlear Implant

Device Trade Name: Nucleus® 24 Cochlear Implant System

Applicant's Name and Address: Cochlear Corporation
61 Inverness Drive East
Suite 200
Englewood, Colorado 80112

Premarket Approval Application (PMA) Number: P970051

Date of Panel Recommendation: The PMA was not referred to Panel (see section XII)

Date of Notice of Approval of Application: June 25, 1998

II. INDICATIONS FOR USE:

The Nucleus 24 Cochlear Implant System, hereinafter referred to as the Nucleus 24, is intended to restore a level of auditory sensation to adults and children via electrical stimulation of the auditory nerve. Nucleus 24 is indicated for the following:

- Postlinguistically deafened adults 18 years of age or older who have bilateral, postlinguistic, sensorineural hearing impairment and obtain limited benefit from appropriate binaural hearing aids. These individuals typically have moderate-to-profound hearing loss in the low frequencies and profound (≥90 dB HL) hearing loss in the mid-to-high speech frequencies. Limited benefit from amplification is defined by test scores of 40% correct or less in the best-aided listening condition on tape recorded tests of open-set sentence recognition.

- Prelinguistically and perilinguistically deafened adults, 18 years of age or older, who have profound sensorineural deafness and do not benefit from appropriate hearing aids.

- Children 18 months through 17 years of age who have bilateral profound sensorineural deafness and demonstrate little or no benefit from appropriate binaural hearing aids. In younger children, little or no aided benefit is defined as lack of progress in the development of simple auditory skills in conjunction with appropriate amplification and participation in intensive aural habilitation over a three-to-six month period. In older children, lack of aided benefit is defined as < 20% correct on the open-set Multi-syllabic Lexical Neighborhood Test (MLNT) or Lexical Neighborhood Test (LNT), depending upon the child's cognitive and linguistic skills. A three-to-six - month hearing aid trial is required for children without previous aided experience.

III. CONTRAINDICATIONS:

The Nucleus 24 should not be implanted in individuals with: 1) deafness due to lesions of the acoustic nerve or central auditory pathway; 2) active middle ear infections; 3) absence of cochlear development; 4) tympanic membrane perforation in the presence of active middle ear disease.

IV. WARNINGS AND PRECAUTIONS:

Warnings and precautions for use of the device are stated in the attached product labeling (Attachment A).

V. DEVICE DESCRIPTION:

The Nucleus 24 is a multi-channel cochlear implant system that provides sound perception by electrically stimulating the auditory nerve in patients with severe-to-profound deafness who derive minimal benefit from conventional hearing aids. The Nucleus 24 Cochlear Implant System consists of an implant (C124M), two speech processors (body-worn SPrint and ear-level ESPrit), two programming systems (PC based Clinic Programming System (CPS) and an optional laptop compatible Portable Programming System (PPS).

A) PRINCIPLES OF OPERATION:

The Nucleus 24 converts sound in the environment into an electrical code and transmits this code to the auditory nerves within the inner ear (cochlea).

The process begins with an ear-level external microphone that converts sound into an electrical signal, which is delivered to an externally worn speech processor. The speech processor converts the electrical signal into a code that has been determined through the device fitting process to be appropriate for the user. The coded signal is delivered from the speech processor to a transmitting coil, which rests over the skin behind the ear and is magnetically aligned to the surgically implanted receiver/stimulator. The signal is delivered to the implanted receiver via electromagnetic induction. The signal is decoded by the receiver and delivered to the 22 electrodes implanted within the cochlea. The pattern of stimulation delivered by the electrode array is determined by the characteristics of the incoming sound (frequency and amplitude) and the measured characteristics of the individual implant recipient.

The device can deliver stimulus pulses ranging from 10 μA and 1750 μA (in logarithmic steps) in amplitude, with a pulse duration as low as 25μs, at stimulation rates up to 14,400 Hz. To ensure safety, the CI24M delivers balanced, bi-phasic current pulses, shorts all electrodes to a common point between stimulus pulses, and it capacitively couples two extra-cochlear electrodes.

Both speech processors are programmed to optimize the coding strategy for the patient. Implant recipients outfitted with the SPrint body-worn speech processor can select up to four independent programs that can be used to select speech processing for specific listening conditions, such as music. The speech processor is controlled by the implant recipient and can be programmed by the audiologist to include separate volume and sensitivity controls, a series of audible or private alarms and/or locks to prevent children from manipulating some controls. Implant recipients outfitted with the ESprit ear level speech processor select between two available programs. One of the two user controls is for program selection; the other control can be configured to operate as either a sensitivity or volume control.

B) DEVICE COMPONENTS:

CI24M Cochlear Implant – The CI24M component is a redesign of the Cochlear CI22M implant. Three PMAs have been approved for cochlear implant systems with the CI22M implant component. The CI24M implant consists of the receiver/stimulator hermetically housed in titanium, a platinum receiver coil encased in silicone elastomer, and the same intra-cochlear electrode array (22 banded, platinum, active electrodes and 10 stiffening rings) used in the Nucleus 22. The Nucleus 24 adds extra-cochlear ground electrodes (a 1.5 mm platinum ball electrode designed to be placed under the temporalis muscle and a plate electrode mounted on the lateral surface of the receiver/stimulator). These extra-cochlear electrodes allow the use of monopolar stimulation in addition to bipolar, common ground and variable modes of stimulation available in the Nucleus 22. The two extra-cochlear electrodes provide redundancy and additional programming flexibility and enable the device to perform various telemetry and diagnostic functions. The bi-directional

telemetry feature, "Neural Response Telemetry" (NRT), enables an external processor to measure electrode voltages, internal references, output current, and evoked auditory potentials for clinical diagnostics and research testing. Other new features in the CI24M design include:

- A magnet that can be surgically removed when MRI imaging of the patient is required.
- Increased magnetic strength of the coupling magnet and increased diameter of the antenna coil to provide better headset coil attachment. Markings have been placed on the coupling magnet to indicate the correct orientation of the implanted device.
- An increase in the carrier frequency of the rf link from 2.5MHz to 5.0MHz and addition of a new rf protocol, both designed to permit higher stimulation rates and implementation of new coding strategies.
- Re-design of the receiver/stimulator with a multi-layer ceramic hybrid substrate, resulting in miniaturization of the electronics assembly and reduction in the overall thickness of the implant. The new design reduces the volume of bone that must be excavated from 1400 cubic mm to 380 cubic mm.
- A preformed antenna to fit the natural contour of the skull.

Sprint Body-worn Speech Processor – This device component is a fully digital speech processor capable of storing up to four different programs. The Sprint offers a volume control, in addition to a sensitivity control, and can be powered by either a single or double battery module. The functional status of the Sprint is indicated by a programmable liquid crystal display. A behind-the-ear headset consists of a directional microphone, transmitting coil and cables.

ESPrit Ear-level Speech Processor – This device component is a speech processor that combines a directional microphone, speech processor circuitry and batteries into an ear-level package, the size of a power hearing aid. The ESPrit operates on two high-power hearing aid batteries and is capable of storing two different programs. A programmable potentiometer operates as either a sensitivity or volume control.

VI. ALTERNATIVE PRACTICES / PROCEDURES:

Alternative treatments to a multi-channel cochlear implant for adults and children include conventional hearing aids, tactile devices, or the use of manual communication (sign language). Tactile devices are worn externally and convert sound waves into mechanical vibration or electrical current, which can be detected on the skin by the wearer.

VII. MARKETING HISTORY:

The first Nucleus 22 surgery occurred in 1982, with the first U.S. surgery occurring in 1983, following FDA approval of the adult clinical trial. FDA approval of the PMA for adults then followed in 1985. Pediatric clinical trial approval was granted for the Nucleus 22 in 1986, followed by PMA approval in 1990. The Spectra speech processor was a more recent development and was approved for marketing in 1994.

The Nucleus 24 system is currently being sold in over 40 countries. Cochlear was authorized to affix the CE mark to the Nucleus 24 system for both adults and children on September 27, 1995 and updated on November 27, 1996. As of May 31, 1998 more than 2300 adults and children have been implanted with the Nucleus 24 in Europe, Australia, Asia, Africa and Latin/South America. The Nucleus 24 has not been withdrawn from any country for any reason.

VIII. POTENTIAL ADVERSE EFFECTS OF DEVICE ON HEALTH:

Insertion of the electrode into the cochlea will result in complete loss of residual hearing in the implanted ear.

Implant patients will incur the normal risks associated with surgery and general anesthesia. In addition, this procedure may result in infection or bleeding, numbness or stiffness about the ear, injury to or stimulation of the facial nerve, taste disturbance, dizziness, increased tinnitus, neck pain and perilymph fluid leak. Perilymph fluid leak may result in meningitis.

The cochlear implant results in a palpable lump under the skin behind the ear. The presence of a foreign body may cause irritation, inflammation, or breakdown of the skin and, in some cases, extrusion of the device. The electrode array may migrate partially or completely out of the cochlea, resulting in decreased hearing ability. The electrode lead may perforate structures of the external ear, such as the tympanic membrane or canal wall. Misplacement of the electrode array may result in the perception of non-auditory sensations. Such complications may require additional medical treatment, surgery, or removal of the device.

Electrical stimulation may result in increased tinnitus, facial nerve stimulation, dizziness, or pain. Individuals who have residual hearing in the ear selected for implantation have a slightly greater risk of short-term postoperative dizziness than individuals with no residual hearing in that ear.

The long-term effects of electrode insertion trauma or chronic electrical stimulation are unknown. Such effects may include new bone growth in the cochlea or deterioration of nerve cells. These effects may preclude replacement of the electrode array or may lead to eventual deterioration of cochlear response.

Failure of component parts (both external and internal) can result in the perception of uncomfortably loud sounds or no sound. Failure of various parts of the implanted device may result in removal, replacement of the implant, or a reduction of the number of electrodes in use.

IX. SUMMARY OF PRE-CLINICAL STUDIES:

A) LABORATORY STUDIES:

1) Microbiological

a) Sterility Assurance: Three half cycles and three full cycles of ethylene oxide sterilization were performed on six C124M devices to verify sterilization efficacy. One fractional cycle exposure was used to demonstrate the relative resistance of the biological indicator to the naturally occurring bioburden. All three half cycle and full cycle sterilization runs were 100 per cent lethal to the biological indicator.

b) Ethylene Oxide Residual Analysis: Ethylene oxide, ethylene chlorhydrin, and ethylene glycol residuals were determined by gas chromatography analysis after 24 hour aeration of the test samples. All residual values were below the acceptance criteria and met the required minimum for sterilant residuals.

c) Pyrogenicity: Pryogen levels were determined by Limulus Amebocyte Lysate (LAL) Gel Clot testing. Test articles were immersed in sterile non-pyrogenic water for injection. Extracts were incubated at 37°±1° for 60 min ± 2min. Assays performed on 95 C124M test articles for the 12 months preceding submission of the PMA showed no signs of pyrogenicity.

2) Biocompatibility

The materials of construction for the C124M implant are the same as those for the previously approved C122M device except for NuSil MED-4516 silicone used on the receiver coil tube. Data from a series of in-vitro and in-vivo studies demonstrated the biocompatibility of the following tissue contacting components of the C122M device:

Material	Device Component
Platinum (Grades 99.95/99.80)	Electrodes and Electrode Array Rings
Platinum/Irridium (10%)	Electrode Wires
Titanium (Grades 1 and 2)	Electronics Case and Magnetic Package
Silicone MDX-4-4210	Electrode Array Support, Outer Moldings
Silicone MDX-4-4515	Electrode Lead Support
Parylene	Wire Coating
Ceramic (Per A20103)	Feed Through
Polyurethane	Receiver Coil Tube
Silicone Adhesive (Type A)	

NuSil MED-4516 silicone is used for the reciever coil tube in the C124M implant, replacing the polyurethane used in the C122M. The receiver coil tube is within the outer molding of the C124 implant, and under normal conditions should not be in direct tissue contact, but may contact body fluids.

The manufacturer of Nusil MED-4516 has performed detailed biocompatibility studies of the material to the requirements of FDA's "Guidance for Manufacturer's of Silicone Devices Affected by the Withdrawal of Dow Corning Silastic Materials". The material has been tested for cytotoxicity, acute systemic toxicity, intracutaneous irritation, cytogenic damage, and sensitization. Salmonella/Ames Mutagenic and 90 day implantation testing was also conducted. The testing confirmed the biocompatibility of the material.

(3) Electrode Insertion and Cochlear Histopathology

Studies in human cadaver temporal bones have been conducted to evaluate the effects of surgically implanting the type of multi-electrode array found in the C124M implant (Ref 1,2). Fourteen fresh temporal bones were used in one study and nine in the second study. The induced trauma was considered to be within acceptable limits provided that insertion was stopped at the point of resistance. Subsequent work has led to improved techniques for electrode insertion. A study of the relative mechanical properties of stiff single wire electrodes and the Cochlear multi-electrode array demonstrated mechanical superiority of the banded array (Ref 3).

It has been shown clinically that intracochlear electrodes can be removed and replaced without any apparent adverse effect on performance. However, mechanical injury from the insertion of any intracochlear electrode may occur, even in apparently atraumatic cases (Ref 4).

(4) Measurement of DC Levels

Direct current in the several microamperes range has been associated with neural tissue damage. To minimize the level of the potential direct current the CI24M uses capacitively coupled extra-cochlear electrodes and the receiver/stimulator uses a charge recovery system which is effective in minimizing the level of direct current both at low and high stimulation rates. The levels of direct current were measured as a function of the stimulation rate (Ref 5). The measurements were taken using a continuous stimulation pattern (e.g., 100% duty cycle), which is more severe than the stimulation pattern associated with a worst case listening environment. The results of the study indicate that the average magnitudes of the direct current delivered to the cochlea, at maximum stimulation currents and a total stimulation rate of 2000 Hz, were below 20 nA in the monopolar mode and below 30 nA in the bipolar

mode. The results were well below the known biologically safe level for long-term direct current delivery to the auditory nerve or cochlea.

B) DEVICE TESTING

1) Electromagnetic Compatibility

The C124M implant was tested for susceptibility to electromagnetic fields (far field and GSM digital mobile phones) and for susceptibility to electrostatic discharges. The device was also tested for radiated emissions.

a) **Electromagnetic Susceptibility**

The C124M device and both speech processors were tested to determine the susceptibility of the implant to GSM digital mobile phone electromagnetic fields and to rf electromagnetic fields when placed in a normal functioning configuration and when subjected to electromagnetic radiation in the far field regions of the electromagnetic field source. Two separate systems were subjected to high frequency electric fields in accordance with the IEC 601-1-2 and IEC 801-3 - and to GSM digital mobile phones at a severity level of 3 V/m.

The test results indicate that exposure of the device to electromagnetic fields or to GSM digital mobile telephones will generate some unwanted stimuli but will not result in interference with the normal operation of the system. Exposure will not: induce damage to the cochlear prothesis; will not result in unintended or unwanted stimulation; and will not result in intermittent or ceased operation for the duration of the exposure.

b) **Susceptibility to Electrostatic Discharge (ESD)**

Testing was conducted to determine if the device meets the IEC 801-2 standard for ESD. The C124M implant and both speech processors were tested for the following ESD test levels:

Common Mode discharge:	+/- 8 kV, contact discharge
	+/- 16 kV air discharge
Differential Mode:	+/- 8 kV, contact discharge
	+/- 16 kV, air discharge

The C124M device meets IEC 801-2, Test Level 4, for both contact and air discharge methods. The testing indicates normal performance within the manufacturer's specification limits. Both speech processors meet IEC 801-2, Test Level I for contact discharge method, and IEC 801-2, Test Level 2 for air discharge method .

2) Environmental Testing

Ten units of the C124M were tested to evaluate the implant's ability to withstand extreme environmental conditions which can occur during manufacture, shipping, and use. Following the environmental testing each unit was tested for functionality and hermiticity.

Test (Test Standard)

a) Random Vibration (IEC 68-2-47)
b) Thermal Cycling (As 1099.2.Nb)
c) Shock Acceleration (As 1099 test Ea)
d) Low Temperature (As 1099 test Aa)
e) Dry Heat (As 1099 Bd)

There was no change in the function of the device following each environmental test and no change in the hermiticity following all the tests.

3) Stress and Wear Testing

a) Dynamic Fatigue

Test samples of the intracochlear electrode array and the extracochlear electrode lead at its exit from the stimulator, were tested for linear fatigue by deflecting the leads by 10 per cent of their length for 2 million cycles. The test articles experienced no mechanical, electrical, or insulation failures for the duration of the testing.

The receiver coil was subjected to in-plane and out-of-plane angular deformation for 2.5 million cycles without loss of continuity. Microscopic examination showed no evidence of damage to the test article.

b) Severe Stress

The C124M implant was subjected to a series of tests designed to determine the effects of extreme stress that could occur in manufacture and surgery, and the effects of severe mechanical trauma during use.

Twisting and Stretching – The electrode lead was subjected to 10 cycles of 360° clockwise and counter-clockwise twisting while stretched at 10 per cent of the electrode lead length. The test specimen experienced no failure or damage.

Shear – Three electrode leads were tested in four different orientations to determine the ability of the lead to withstand shear at the point of lead exit from the stimulator body. A shear force up to 0.4 N was applied perpendicular to the lead at a distance of 1.2 mm from the titanium case. Lead deformations of 32 mm – 35 mm were observed. Under the applied shear conditions, the test results demonstrate that sufficient energy is dissipated in the electrode leads to avoid damage due to shear.

Bending –To determine the ability of the receiver coil to withstand mechanical stress that could occur during manufacture, implantation, and use, two test samples were subjected to severe bending forces and tested for changes in electrical resistance. No change in electrical resistance was observed. Microscopic examination of the test samples revealed no observable damage.

c) Destructive Testing

Single cycle destructive testing at very high stress levels was used to determine the limits of device design. A variable number of samples was used to assess the tensile strength of the electrode lead wire configuration.

Tensile force was applied to the electrode lead of five test articles at a displacement rate of 0.25 mm/sec. Lead elongation of 71% to 85% was recorded before failure. An elongation of 50 % is considered to be far beyond reasonable expectations of severe handling.

d) Activity Testing

The receiver/stimulator was tested to determine the ability of the implant to withstand severe conditions that could occur during sporting activities.

Pressure – To determine if the implant can withstand a simulated under-water pressure of 100 feet without physical or electrical damage, two test samples were subjected to an upper level pressure of 5 atm + 0.1/-0 atm for 15 minutes. The applied pressure caused no physical or electrical damage to the implant.

Compressive Impact – The implant was subjected to an impact from a 3.6 kg weight at a distance of 0.45 meters for 5 cycles to simulate the impact of a T-ball traveling at 40 mph. The implant was tested for functional performance after each impact. None of the collisions caused significant electrical or mechanical damage.

Crushing – A sample was tested to determine the maximum compressive force that the implant can withstand before damage occurs. The implant failed under a compressive force of 911 newton, a force well in excess of the force that would result in permanent damage to a skull.

e) **Magnet Removal Damage**

The C124M is designed with a removable magnet to enable an implant patient to be examined with Magnetic Resonance Imaging (MRI). The magnet is surgically removed from its silicone cavity, replaced with a non-magnetic plug of titanium during the procedure, and replaced after the procedure. The device was tested to demonstrate that it can withstand repeated removal and re-insertion of the magnet without damage to the silicon cavity. The opening of the cavity is smaller than the magnet and a silicone lip must be raised with a blunt instrument and the instrument maneuvered between the lip and the magnet, making the lip an area vulnerable to tearing.

A simulated surgical procedure of removing and re-inserting the magnet with a blunt instrument was repeated for 16 magnet removals and 16 magnet lodgments in two test samples. The test samples were then inspected for visual damage to the silicone cavity and tested to determine if the magnet could be dislodged from the cavity by pulling the headset coil.

Visual inspection showed no break in the structural integrity of the silicone cavity. The magnet remained in the cavity after 20 cycles of the pull test.

4) Failure Modes and Effects Analysis

Quantitative and qualitative analyses were performed to identify and to estimate the likelihood of potential safety hazards that may be associated with the use of the Nucleus™ CI24M Cochlear Implant. No failure that could lead to a life-threatening situation was identified. The theoretical failure rate, derived from the electrical and mechanical reliability characteristics of the components, interconnections and materials used in the CI24M is estimated as 4 failures in 100 implants per 10 years (with 90% probability). The observed failure rate in the sample of 133 adults described in the PMA application was zero.

The effects and severity of the worst case CI24M component failure which could result in potentially hazardous direct current was assessed The worst case magnitude of the direct current delivered, during monopolar stimulation at *maximum* stimulation currents and a pulse rate of 2000Hz, were below the safe level of 100 nA.

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X. SUMMARY OF CLINICAL STUDIES:

The objectives of the clinical studies were to validate the clinical function and demonstrate the safety and effectiveness of the Nucleus 24 Cochlear Implant System, programmed to implement the SPEAK speech coding strategy in a representative sample of pediatric and adult subjects. The SPEAK strategy was provided to investigational subjects in two speech processing devices: a body-worn (SPrint) processor and an ear-level (ESPrit processor).

A) STUDY POPULATION:

1) Adults

One-hundred, thirty-five (135) adults were implanted with the C124M cochlear implant at 32 investigational sites as of September 16, 1997. Data was collected on 67 of the 135 implant recipients to support device effectiveness. The other 66 subjects had not reached the three-month postoperative evaluation interval at the time of the reporting. With two exceptions, all of the 135 subjects are full-time users of the device. One subject became dissatisfied with his implant shortly after the initial fitting and has refused to return to his center. The other subject qualified for the study and received the device, but died of complications related to drug use several weeks after a successful initial stimulation. Data was collected on the remaining 133 subjects to support device safety.

2) Children

One-hundred seventy-nine (179) children were implanted with the C124M cochlear implant at 30 investigational sites located in the United States (28 sites) and Canada (2 sites). One-hundred-fifty (150) of the implant recipients were used to support device safety. Seventy-one (71) children with three month postoperative data on January 7, 1998 were included in the data supporting effectiveness. Seventy-nine (79) children had not reached the three-month postoperative evaluation interval by January 7, 1998. Six month post-operative data on 47 pediatric patients (as of March 31, 1998) was submitted on April 9, 1998 as a PMA amendment in support of effectiveness.

B) STUDY DESIGN

Device effectiveness was investigated using a single subject, repeated measures research design with subjects acting as their own controls. Blinding (masking) procedures were not included in the design, as the presence/absence of a cochlear implant is not easily concealed from the device recipients and/or clinical investigators.

1) Adults

Preoperatively, subjects were evaluated with a number of audiological tests in the best-aided condition. Postoperatively, auditory performance was assessed at two weeks, four weeks, and three months post-activation , using the body-worn (SPrint) processor. Subjects were fitted with the ear level (ESPrit) processor following a minimum of three months experience with the body-worn processor, and at that time, baseline auditory performance using the body-worn processor was re-assessed. After 30 days of daily ESPrit use, subjects were evaluated using the ESPrit processor.

2) Children

In order to establish a baseline level of auditory function, investigational subjects were evaluated with an appropriate personal amplification system, preoperatively. Due to the confounding influence of developing listening, linguistic and cognitive skills in young children, separate selection criteria and evaluation materials were prescribed for young (< 5 years) and older (≥ 5 years) children. Young

children were evaluated preoperatively following an appropriate trial period with amplification and rehabilitation. Following surgical implantation of the investigational device and a four-to-six week period of healing, the cochlear implant was activated and auditory performance re-assessed at a series of intervals. Postoperative evaluations were conducted at three months, six months and twelve months post activation, as well as annually thereafter. Preoperative and postoperative auditory function was evaluated using a common battery of psycho-physical, speech perception, and questionnaire measures.

C) DATA ANALYSIS

The 67 adult and 47 pediatric subjects were studied using a repeated measures, single-subject research design. Statistical analysis was performed to determine the significance of each pre/postoperative comparison on each measure for each subject. Outcome measures were represented as the preoperative performance achieved by each subject, in their best-aided condition (e.g. implanted ear alone, non-implanted ear alone or binaurally aided) compared with their implant-alone performance after three months of device use. In this way, each of the subjects constituted an independent replication of the experiment. The strength and consistency of the investigational findings across the 67 adult and 47 pediatric replications, provided evidence that the investigational findings can be generalized to the larger population of adult and pediatric CI24M implant recipients.

Experimental hypotheses were tested using three inferential statistical models. The binomial model was used to evaluate whether the percentage of items, passed by a single subject on a particular test measure, was significantly above chance. The binomial model also was used to determine whether two percentage scores, obtained by a single subject on two different occasions, were significantly different. For data pooled across subjects, T-tests and non-parametric Wilcoxin Signed Rank tests confirmed the primary results obtained from the single subject analysis.

In addition to the inferential models, well known descriptive statistics were used to characterize the investigational sample and standardized measures of incidence were applied to the safety data.

Performance on the outcome measures is expressed as the number and percentage of patients who achieved a postoperative score that exceeded either chance or their preoperative score. A range of improvement in auditory communication skills was expected with use of the implant. No consensus exists regarding the level of communication skills or the exact amount of improvement that constitute clinical significance. Previous experience with implants has shown that any improvements in communication skill beyond that expected by chance or guessing may be meaningful and significant to the patient. The design of the clinical trial and statistical methods employed were based on this assumption.

D) SUMMARY OF EFFECTIVENESS DATA

1) Children

a) **Methodology**

Claims of device effectiveness for children are based on various speech perception measures administered using recorded materials for children ages 5 years and older, or presented monitored live-voice to children under the age of five years. Separate evaluation batteries were developed for younger (18 months to < 5 years) and older (≥ 5 years) children in an attempt to address the broad diversity of linguistic and cognitive skills displayed by the two segments of the investigational sample.

Almost all of the older children were administered the entire battery of tests specified by the investigational protocol. In contrast, the majority of younger children did not have the requisite cognitive or linguistic skills to take any formal speech perception tests. For these children the MAIS provide the best indication of changes in hearing through parental ratings of the child's listening behaviors before and after implantation.

Effectiveness of the Nucleus 24 system in young children (18 months up to 5 years of age) was primarily assessed through parental ratings of their child's auditory behaviors in a variety of everyday listening situations on the Meaningful Auditory Integration Scale (MAIS). For 24 of the 47 children, preoperative ratings in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) were compared with postoperative ratings after six months of implant use. Ratings describing the frequency of occurrence of the child's auditory behaviors ranged from 0 (Never) to 4 (Always). Results were analyzed as the proportion of children rated who demonstrated the specific behavior either "frequently" or "always".

Effectiveness of the Nucleus 24 system in older (≥5 years) children was assessed by comparing the speech perception abilities of 23 pre- and postlinguistically deafened subjects preoperatively in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) with their postoperative performance in the implanted ear alone, after six months of device use. Various pediatric speech perception measures were presented by monitored live voice at 70 dB SPL. Various speech perception measures were also administered to the 24 younger children (18 months up to 5 years of age) with varying degrees of success.

The following claims of device effectiveness represent either performance on formal measures of speech perception or parental ratings of their child's auditory behaviors. The acquisition of speech perception skills, over an extended period of time, by prelinguistically and postlinguistically deafened children has been well documented.

b) Younger Children (Ages 18 months up to five years of age)

Evaluation Measures

All speech perception materials were administered monitored live voice without lipreading at 70 dB SPL to the children.

Central Institute for the Deaf Early Speech Perception (ESP) Low Verbal and Standard Versions - This set of three tests, developed by Moog and Geers (1988), was used to evaluate pattern perception and closed-set word identification (spondees and monosyllabic words) using objects (low verbal) or pictures (standard). The tests use vocabulary items that are appropriate for young deaf children. The tests were administered to children under the age of 3 years, 11 months. The tests are given in the auditory-only condition.

Glendonald Auditory Screening Procedure (GASP) Words. - This test, developed by Erber (1982), was used to evaluate the beginnings of open-set word recognition. It consists of 12 words of differing length that would be familiar to deaf children. The words are presented auditory-only in an open-set format. The test is scored as the number of words correct. There are 24 items.

Multisyllabic Lexical Neighborhood Test (MLNT) - The MLNT, developed by Kirk et al. (1995), was administered to children four years of age or older who demonstrated requisite cognitive and vocabulary skills. It was used to evaluate open-set word recognition. The MLNT was developed to assess word recognition in young hearing-impaired children.

Meaningful Auditory Integration Scale (MAIS) Parent Interview - This 10-item scale, developed by Robbins et al. (1991), assesses the child's use of residual hearing within everyday, meaningful contexts. The MAIS is a parent-report scale that assess the auditory skills of a child as observed by the parents in everyday situations. During a sructured interview, information is obtained from the parent about the frequency with which the child demonstrates a set of 10 different behaviors in

everyday situations. Strict scoring criteria have been developed for the MAIS to ensure uniformity amoung examiners in scoring the parents' responses. Inter-rater reliability is high (i.e., .90). Results are expressed in terms of the percentage of patients who "frequently" or "always" demonstrated the target behavior.

Results

After six months of experience with the Nucleus 24 the younger children demonstrated significant improvement on the MAIS:

- 68% (15/22) of the children frequently or always responded to their name in quiet compared with only 27% (6/22) preoperatively with hearing aids.
- 45% (10/22) of the children frequently or always responded to their name in noise compared with only 14% (3/22) preoperatively with hearing aids.
- 41%% (9/22) of the children frequently or always spontaneously recognized common sounds in the classroom compared with only 14% (3/22) preoperatively with hearing aids.

Of the younger children who were capable of being tested on open-set word recognition tasks:

- 29% (6/21) demonstrated significant improvement on the ESP: Low Verbal Version: Pattern Perception
- 40% (2/5) demonstrated significant improvement on the ESP: Standard Version: Pattern Perception
- 20% (4/20) demonstrated significant improvement on the ESP: Low Verbal Version: Spondee Identification
- 55% (5/9) demonstrated significant improvement on the ESP: Standard Version: Spondee Identification
- `10% (2/21) demonstrated significant improvement on the ESP: Low Verbal Version: Monosyllabic Word Identification
- 50% (2/4) demonstrated significant improvement on the ESP: Standard Version: Monosyllabic Word Identification
- 17% (4/24) demonstrated significant improvement on the GASP
- 33% (3/9) demonstrated significant improvement on the MLNT: Open Set Word Recognition
- 44% (4/9) demonstrated significant improvement on the MLNT: Open Set Phoneme Recognition

c) **Older Children (Ages 5 years and older)**

Evaluation Measures

All tests were administered tape-recorded at 70 dB SPL with the exception of GASP words which were administered monitored live voice .

Central Institute for the Deaf Early Speech Perception (ESP) Standard Version

Glendonald Auditory Screening Procedure (GASP) Words.

Common Phrases Test *- This test, developed at Indiana University School of Medicine, was used to evaluate open-set sentence recognition. It consists of 10 phrases that could be heard in everyday situations and would be familiar to young profoundly hearing-impaired children. There are 6 different lists. The sentences are presented auditory-only in an open-set format.*

Multisyllabic Lexical Neighborhood Test (MLNT)

The Lexical Neighborhood Test (LNT): Level 1 - The LNT, developed by Kirk et al. (1995), was used to evaluate open-set word recognition. It was developed to assess monosyllabic word recognition in young hearing-impaired children. The vocabulary items were drawn from set of words produced by normal-hearing children between the ages of three and five years.

Phonetically Balanced Kindergarten Words (PB-K 50) - The PBKs were used to assess open-set, monosyllabic word recognition. This test is a standard pediatric speech perception measure. There are three lists. Each list contains 50 items, scored for number of words and phonemes correct.

Revised Bamford-Kowal-Bench (BKB) Sentences - *BKB Sentences were used to assess open-set sentence recognition. This test was developed in England by Bamford, Kowal and Bench (1979), to assess speech recognition in hearing-impaired children. The sentences have been revised to be consistent with American English vocabulary and syntax.*

Meaningful Auditory Integration Scale (MAIS) Parent Interview

Results

Of the children age five years and older who were capable of being tested on open-set word recognition tasks:

- 61% (14/23) demonstrated significant improvement on the GASP
- 44% (10/23) demonstrated significant improvement on the MLNT
- 57% (12/23) demonstrated significant improvement on the LNT
- 48% (11/23) demonstrated significant improvement on the PBK

Group mean performance was significantly higher after six months of experience with the Nucleus 24, on all 11 measures of speech perception administered to children age five years and older. These measures ranged from simple closed-set tests to more difficult open-set word and sentence recognition tests.

After six months of experience with the Nucleus 24 the older children demonstrated significant improvement on the MAIS:

- 83% (15/18) of the children frequently or always responded to their name in quiet compared with only 47% (9/19) preoperatively with hearing aids.
- 47% (9/19) of the children frequently or always responded to their name in noise compared with only 11% (2/19) preoperatively with hearing aids.
- 79% (15/19) of the children frequently or always spontaneously recognized common sounds in the classroom compared with only 26% (15/19) preoperatively with hearing aids.

2) Adults

a) **Methodology**

Claims of device effectiveness for adults were based on recorded measures of speech perception or on questionnaires that were administered to all 67 subjects preoperatively and after three months of device use. Each outcome measure was administered to all 67 subjects at the two intervals (preoperatively and three months postoperatively) represented. However, not all subjects filled out the performance questionnaires at both intervals and therefore the actual number of respondents is represented for these measures.

Effectiveness of the Nucleus 24 system using the Sprint speech processor was assessed by comparing the speech perception abilities of 67 adults preoperatively in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) with their postoperative performance in the

implanted ear alone, after three months of device use. Recorded measures of open-set word and sentence recognition were presented in quiet, in the presence of background noise (+10 dB SNR) and over the telephone (long distance). Lipreading enhancement and closed-set speech perception were not included in the evaluation battery.

After a minimum of three months experience with the SPrint speech processor, 36 subjects were fitted with the ESPrit ear-level speech processor and speech perception was evaluated following one month of ESPrit use. Recorded measures of open-set word and sentence recognition were presented in quiet and in the presence of background noise (+10 dB signal-to-noise ratio). ESPrit performance was compared with each subject's preoperative baseline, as well as with the SPrint postoperative baseline. The evaluation measures for the ESPrit were the same as those used to assess the SPrint, except that telephone use with the ESPrit was not assessed.

The claims of device effectiveness are conservative in several respects. First, the acquisition of speech perception skills by postlinguistically deafened adults using a multichannel cochlear implant, has been found to occur over a six-to-twelve month period. Therefore, using three months of experience to characterize the performance of a cochlear implant may underestimate the eventual level of performance derived by recipients of the device over a longer period of time. Second, telephone testing was assessed under more adverse conditions than typical interactive conversations. Recorded (CD) open-set sentences were presented over long distance telephone lines both preoperatively and postoperatively. The level of performance demonstrated by subjects under these conditions probably underestimates their level of performance where subjects may be speaking to a familiar individual, have contextual cues to the conversation, receive additional cues from live-voice dialogue and would generally use local telephone lines.

b) **Evaluation Measures**

A variety of tests were selected to assess device effectiveness for speech perception and comprehension. All sound-field and telephone tests of speech perception were recorded and presented at 70 dB SPL.

Open-set monosyllabic word recognition in quiet *- The Consonant-Nucleus-Consonant (CNC) Word Test was used to evaluate open-set monosyllabic word recognition in quiet. The CNC Word Test consists of 50 words per list and was scored for both words and phonemes correctly identified.*

Open-set sentence recognition in quiet *- Two measures were used to evaluate open-set speech recognition in quiet: (i) City University of New York (CUNY) Sentences, and (ii) Hearing in Noise Test (HINT) Sentences. The CUNY Sentence Test consists of lists of 12 sentences and is scored as number of words correct (102 words per list). The HINT Sentence Test consists of lists of ten sentences scored as number of words correct (49 to 57 words per list).*

Open-set sentence recognition in noise *- The CUNY Sentence Test presented at +10 dB signal-to-noise ratio was used to evaluate open-set speech recognition in noise. Multitalker babble (re-recorded Auditec four-talker babble) was used as the competing stimulus.*

Sentence recognition over the telephone *- Sentence recognition over the telephone was assessed by presenting recorded Central Institute for the Deaf (CID) Sentences of Everyday Speech over long-distance telephone lines. The CID Sentence Test used consisted of lists of 20 sentences (100 key words per list).*

Sentence comprehension over the telephone *- The Psychoacoustics Laboratory (PAL) Sentences were presented over long-distance telephone lines to assess the ability of subjects to comprehend speech over the telephone. The PAL Sentences consist of lists of 20 questions that are answered by the subject.*

General Performance Questionnaire *- A general performance questionnaire was developed for this study to assess hearing device use, ability to hear and understand speech with and without lipreading, environmental sound recognition and music appreciation.*

Communication Profile for the Hearing-Impaired *- The 18-item Communication Performance Scale from the Communication Profile for the Hearing Impaired (CPHI) was used to assess how effectively a hearing-impaired individual is able to communicate with others in a variety of listening situations.*

c) **Results**

Adult Study With Sprint Speech Processor

Open-set sentence recognition in quiet:

- Almost all recipients (66/67, 98.5%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) after 3 months of device use, compared with their preoperative performance with hearing aids.
- After 3 months of experience with the Nucleus 24, recipients recognized an average of 78% of recorded words in sentences (CUNY) without lipreading.
- The median recorded sentence recognition score (CUNY) after three months of device use was 87%.
- Approximately one-half of the recipients (49.3%) recognized 90% or more of recorded words in sentences (CUNY) without lipreading, after three months of device use.
- Approximately two-thirds (62.7%) of recipients recognized 80% or more of recorded words in sentences (CUNY) without lipreading, after three months of device use.
- All recipients demonstrated significantly above-chance recorded sentence recognition (CUNY) without lipreading after only 3 months of experience with the Nucleus 24.
- Recipients rapidly developed high levels of open-set speech perception after limited experience with the Nucleus 24. Average recorded sentence recognition (CUNY) without lipreading increased from 56% to 65% to 78%, after two weeks, one month and three months of device use, respectively.
- Recipients rapidly developed high levels of open-set speech perception after limited experience with the Nucleus 24. Median recorded sentence recognition (CUNY) without lipreading increased from 58% to 72% to 87%, after two weeks, one month and three months of device use, respectively.
- After only 2 weeks of device use, approximately one-third (31.3%) of the recipients recognized 80% or more of recorded words in sentences (CUNY) without lipreading.
- After only 1 month of device use, approximately half (47.8%) of the recipients recognized 75% or more of recorded words in sentences (CUNY) without lipreading.
- Almost all recipients (63/67, 94.0%) demonstrated significant improvement in the recognition of more difficult open-set sentences (HINT) after three months of device use, compared with their preoperative performance with hearing aids.
- After 3 months of experience with the Nucleus 24, recipients recognized an average of 60% of recorded words in more difficult sentences (HINT) without lipreading.
- The median recorded sentence recognition score on more difficult HINT sentences was 63% after three months of device use.
- Approximately one-third of the recipients (35.8%) recognized 75% or more of recorded words in more difficult sentences (HINT) without lipreading, after three months of device use.
- Almost all subjects demonstrated significantly above-chance recorded speech recognition on more difficult sentences (HINT) without lipreading, after only 3 months of experience with the Nucleus 24.

Open-set sentence recognition in noise (+10 dB SNR):

- Eighty-eight percent of recipients demonstrated significant improvement in the recognition of open-set monosyllabic words after three months of device use, compared with their preoperative performance with hearing aids.
- After 3 months of experience with the Nucleus 24, recipients recognized an average of 37% of recorded monosyllabic words without lipreading.
- The median monosyllabic word recognition score after three months of device use was 36%.
- Eighteen percent of the recipients (12/67) recognized 60% or more of recorded monosyllabic words without lipreading, after three months of device use.
- Twenty-eight percent of recipients (19/67) recognized 50% or more of recorded monosyllabic words, after three months of device use .
- Open-set monosyllabic word recognition without lipreading ranged from 0% to 80%, after three months of device use.

Open-set word recognition

- Almost all recipients (61/66, 92.4%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) in the presence of background noise after three months of device use, compared with their preoperative performance with hearing aids.
- When tested in noise, recipients recognized an average of 59% of recorded words in sentences (CUNY) without lipreading.
- When tested in noise, the median recorded sentence recognition score (CUNY) was 67% after three months of device use.
- When tested in noise, approximately one-third of the recipients (36.3%) recognized 75% or more of recorded words in sentences (CUNY) without lipreading, after three months of device use.
- When tested in noise, approximately one-half of the recipients (47.0%) recognized 70% or more of recorded words in sentences (CUNY) without lipreading, after three months of device use.
- When tested in an environment designed to represent "real world" situations (background noise), recipients were able to recognize on average 59% of words in sentences without lipreading.
- When tested in background noise, all but one recipient demonstrated significantly above-chance recorded speech recognition on sentences (CUNY) without lipreading, after only 3 months of experience with the Nucleus 24.

Telephone testing:

- Ninety-one percent of the recipients (61/67) demonstrated significant improvement in the recognition of open-set sentences (CID) over the telephone compared with preoperative performance with hearing aids.
- Seventy-nine percent of the recipients (53/67) demonstrated significant improvement in the comprehension of open-set sentences (PAL) over the telephone compared with preoperative performance with hearing aids.
- Almost all recipients (65/67, 97%) were able to recognize recorded open-set sentences (CID) presented over long distance telephone lines at significantly above chance levels.
- Over the telephone, recipients scored an average of 60% and 58% on open-set CID and PAL sentences after three months of device use.
- Over the telephone, the median score was 66% on open-set CID sentences and 65% on PAL sentences.
- Over the telephone, approximately one-half of the recipients (47.8%) recognized 70% or more of recorded words in sentences (CID), after three months of device use.
- Over the telephone, 21% of recipients recognized 90% or more of recorded words in sentences (CID), after three months of device use.
- Approximately one-quarter (23.9%) of the recipients correctly answered 90% or more of recorded questions (PAL), presented over long distance telephone lines.

- Approximately one-half (50.8%) of the recipients correctly answered 70% or more of recorded questions (PAL), presented over long distance telephone lines.

Questionnaires:

Self assessment questionnaires were administered pre- and postoperatively to explore the recipients' perspectives on the benefits and detriments of implantation. The Communication Performance Scale of the Communication Profile for the Hearing Impaired (CPHI) assessed the ability to communicate effectively in a variety of work home and social situations. A General Performance Questionnaire (GPQ) assessed how recipients felt about and used their implant in day-to-day environments.

- Three fourths (35/51, 69%) of the respondents reported that they enjoyed listening to music (at least to some degree) postoperatively, compared to one-third of the respondents (15/51, 29%), preoperatively.
- With the Nucleus 24, two-thirds (32/51, 63%) of the respondents recognized (at least occasionally) songs and tunes that were familiar to them before they lost their hearing, compared to 35% (18/51) preoperatively.
- Postoperatively, over one-third (20/51, 39%) of the respondents recognized familiar songs and tunes at least half of the time.
- Eighty-six percent of the respondents (44/51) reported that they could frequently or almost always monitor the loudness and quality of their voice postoperatively, compared to only 35% (18/51) preoperatively.
- Postoperatively, 90% of the respondents (46/51), reported an overall improvement in communication ability, when using the Nucleus 24 system without lipreading.
- After using the Nucleus 24 system for three months, 88% of the respondents (45/51) indicated that they were satisfied with the cochlear implant system.
- Ninety-two percent of the respondents (47/51) were happy that they made the decision to undergo surgery and receive the implant.
- Ninety-two percent of the respondents (47/51) indicated that the quality of their lives improved after receiving the Nucleus 24.
- When using the Nucleus 24, approximately three fourths (76.3%, 45/59) of the subjects responding, reported being able to communicate more effectively when driving in a car with family members.
- When using the Nucleus 24, 74.1% (40/54) of the subjects responding, reported being able to communicate more effectively when ordering in a restaurant.
- When using the Nucleus 24, 76.4% (42/55) of the subjects responding, reported being able to communicate more effectively at a dinner party.
- When using the Nucleus 24, 78.3% (36/46) of the subjects responding, reported being able to hear religious services more effectively with their Nucleus 24.
- When using the Nucleus 24, 85.4% (41/48) of the subjects responding, reported being able to communicate more effectively in meetings.

Adult Study With Esprit Speech Processor

- Almost all recipients (34/36, 94.4%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) using the ESPrit (ear-level) speech processor, compared with their preoperative performance with hearing aids.
- Using the ESPrit (ear-level) speech processor, recipients recognized an average of 79.6% of recorded words in sentences (CUNY) without lipreading.
- The median recorded sentence recognition score (CUNY) using the ESPrit (ear-level) speech processor was 91%.
- All recipients tested (35/35, 100%) demonstrated significant improvement in the recognition of more difficult open-set sentences (HINT) using the ESPrit (ear-level) speech processor, compared with their preoperative performance with hearing aids.

- Using the ESPrit (ear-level) speech processor recipients recognized an average of 63.4% of recorded words in more difficult sentences (HINT) without lipreading.
- The median recorded sentence recognition score on more difficult HINT sentences was 65%, using the ESPrit (ear-level) speech processor.
- Eighty-nine percent of recipients demonstrated significant improvement in the recognition of open-set monosyllabic words using the ESPrit (ear-level) speech processor, compared with their preoperative performance with hearing aids.
- *Using the ESPrit (ear-level) speech processor, recipients recognized an average of 38.3% of recorded monosyllabic words without lipreading.*
- The median monosyllabic word recognition score using the ESPrit (ear-level) speech processor was 40%.
- Almost all recipients (32/36, 88.9%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) in the presence of background noise using the ESPrit (ear-level) speech processor, compared with their preoperative performance with hearing aids.
- When tested in noise using the ESPrit (ear-level) speech processor, recipients recognized an average of 57.9% of recorded words in sentences (CUNY) without lipreading.
- When tested in noise, the median recorded sentence recognition score (CUNY) was 64% using the ESPrit (ear-level) speech processor.
- When tested in an environment designed to represent "real world" situations (background noise), recipients were able to recognize on average 57.9% of words in sentences without lipreading when using the ESPrit (ear-level) speech processor.
- When tested in background noise, all but four recipients demonstrated significantly above-chance recorded speech recognition on sentences (CUNY) without lipreading, when using the ESPrit (ear-level) speech processor.
- There was no significant difference in performance between the body-worn SPrint and the ear-level ESPrit speech processors, on any measure of open-set speech perception in quiet or in noise.

E) SUMMARY OF SAFETY DATA

1) Methodology

All complications and adverse effects were obtained from the investigation sites and entered into a database by type; surgical and postoperative effects, device failures and malfunctions, as well as performance degradation over time. Subjects were asked to report possible occurrences of electromagnetic interference (EMI), as part of a questionnaire administered following 3 months of device use. Complications are defined as minor if they resolved with noninvasive medical treatment, replacement of external system components, device re-programming, or with patient counseling. Major complications are defined as those that are resolved with surgical intervention.

2) Adult Subjects (133)- Complications and Adverse Effects

During the 12 month observation period, 20 of the 133 investigational subjects experienced either a medical/surgical or device-related complication. Eighteen (18) complications were classified as minor and resolved without surgical intervention. Two (2) complications were classified as major and required surgical intervention.

a) **Medical/Surgical (11)**

- Facial Nerve Stimulation (4)
- Tinnitus Related to Implant Use (2)
- **Electrode Array Migration (1) – Required Surgical Intervention**
- **Wound Hematoma (1) – Required Surgical Intervention**
- Short-term Postoperative Dizziness (1)
- Compressed Electrode Array (1)
- Fluctuating Levels Due to Skin Flap Thickness (1)

b) **Device-Related (9)**

- Electrode Insulation Fault (short) (4)
- Over stimulation (2)
- Lightning
- Programming System
- Allergic Reaction to Cable (2)
- Non-auditory Sensation (1)

c) **EMI Occurrence (9) None of the subjects reported discomfort**

- Unknown Source (3)
- Video Store Theft Detector (1) *
- Heavy Construction Equipment (1)
- Car Ignition and Street Lights (1) *
- Leaf Blower (1)
- Neon Signs (1) *
- Computer Monitor (1) *

* Reported event likely to be electromagnetic (vs. acoustic) in origin.

d) **Major Medical Complications**

i. In one subject, post-implantation, an air pocket appeared under the skin in the area of the receiver-stimulator . Despite medical treatment, the air pocket persisted and filled with fluid. Approximately 6 weeks post-implantation, the receiver-stimulator displaced from its mastoid seat and the electrode array migrated into the middle ear. The case report notes that surgery was also performed to correct a nasal defect at the time of implantation, and a middle ear infection developed concomitant with the air pocket fluid. Following healing of the septoplasty and resolution of the ear infection, the extruded device was replaced. No further problems have developed.

ii. The subject developed a wound hematoma shortly after implantation. The hematoma was evacuated during a second surgical procedure, and the wound healed completely with no additional intervention.

3) Pediatric Subjects (150) - Complications and Adverse Effects

During the 11 month observation period, 24 of the 150 investigational subjects experienced 27 medical/surgical (9) and device-related (18) complications. Twenty-three (23) complications, classified as minor, were resolved without surgical intervention. Three (3) complications, classified as major, required surgical intervention. The remaining complication could not be resolved.

a) **Medical/Surgical (9)**

- **No post-operative Response to Electrical Stimulation (1)**
- Compressed Electrode Array (2)
- Facial Nerve Stimulation (1)
- **Post-operative Meningitis (1) - Required Surgical Intervention**
- Short-term Postoperative Dizziness (2)
- **Skin Flap Infection (1) - Required Surgical Intervention**
- **Incorrect Device Placement (1) - Required Surgical Intervention**

b) **Device Related (18)**

- Allergic Reaction to Cable (3)
- Electrode Insulation Fault (8)
- Electrode Weld Fault (5)
- Non-auditory Sensation (1)
- Over stimulation (1)

c) **Major Medical Complications**

i. One subject contracted meningitis following surgery, received extensive medical treatment for approximately 2 weeks, and was discharged without sequelae.

ii. One subject developed an infection post-operatively and was treated by the implanting surgeon. The wound was not maintained appropriately and the infection progressed. To prevent additional complications, the device was explanted. The subject will be considered for re-implantation at a later date.

iii. Post-operative x-rays in a subject indicated the electrode array was not placed within the cochlea, but within the internal auditory canal of this subject. Studies revealed the patient had an unusual congenital anomaly where the medical wall of the cochlea was either fibrous in nature, or completely absent. The device was removed from the internal canal without difficulty and the child recovered with no additional problems.

iv. One subject presented for surgery with bilaterally ossified cochlea, secondary to a meningitic infection. The lateral wall of the cochlea was removed to seat the electrode array. After six months of use the subject was unable to respond to stimulation from the device. It was concluded that ossification was complete and the problem could not be resolved. It was recommended that the child discontinue use of the device.

XI. CONCLUSIONS DRAWN FROM THE STUDIES:

A) SAFETY

Safety data was collected on 283 (133 adults and 150 children) Nucleus 24 implant recipients. Twenty (20) medical/surgical and 27 device-related complications were reported. All complications have been resolved. There have been no life-threatening or hazardous, permanent side effects. There were no device failures during the study period.

B) EFFECTIVENESS

One-hundred, thirty-five (135) adults and 179 children were implanted with the Nucleus 24 Cochlear Implant System. One hundred-thirty-three (133) adults and 150 children were studied for device safety, and 67 adults (3 months data) and 47 children (six months data) were studied for device effectiveness.

For the adult subjects, tape recorded measures of speech perception and questionnaires were administered to subjects preoperatively and after three months of device use. Significant improvements in scores for the majority of subjects demonstrated the effectiveness of the device in adult subjects. Test results for the Sprint (body worn) and ESPrit (ear-level) speech processors showed no significant difference in performance between the two speech processors.

Device effectiveness in the youngest group of children was primarily demonstrated through administration of a parental rating scale (MAIS) rather than through formal tests of speech perception. Due to the immature linguistic and cognitive abilities of very young deaf children, formalized speech perception testing often was not appropriate. After six months of experience with the Nucleus 24 device the younger children demonstrated significant improvement on the MAIS. For younger subjects who were able to take the formal speech perception tests there were improvements in postoperative mean scores compared with preoperative testing in the best-aided condition. As a condition for the approval of this PMA the existing investigational protocol will be continued for 3 years (following PMA approval) in the first 100 children implanted between 18 months and five yearsof age as a part of the clinical trial. The three year post-market speech perception study will allow sufficient time for all children within the sample to achieve linguistic and cognitive competence, providing valid and reliable data for all tests within the investigational protocol.

Device effectiveness was demonstrated in the older group of children through administration of formal tests of speech perception. Forty-eight percent (11/23) of the older children demonstrated significant improvement on the PBK Phoneme Test. Sixty-one percent (14/23) demonstrated significant improvement on the GASP Words Test. Results of the MAIS parental ratings for the older children also showed significant gains in auditory behaviors in everyday communication situations when compared to the preoperative best-aided test condition.

C) RISK/BENEFIT

Implant experience with 133 adults over a 12 month period and with 150 children over an 11 month period indicate that the incidence of adverse post-operative effects, medical/surgical complications, and device-related problems with the Nucleus 24 device is low. This experience also indicate that most problems are encountered within a short time of surgery, and that most problems resolve without surgical intervention. Only six of the 47 medical complications (20 adult and 27 children) had to be resolved with surgical intervention. Most device-related problems involved electrode insulation, weld faults and allergic reaction to the cable. There were no internal device failures during the observation period.

The clinical data demonstrate benefits for the adult population within 3 months of initial stimulation. The effectiveness data for pediatric implants demonstrate benefits within 6 months of initial stimulation. The clinical results for older children demonstrate consistent improvement over a broad range of auditory functions. Device effectiveness in the youngest group of children was primarily demonstrated through administration of a parental rating scale (MAIS) rather than through formal tests of speech perception. Due to the immature linguistic and cognitive abilities of very young deaf children, formalized speech perception testing often was not appropriate. For very young children who acquire speech and language skills over the first five years of life, auditory abilities develop over a longer period of time and can be measured using conventional test measures only after the emergence of related speech and language competencies. Experience with cochlear implant systems has shown that measurable gains on objective tests of auditory speech perception emerge with a young child's ongoing cognitive and linguistic maturation.

There is no evidence to indicate that the benefits demonstrated in the clinical study degrade over time. The Nucleus 24 Cochlear Implant device has performed according to design, and the data from the clinical trial support the safety and effectiveness of the device for the intended population.

XII. CENTER FOR DEVICES AND RADIOLOGICAL HEALTH (CDRH) DECISION:

This PMA was not referred to the Ear, Nose and Throat Devices Panel of the Medical Devices Advisory Committee, an FDA advisory committee, for review and recommendation because the information in this PMA substantially the same safety and effectiveness information in other cochlear implant PMAs previously reviewed by the panel. This decision is permitted under the provisions of section 515(c)(2) of the act as amended by the Safe Medical Devices Act of 1990

The applicant has agreed to conduct a post-approval speech perception study of 100 children in the investigational study, implanted between 18 months and up to five years of age, and a study to assess language development in children.

The speech perception study will be a continuation of the existing investigational protocol. For the group of 100 children post-operative evaluations will be conducted at three, six, and twelve month intervals, and annually thereafter for a period of three years following approval of the PMA. Proposed evaluation measures will assess auditory benefit from the cochlear implant and include (1) electrical threshold and maximum comfort level measurements, (2) aided sound field detection thresholds, (3) meaningful auditory integration scale (MAIS), (4) early speech perception battery, (5) GASP words, and (6) multi-syllabic lexical neighborhood test (MLNT).

A language development study of 28 children will be conducted to assess expressive and receptive language competency. The study will be performed at 3 investigational sites for children implanted between 18 months and up to five years of age. The children will be assessed annually using the Reynell Developmental Language Scales (RDLS). The study will be conducted for a period of 5 years from the date of PMA approval.

XIII. CDRH ACTION ON THE APPLICATION

CDRH issued an approval order for the applicant's PMA Nucleus 24 Cochlear Implant System on June 25, 1998. The applicant's manufacturing facility was inspected on March 3, 1998 and was found to be in compliance with the device Good Manufacturing Practice regulations (GMPs)

The shelf-life of the Nucleus 24 Cochlear Implant System has been established at 24 months for a product stored between -20° and +50° Centigrade. The "use by" date is stamped on the outside package. If the data has expired, return the device to Cochlear Corporation.

XIV. APPROVAL SPECIFICATIONS:

Directions for use: See attached labeling
Conditions of Approval: FDA approval of this PMA is subject to full compliance with the conditions described in the approval order

XV. REFERENCES:

1. Shepard, RK, et al. Banded Intracochlear Electrode Array: Evaluation of Insertion Trauma in Human Temporal Bones. Annals of Otology, Rhinology and Laryngology, Jan.-Feb. 1985, Vol. 94, No. 1;
2. Kennedy, DW, Multichannel Intracochlear Electrodes: Mechanism of Insertion Trauma, Laryngoscope 97, Jan. 1987;
3. Franz BK-H, Clark, GM, Webb, RL, Shepherd, RK, and Pyman, BC, The Biologic safety of the Cochlear Corporation Multiple-Electrode Intracochlear Implant, The American Journal of Otology, Vol. 9, No. 1, Jan. 1988;
4. Jackler, RK, Leake, PA, McKerrow, WS, Cochlear Implant Revision: Effects of Reimplantation on the Cochlea, Ann. Otol. Rhinol. Laryngol. 98, 1989;
5. Carter, P., In Vivo Direct Current Measurements for High Stimulation Rates, Cochlear Limited Technical Memo Ref. No. TM 0111, 1996

PACKAGE INSERT

DEVICE DESCRIPTION

The Nucleus® 24 Cochlear Implant System is designed to provide useful hearing and includes both implanted and external components. The cochlear implant is surgically implanted under the skin behind the ear. It includes a receiver/stimulator to receive and decode the electrical signals and an electrode array to deliver these signals to the cochlea. The external components include the SPrint, a body-worn speech processor, headset and cables and the ESPrit, an ear-level speech processor. The Nucleus 24 system changes sound in the environment into electrical code and transmits this code to the auditory nerve, and on to the brain where it is interpreted as sound.

INDICATIONS

The Nucleus 24 Cochlear Implant is intended to restore a level of auditory sensation via the electrical stimulation of the auditory nerve.

Postlinguistically Deafened Adults

The Nucleus 24 Cochlear Implant System, hereinafter referred to as the Nucleus 24, is intended for use in individuals 18 years of age or older who have bilateral, postlinguistic, sensorineural hearing impairment and obtain limited benefit from appropriate binaural hearing aids. These individuals typically have moderate-to-profound hearing loss in the low frequencies and profound (≥90 dB HL) hearing loss in the mid-to-high speech frequencies. Limited benefit from amplification is defined by test scores of 40% correct or less in the best-aided listening condition on tape-recorded tests of open-set sentence recognition.

Prelinguistically and Perilinguistically Deafened Adults

The Nucleus 24 is intended for use in prelinguistically and perilinguistically deafened individuals, 18 years of age or older, who have profound sensorineural deafness and do not benefit from appropriate hearing aids.

Children

The Nucleus 24 is intended for use in children 18 months through 17 years of age who have bilateral profound sensorineural deafness and demonstrate little or no benefit from appropriate binaural hearing aids. In younger children, little or no aided benefit is defined as lack of progress in the development of simple auditory skills in conjunction with appropriate amplification and participation in intensive aural habilitation over a three-to-six month period. It is recommended that limited benefit be quantified on a measure such as the Meaningful Auditory Integration Scale or the Early Speech Perception test. In older children, lack of aided benefit is defined as <20% correct on the open-set Multisyllabic Lexical Neighborhood Test (MLNT) or Lexical Neighborhood Test (LNT), depending upon the child's cognitive and linguistic skills. A three-to-six month hearing aid trial is required for children without previous aided experience.

CONTRAINDICATIONS

A cochlear implant is not indicated for individuals who have the following conditions: 1) Deafness due to lesions of the acoustic nerve or central auditory pathway; 2) Active middle ear infections; 3) Absence of cochlear development; 4) Tympanic membrane perforation in the presence of active middle ear disease.

WARNINGS

Medical Treatments Generating Induced Currents

Some medical treatments generate induced currents that may cause tissue damage or permanent damage to the cochlear implant. Warnings for specific treatments are given below.

- **Electrosurgery:** Electrosurgical instruments are capable of inducing radio frequency currents that could flow through the electrode array. **Monopolar** electrosurgical instruments must **not** be used on the head or neck of a cochlear implant patient as induced currents could cause damage to cochlear tissues or permanent damage to the implant. **Bipolar** electrosurgical instruments may be used on the head and neck of patients, however, the cautery electrodes must not contact the implant and should be kept more than 1 cm (~ 1/2 inch) from the extracochlear electrodes.
- **Diathermy or Neurostimulation:** Do not use diathermy or neurostimulation directly over the cochlear implant. High currents induced into the electrode lead can cause tissue damage to the cochlea or permanent damage to the implant.
- **Electroconvulsive Therapy:** Do not use electroconvulsive therapy on a cochlear implant patient under any circumstances. Electroconvulsive therapy may cause tissue damage to the cochlea or damage to the cochlear implant.

Ionizing Radiation Therapy

Do not use this therapy directly over the cochlear implant because it may cause damage to the implant.

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) is contraindicated except under the circumstances described below. Do not allow patients with a cochlear implant to be in the room where an MRI scanner is located except under the following special circumstances.

The Nucleus 24 cochlear implant has a removable magnet and specific design characteristics to enable it to withstand MRI up to 1.5 Tesla, but not higher. If the cochlear implant's magnet is in place, it must be removed surgically before the patient undergoes a MRI procedure. The patient must take off the speech processor and headset before entering a room where a MRI scanner is located.

If the implant's magnet is still in place, tissue damage may occur if the recipient is exposed to MRI. Once the magnet is surgically removed, the quality of the MRI will be affected by the metal in the cochlear implant. Image shadowing may extend as far as 6 cm from the implant, thereby, resulting in loss of diagnostic information in the vicinity of the implant.

If the physician is unsure that the patient has a Nucleus 24 cochlear implant with a removable magnet, the physician should use an x-ray to check the radiopaque lettering on the implant. There are three platinum letters printed on each implant. If the middle letter is a "J", "L", or "T", the implant has a removable magnet. Once the magnet has been removed, MRI can be performed. If you require additional information about removal of the magnet, please contact Cochlear.

Loss of Residual Hearing

Insertion of the electrode into the cochlea will result in complete loss of residual hearing in the implanted ear.

Long-term Effects of Electrical Stimulation

Most patients can benefit from electrical stimulation levels that are considered safe, based on animal experimental data. For some patients, the levels needed to produce the loudest sounds exceed these levels. The long-term effects of such stimulation in humans are unknown.

Ingestion of Small Parts

Parents and caregivers should be counseled that the external implant system contains small parts which may be hazardous if swallowed.

Head Trauma

A blow to the head in the area of the cochlear implant may damage the implant and result in its failure.

PRECAUTIONS

Use of Another Person's Speech Processor

Cochlear implant recipients should never use another person's speech processor. The information programmed into the processor is customized for individual use and it is not suitable for another person. Use of another person's speech processor may cause uncomfortably loud or distorted sounds.

Theft and Metal Detection Systems

Devices such as airport metal detectors and commercial theft detection systems produce strong electromagnetic fields. Some cochlear implant recipients may hear distorted sounds when passing through or near one of these devices. To avoid this, turn off the speech processor when in the vicinity of one of these devices. The materials used in the cochlear implant also may activate metal detection systems. For this reason, recipients should carry the Cochlear Implant Patient Identification Card with them at all times.

Electrostatic Discharge

A discharge of static electricity can damage the components of the cochlear implant system or corrupt the program in the speech processor. Static electricity may be generated, for example, when putting on or removing clothes over the head or when getting out of a vehicle. Cochlear implant recipients should touch something conductive, such as a metal door handle before the cochlear implant system contacts any object or person. Before implant recipients participate in activities that create extreme electrostatic discharge, such as playing on plastic slides, they should remove the speech processor and headset.

Clinicians should use an anti-static shield on the computer monitor when programming a cochlear implant recipient.

Mobile Telephones

Some types of digital mobile telephones may interfere with the operation of the speech processor or headset. Individuals may hear distorted sounds within 1-4 meters (3-12 feet) of a digital mobile telephone in use.

ADVERSE EVENTS

The following information summarizes adverse events for the adult and pediatric study populations.

Adults

Adult safety data are based on a total of 133 patients implanted during the adult clinical investigation at 27 U.S. sites. Twenty patients experienced either a medical/surgical or device-related complication. Eleven of the 20 complications were medical/surgical in nature and the remaining nine were device-related. Eighteen of the 20 adverse events resolved without surgical or extensive medical intervention.

Medical/Surgical Complications:

One patient experienced device migration which required revision surgery to reposition the device. One patient experienced a wound hematoma which required minor surgery to resolve. One patient experienced a slightly compressed electrode array and the surgeon elected to remove the device and replace it with a second one during the initial surgery. Four patients experienced facial nerve stimulation. All cases of facial nerve stimulation were resolved through reprogramming. Two patients experienced tinnitus related to cochlear implant use. One case resolved without intervention and the second case was resolved through reprogramming. One patient experienced short-term postoperative dizziness which resolved without medical treatment. One patient experienced fluctuating psychophysical levels related to a relatively thick (10+mm) skin flap. This case was resolved through replacement of external equipment.

Device-related Complications:

No device failures or other serious device malfunctions occurred during this study. Four patients experienced electrode insulation faults (short-circuits) that were resolved through reprogramming. Two patients were inadvertently overstimulated during device programming and one patient reported a nonauditory sensation during device programming. Two patients experienced a mild skin reaction to the speech processor cable. These were resolved completely with topical medical treatment.

Children

Pediatric safety data are based on a total of 150 children implanted during the clinical investigation. Twenty-four patients experienced 27 medical/surgical or device-related complications. Nine of the 27 complications were medical/surgical in nature and the remaining 18 were device-related. Twenty-four of the complications resolved without surgical or extensive medical intervention.

Medical/Surgical Complications:

One postmeningitically deafened child with bilaterally ossified cochleae failed to experience auditory stimulation through the fully functional cochlear implant. One patient developed streptococal meningitis less than 24 hours following cochlear implant surgery. The infection was successfully managed with medical treatment. One patient experienced a wound infection that was resolved through surgical explantation of the device. One patient experienced extracochlear electrode placement related to a congenital malformation of the inner ear. This complication was resolved through surgical explantation of the device. Two patients experienced slight compression of the electrode array which resulted in two short-circuited electrodes in one case and no electrode anomalies in the other. The case with electrode

short circuits was resolved through reprogramming. One patient experienced facial nerve stimulation related to a severe congenital malformation of the inner ear. This complication was resolved through reprogramming, however, the patient continues to experience occasional slight facial nerve stimulation. Two patients experienced mild short-term postoperative dizziness. Both cases resolved without medical intervention.

Device-related Complications:
No device failures or other serious device malfunctions were observed during this study. Thirteen patients experienced electrode faults (short-circuit or open-circuit electrodes) on one or more electrodes. All of these cases were resolved through reprogramming. One patient experienced non-auditory sensations during psychophysical testing. This case was resolved through reprogramming. One patient experienced an unanticipated overstimulation. This complication was resolved through replacement of external equipment. Three patients experienced mild skin reactions to the speech processor cable. One case was resolved through covering the cable, one case was resolved through an alternative polyurethane coating of the cable, and one case resolved spontaneously without intervention.

In addition to the adverse events experienced during the clinical study, the following potential adverse events could occur:

- Individuals are exposed to the normal risks associated with surgery and general anesthesia. In addition, this procedure may result in infection or bleeding, numbness or stiffness about the ear, injury to or stimulation of the facial nerve, taste disturbance, dizziness, increased tinnitus, neck pain and perilymph fluid leak. Perilymph fluid leak may result in meningitis.
- The cochlear implant results in a palpable lump under the skin behind the ear. The presence of a foreign body may cause irritation, inflammation, or breakdown of the skin and, in some cases, extrusion of the device. The electrode array may migrate partially or completely out of the cochlea, resulting in decreased hearing ability. The electrode lead may perforate structures of the external ear, such as the tympanic membrane or canal wall. Misplacement of the electrode array may result in the perception of non-auditory sensations. Such complications may require additional medical treatment, surgery, or removal of the device.
- Electrical stimulation may result in increased tinnitus, facial nerve stimulation, dizziness, or pain. Individuals who have residual hearing in the ear selected for implantation have a slightly greater risk of short-term postoperative dizziness than individuals with no residual hearing in that ear.
- The long-term effects of electrode insertion trauma or chronic electrical stimulation are unknown. Such effects may include new bone growth in the cochlea or deterioration of the nerve cells. These effects may preclude replacement of the electrode array or may lead to eventual deterioration of cochlear response.
- Failure of component parts (both external and internal) could result in the perception of uncomfortably loud sounds or no sound. Failure of various parts of the implanted device could result in removal, replacement of the implant, or a reduction of the number of electrodes in use.

RESULTS OF CLINICAL STUDIES: ADULTS

Effectiveness of the Nucleus 24 system using the SPrint body-worn speech processor was assessed by comparing the speech perception abilities of 67 postlinguistically deafened adults preoperatively in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) with their postoperative performance in the implanted ear alone, after three months of device use. Recorded measures of open-set sentence recognition were presented in quiet using City University of New York (CUNY) and Hearing in Noise Test (HINT) Sentences. CUNY Sentences also were presented in background noise at a level that was moderately difficult for the typical cochlear recipient (+10 dB signal-to-noise ratio). Open-set speech recognition was also assessed over long-distance telephone lines using Central Institute for the Deaf (CID) Everyday Sentences of Speech Test and the Psycho-Acoustic Laboratory Sentences (PAL). Recorded measures of open-set, monosyllabic word recognition (Northwestern University #6) were presented in quiet. Due to the high levels of performance exhibited by adults using the Nucleus 24, more simple measures of lipreading enhancement and closed-set speech perception were not included in the evaluation battery. Individual subject results were analyzed using a binomial statistical model.

Hearing-only, Open-set Sentences in Quiet:

- After 3 months of experience with the Nucleus 24, almost all recipients (66/67, 98.5%) demonstrated significant improvement in open-set sentence recognition (CUNY) compared to their preoperative performance with hearing aids. All individuals demonstrated significantly above-chance sentence recognition. Recipients recognized an average of 78% of words in sentences, with a median score of 87%. Approximately one-half of the recipients (49.3%) recognized 90% or more words and approximately two-thirds (62.7%) recognized 80% or more words.
- Recipients rapidly developed high levels of open-set speech perception after limited experience with the Nucleus 24. Average sentence recognition (CUNY) increased from 56% to 65% to 78% and median scores increased from 58% to 72% to 87% after two weeks, one month and three months of device use, respectively. After only 2 weeks, approximately one-third (31.3%) of the recipients recognized 80% or more words. After only 1 month, approximately half (47.8%) of the recipients recognized 75% or more words.
- After 3 months of experience with the Nucleus 24, almost all recipients (63/67, 94.0%) demonstrated significant improvement in the recognition of more difficult open-set sentences (HINT) compared to their preoperative performance with hearing aids. Almost all individuals demonstrated significantly above-chance speech recognition. Recipients recognized an average of 60% of the words in these more difficult sentences, with a median score of 63%. Approximately one-third of the recipients (35.8%) recognized 75% or more words.

Hearing-only, Open-set Sentences in Noise (+10 dB SNR): After 3 months of experience with the Nucleus 24:

- Almost all recipients (61/66, 92.4%) demonstrated significant improvement in the recognition of recorded, open-set sentences (CUNY) in the presence of background noise, compared to their preoperative performance with hearing aids. All but one recipient demonstrated significantly above-chance speech recognition.

- When tested in an environment designed to represent "real world" listening situations (background noise), recipients recognized an average of 59% of the words, with a median score of 67%. One-third of the recipients (36.3%) recognized 75% or more words and approximately one-half of the recipients (47.0%) recognized 70% or more words.

Hearing-only, Open-set Words in Quiet: After 3 months of experience with the Nucleus 24:

- Eighty-eight percent of recipients (59/67) demonstrated significant improvement in the recognition of recorded, open-set monosyllabic words compared to their preoperative performance with hearing aids. Monosyllabic word recognition ranged from 0% to 80%.
- Recipients recognized an average of 37% of the words, with a median score of 36%. Eighteen percent of the recipients (12/67) recognized 60% or more words and 28% of recipients (19/67) recognized 50% or more words.

Telephone Testing:

All telephone testing was administered over long-distance telephone lines using recorded, open-set sentence measures (CID and PAL sentences). Under these difficult listening conditions, after 3 months of experience with the Nucleus 24:

- Ninety-one percent of the recipients (61/67) demonstrated significant improvement in the recognition of open-set sentences (CID) compared to their preoperative performance with hearing aids. Almost all recipients (65/67, 97%) recognized these sentences at significantly above chance levels. Seventy-nine percent (53/67) demonstrated significant improvement in the comprehension of open-set sentences (PAL) compared to their preoperative performance with hearing aids.
- Recipients scored an average of 60% and 58% on CID and PAL Sentences, with median scores of 66% and 65%, respectively. Approximately one-half of the recipients (47.8%) recognized 70% or more of recorded words in sentences (CID), and 21% of recipients recognized 90% or more words. Approximately one-quarter (23.9%) of the recipients correctly answered 90% or more of recorded questions (PAL), and approximately one-half (50.8%) correctly answered 70% or more questions.

Clinical Results with the ESPrit (ear-level) Speech Processor

After a minimum of three months experience with the SPrint speech processor, 36 subjects were fit with the ESPrit ear-level speech processor and speech perception was evaluated following one month of ESPrit use. Recorded measures of open-set sentence recognition were presented in quiet and in the presence of background noise (+10dB SNR), a level that was moderately difficult for the typical cochlear recipient. Recorded measures of open-set word recognition were presented in quiet. ESPrit performance was compared with each subject's preoperative baseline, as well as with the SPrint postoperative baseline. The evaluation measures for the ESPrit were the same as those used to assess the SPrint, except that telephone use with the ESPrit was not assessed. Individual subject results were analyzed using a binomial statistical model.

Hearing-only, Open-set Sentences in Quiet:

- Almost all recipients (34/36, 94.4%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) using the ESPrit compared to their preoperative performance with hearing aids. Recipients recognized an average of 79.6% of the words in sentences, with a median score of 91%.

- All recipients tested (35/35, 100%) demonstrated significant improvement in the recognition of more difficult open-set sentences (HINT) using the ESPrit compared to their preoperative performance with hearing aids. Recipients recognized an average of 63.4% of the words, with median score of 65%.

Hearing-only, Open-set Sentences in Noise (+10 dB SNR)

- Almost all recipients (32/36, 88.9%) demonstrated significant improvement in the recognition of open-set sentences (CUNY) in the presence of background noise using the ESPrit compared to their preoperative performance with hearing aids. All but four recipients demonstrated significantly above-chance speech recognition.
- When tested in an environment designed to represent "real world" situations (background noise), recipients recognized an average of 57.9% of words in sentences, with a median score of 64%.

Hearing-only, Open-set Words in Quiet:

- Eighty-nine percent of recipients (32/36) demonstrated significant improvement in the recognition of open-set monosyllabic words using the ESPrit compared to their preoperative performance with hearing aids. Recipients recognized an average of 38.3% of the words, with a median score of 40%.

Communication Profile for the Hearing-Impaired (CPHI), Communication Performance Scale

The 18-item Communication Performance Scale of the CPHI was completed pre- and postoperatively by 59 of the 67 clinical trial subjects. The CPHI uses a five-point rating scale to assess respondents' ability to communicate effectively in a variety of social, work-related and home settings. An improvement of one level rating is considered by the authors of the CPHI to represent a clinically significant difference. Not all of the communication environments assessed by the CPHI were experienced by all subjects. The following statements summarize self-reported changes in communication abilities as assessed by the CPHI. When using the Nucleus 24:

- Three fourths (76.3%, 45/59) of the respondents reported communicating more effectively when driving in a car with family members.
- Three-fourths (74.1%, 40/54) of the respondents reported communicating more effectively when ordering in a restaurant.
- Three-fourths (76.4%, 42/55) of the respondents reported communicating more effectively at a dinner party.
- Three-fourths (78.3%, 36/46) of the respondents reported hearing religious services more effectively.
- Over three-fourths (85.4%, 41/48) of the respondents reported communicating more effectively in meetings.

General Performance Questionnaire

The General Performance Questionnaire was administered pre- and postoperatively to 51 of 67 clinical trial participants. The 14-item, self-report questionnaire evaluated possible device-related benefits, such as enjoyment of music, ability to monitor individual voice quality, improvements in communication ability and general quality of life issues. The following statements summarize these self-reported benefits. When using the Nucleus 24:

- Three fourths (35/51, 69%) of the respondents reported they enjoyed listening to music (at least to some degree) compared to one-third of the respondents (15/51, 29%) preoperatively.
- Two-thirds (63%, 32/51) of the respondents recognized (at least occasionally) songs and tunes that were familiar to them before losing their hearing, compared to 35% (18/51) preoperatively.
- Over one-third (39%, 20/51) of the respondents recognized familiar songs and tunes at least half of the time.
- Eighty-six percent of the respondents (44/51) reported they could frequently or almost always monitor the loudness and quality of their voice compared to only 35% (18/51) preoperatively.
- Ninety percent (46/51) of the respondents reported an overall improvement in communication ability without lipreading.

Regarding general quality of life issues:

- Eighty-eight percent (45/51) of the respondents indicated that they were satisfied with the cochlear implant system after 3 months of experience.
- Ninety-two percent (47/51) of the respondents were happy they made the decision to undergo surgery and receive the implant.
- Ninety-two percent (47/51) of the respondents indicated that the quality of their lives improved after receiving the Nucleus 24.

RESULTS OF CLINICAL STUDIES: CHILDREN

Effectiveness of the Nucleus 24 system in older (5 years and above) children was assessed by comparing the speech perception abilities of 23 pre- and postlinguistically deafened subjects preoperatively in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) with their postoperative performance in the implanted ear alone, after six months of device use. Recorded versions of various pediatric speech perception measures were presented at 70 dB SPL. Individual subject results were analyzed using a binomial statistical model and group means were analyzed using paired t-tests and the non-parametric Wilcoxon Signed Ranks tests.

Of the children five years of age and older who were capable of being tested on open-set word recognition tasks:

- Sixty-one percent (14/23) demonstrated significant improvement on the Glendonald Auditory Screening Procedure (GASP)
- Forty-four percent (10/23) demonstrated significant improvement on the Multisyllabic Lexical Neighborhood Test (MLNT)
- Fifty-seven percent (13/23) demonstrated significant improvement on the Lexical Neighborhood Test (LNT)
- Forty-eight percent (11/23) demonstrated significant improvement on the Phonetically-Balanced Kindergarten (PBK) monosyllabic word test
- Group mean performance was significantly higher after six months of experience with the Nucleus 24, on all 11 measures of speech perception administered to children five years of age and older. These measures ranged from simple closed-tests to more difficult open-set word and sentence recognition tests.

Device effectiveness for older children also was assessed through parental ratings of their child's auditory behaviors in a variety of everyday listening situations on the Meaningful Auditory Integration Scale (MAIS). For 19 children, preoperative ratings in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) were compared with postoperative ratings after six months of implant use. Ratings describing the frequency of occurrence of the child's auditory behaviors ranged from 0 (Never) to 4 (Always). Results were analyzed as the proportion of children rated who demonstrated the specific behavior either "frequently" or "always".

After six months of experience with the Nucleus 24:

- Eighty-three percent (15/18) of the children frequently or always responded to their name in quiet compared with only 47% (9/19) preoperatively with hearing aids.
- Forty-seven percent (9/19) of the children frequently or always responded to their name in noise compared with only 11% (2/19) preoperatively with hearing aids.
- Seventy-nine percent (15/19) of the children frequently or always spontaneously recognized common sounds in the classroom compared with 26% (5/19) preoperatively with hearing aids.

YOUNGER CHILDREN (AGES 18 MONTHS TO 4 YEARS, 11 MONTHS):

Effectiveness of the Nucleus 24 system in younger children was assessed in part through parental ratings of their child's auditory behaviors in a variety of everyday listening situations on the Meaningful Auditory Integration Scale (MAIS). For 22 children, preoperative ratings in the best-aided condition (implanted ear aided, non-implanted ear aided or binaurally aided) were compared with postoperative ratings after six months of implant use. Ratings describing the frequency of occurrence of the child's auditory behaviors ranged from 0 (Never) to 4 (Always). Results were analyzed as the proportion of children rated who demonstrated the specific behavior either "frequently" or "always".

After six months of experience with the Nucleus 24:

- Sixty-eight percent (15/22) of the children frequently or always responded to their name in quiet compared with only 27% (6/22) preoperatively with hearing aids.
- Forty-five percent (10/22) of the children frequently or always responded to their name in noise compared with only 14% (3/22) preoperatively with hearing aids.
- Forty-one percent (9/22) of the children frequently or always spontaneously recognized common sounds in the classroom compared with 14% (3/22) preoperatively with hearing aids.

In very young children, the long-term speech perception outcomes are currently unknown and will be evaluated through a three-year post-market surveillance program.

Neural Response Telemetry

The Neural Response Telemetry (NRT) system of the Nucleus 24 is capable of detecting physiological responses of elements of the auditory nerve within the cochlea.

Magnetic Resonance Imaging (MRI) Testing

The Nucleus 24, with the magnet removed, has been tested with a MRI machine having a 1.5 Tesla static field, a 64 MHz RF pulsed field, and pulsed gradient fields up to 20 Tesla/sec with the following results:

- Pulsed gradient fields up to 20 Tesla/sec and with worst case electrode position, do not produce any stimulus output from the cochlear implant.

- There was no observable temperature rise (<0.1°C), in the vicinity of the implant during worst case imaging of the head.
- There can be image distortion. With worst case scan parameters, there was a darkening of the image in an area around the implant, extending approximately 2cm medial and 6cm inferior. The area of darkening was largest in axial scans.

The MRI static field exerts a small force on the implant. The maximum force is less than the normal weight of the implant. This may be perceptible during the MRI procedure but is not harmful.

INDIVIDUALIZATION OF TREATMENT

PATIENT SELECTION CRITERIA

Postlinguistically Deafened Adults

1) Bilateral sensorineural hearing impairment; appropriate individuals typically will have moderate-to-profound hearing loss in the low frequencies and profound (≥90 dB HL) hearing loss in the mid-to-high speech frequencies; 2) Limited benefit from appropriate binaural hearing aids, as defined by scores of 40% correct or less in the individual's best-aided (i.e., monaural or binaural) listening condition on tape-recorded tests of open-set sentence recognition; 3) 18 years of age or older; 4) Psychologically and motivationally suitable.

Recorded sentence recognition tests appropriate for patient selection include CID Sentences and Iowa Sentences without Context or equivalent measures, administered in sound field at an average presentation level of 70 dB SPL. For purposes of patient selection, sentence recognition measures should not be abbreviated or, otherwise, modified.

Prelinguistically and Perilinguistically Deafened Adults

1) Bilateral profound sensorineural hearing impairment; 2) Little or no benefit from a hearing aid; 3) 18 years of age or older; 4) Psychologically and motivationally suitable.

Children

1) Bilateral profound sensorineural deafness (It is recommended that electrophysiological assessment corroborate behavioral evaluation in younger children.); 2) 18 months through 17 years of age; 3) Little or no benefit from appropriate amplification, as demonstrated by failure to develop basic auditory skills and, for older children, <20% correct on open-set tests (Multisyllabic Lexical Neighborhood Test or Lexical Neighborhood Test). A three-to-six month hearing aid trial in conjunction with intensive aural habilitation is required in order to assess the potential for aided benefit in candidates without prior aided experience; 4) Families and, when appropriate, candidates should be well motivated and possess appropriate expectations.

CLINICAL CONSIDERATIONS

Adult and pediatric patients deafened from birth to two years of age are considered to be prelinguistically deafened, while those with an onset of deafness from two to five years of age are considered to be perilinguistically deafened. Postlinguistically deafened patients typically are deafened after the age of five and present with age-appropriate speech and language skills.

Optimized hearing aid fitting and evaluation procedures are critical to the selection of suitable cochlear implant candidates. In order to ensure selection of appropriate candidates, hearing health-care professionals should utilize state-of-the-art amplification and diagnostic instruments and clinically accepted hearing aid evaluation and fitting procedures.

Adults with severe-to-profound, postlinguistic, sensorineural hearing loss commonly present with asymmetrical audiometric profiles. **When clinically appropriate, it is recommended that the poorer ear be selected for implantation, as surgical placement of the device will result in complete loss of residual hearing in the implanted ear.** When selecting the ear for implantation, open-set sentence recognition scores with hearing aids should be considered over more conventional audiological measures, as appropriate clinical indicators of preoperative auditory function.

Prelinguistically and perilinguistically deafened adults who do not have functional oral speech and language skills, and who are not highly motivated to participate in the rehabilitation process, are more likely to become nonusers of the device than are other adult patients. Prospective patients and their families should be counseled extensively regarding the limited nature of expected postoperative benefits, and should understand that prelinguistically and perilinguistically deafened adults are at risk for device nonuse. Many prelinguistically and perilinguistically deafened adults demonstrate improved detection of medium-to-loud environmental sounds, including speech. A few individuals demonstrate improved lipreading abilities, following extensive rehabilitation. (Average test scores improved by less than 10%, when the device was used in conjunction with lipreading.)

There was no significant difference in performance between the SPrint (body-worn) and the ESPrit (ear-level) speech processors on any measure of open-set speech perception in quiet or in noise.

PATIENT COUNSELING

Preoperative Counseling

Prospective cochlear implant candidates should be counseled regarding potential benefits, warnings, precautions and adverse effects of cochlear implantation, using the information in this document or in the booklet entitled Issues and Answers.

STORAGE, HANDLING AND STERILIZATION

Store cochlear implants at temperatures between -20 and +50 degrees Centigrade. Implants are not subject to aging, however, the certificate of sterilization is valid for 24 months. The "use by" date is stamped on the outside package. If it has expired, return the device to Cochlear.

Handle the implant packages with care. Severe impact which damages the outer storage package may rupture the inner sterile package.

Cochlear implants are supplied sterile in gas-permeable packaging. The titanium plugs and replacement magnets are supplied separately in sterile gas-permeable packaging. These are single use items. The sterilizing gas, ethylene oxide, turns the indicator bar in the inner package blue. Before opening the sterile package, inspect in carefully. If the sterile package is broken or the indicator bar is not blue, return the device to Cochlear.

INFORMATION FOR USE AND RECOMMENDED TRAINING

Physicians should be very experienced in mastoid surgery and the facial recess approach to the round window. It is important that physicians be trained in the implantation procedure for the Nucleus 24. It is strongly recommended that the surgeon work with an experienced team of audiology, speech-language, rehabilitation, education and psychology professionals. It is recommended that audiology professionals attend a training program for this device. Cochlear Corporation conducts periodic training courses.

Caution: Federal law restricts this device to sale, distribution and use by or on the order of a physician.

For more information contact:

Cochlear Corporation
61 Inverness Dr. East
Suite 200
Englewood, CO 80112
U.S.A.
(800) 523 5798
(303) 790 9010

Cochlear Limited
(ACN 002 618 073)
14 Mars Road
Lane Cove, NSW 2066
Australia
(02) 9428 6555

Cochlear AG
Margarethenstrasse47
CH-4053 Basel
Switzerland
(61) 205 04 04

Nihon Cochlear Co., Ltd.
Kizu Building, 8th Floor
3-12 Hongo 3-Chome
Bunkyo-ku, Tokyo 113
Japan
(03) 3817 0241

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