Abstract

Audiometric hearing tests were conducted at the Mayo Clinic in Rochester at the beginning of the 1930s. The list price for one of its audiometers at that time was $3,500, which translates into approximately $37,000 in 2003 currency. Physicians and residents in training were responsible for conducting hearing tests in the 1930s and 1940s. In the early 1940s a registered nurse was trained as an audiometrist to assist for some of the audiometric testing. The first “consulting audiologist” at the Mayo Clinic in Rochester was hired in 1949, early in the development of audiology as a profession. Growth in demand for audiologic services for larger numbers of patients and in the variety of services provided to them led to marked increases in personnel, space, and specialization over the years.

Abbreviations: ENG = electonystagmography ENT = ear nose and throat FTE = full-time-equivalent NICU = neonatal intensive care unit TEOAE = transient evoked otoacoustic emissions

Sumario:

En la Clínica Mayo en Rochester, se llevaron a cabo estudios auditivos desde el inicio de la década de los treinta. El precio de lista, en ese momento, de uno de sus audiómetros fue de $ 3,500, que corresponde en año 2003 a cerca de $37,000. Los médicos y los residentes en entrenamiento eran responsables de conducir estas pruebas auditivas en los treinta y cuarentas. A inicios de la década de los cuarentas se entrenó una enfermera graduada como audiometrista, para que ayudara en la elaboración de estas evaluaciones audiométricas. El primer “audiólogo consultor” en la Clínica Mayo de Rochester fue contratado en 1949, en etapas tempranos del desarrollo de la audiológía como profesión. Un incremento en la demanda de servicios audiológicos para un número mayor de pacientes y un incremento en la variedad de servicios ofrecidos a ellos, llevó con los años a un marcado aumento en el personal, en el espacio de trabajo y en la especialización.

Abreviaturas: ENG = electronistagmografía; ENT = oídos, nariz, garganta; FTE = equivalente de tiempo completo; NICU = unidad de cuidados intensivos neonatales; TEOAE = emisiones otoacústicas evocadas por transientes.
Information about the development and growth of the practice of audiology at the Mayo Clinic, as summarized below, was obtained primarily from archived Annual Reports of the Ear, Nose, and Throat Section (later named the Department of Otorhinolaryngology) to the Board of Governors of the Mayo Clinic. Valuable input was received also from retired members of the audiology section: Kenneth Miller, Carol Murphy, and Kevin Schreurs, and current audiology personnel, most of whom are contributing authors to other articles in this Special Issue of the Journal of the American Academy of Audiology. Information or quotations from Annual Reports are simply identified as [year] Annual Report. For the most part, the discussion is chronological over the years.

Pre-audiology

Interest in the precise measurement of hearing at Mayo Clinic, more precise than allowed by tuning forks, was demonstrated as early as 1924. In that year an article by H. I. Lillie (chair of the Ear Nose and Throat Service at Mayo Clinic) and F. W. Kranz, titled “A quantitative study of hearing with and without cotton plug prosthesis in the middle ear” was published in the Annals of Otology, Rhinology and Laryngology (volume 33, pages 458-471, 1924). Their article reported the results of hearing measurements made on Mayo Clinic patients at the Riverbank Laboratories in Geneva, IL under the conditions cited in the title of the manuscript. The frequency range covered was 256 to 3400 Hz and stimulus intensity was reported in units of 100, 1,000, 1,000,000, etc.

Based on correspondence between one of the authors (WOO) and the late Sam Lybarger, dated November 18, 1982, a Radioear Dual Audiometer Type DO-25 (shown in Figure 1) was supplied to Mayo Clinic in 1930. It was built by the E. A. Myers & Sons company and listed at $3,500, which, according to USA BLS Consumer Price Index, January 1930-December 2002, would amount to approximately $37,000 today. A copy of a blank audiogram intended for use with this audiometer was found in the chart of a Mayo Clinic patient and is shown in Figure 2. In his correspondence Mr. Lybarger mentioned that he did all the drafting for this form, and was assisted by Mayo Clinic in preparing its format; it was copyrighted by E. A. Myers & Sons in 1931. In addition to all the frequencies shown on the chart, this audiometer incorporated a phonograph for assessing the level at which music was heard (note the spaces provided for entering music selection and the level for each ear at the top of the audiogram form), plus a microphone for testing hearing with speech (voice as noted on the chart).

From Lybarger’s description the operation of this unit was a bit cumbersome to use in that selecting the desired frequency from its General Radio audio oscillator necessitated setting a decade capacitor and inductance selector in accordance with a
chart supplied with the unit. Similarly, a feedback control in the grid circuit of the oscillator tube was adjusted to control signal level prior to the hearing level attenuator. This cumbersome operation may have been responsible for the notation in the 1934 Annual Report that, “We loaned a Myers Radioear Audiometer to Dr. Anderson Hilding of Duluth [MN] to be used in some experimental work he wished to do in this time.” (Page 2) The 1935 Annual Report states that, “The Myers Radioear Audiometer loaned last year to Doctor Anderson Hilding of Duluth, Minnesota, has been returned in good condition.” (Page 1)

Other audiometers continued to be used for hearing assessment in the 1930s and early 1940s with the hearing tests being conducted by the ENT staff physicians (consultants) and their “fellows” (residents in training). An example is a 1941 article in the Proceedings of the Staff Meetings of the Mayo Clinic titled, “Hearing among experienced aviators” by P. N. Pastore (volume 21, pages 214-217) which reported the experience of 8 physicians’ use of 2 Maico audiometers in assessing the hearing of airline pilots. Pastore reported the incidence of hearing loss in this sample, including the configuration of normal hearing through 2048 Hz, and greatest loss at 4096 Hz. Use of hearing protection was strongly recommended. Also, Pastore noted that tests of the same pilots by different physicians revealed no significant differences in results.

Demand for audiometric hearing tests was highlighted in the 1942 Annual Report. “The use of the audiometer in tests for hearing...has been increasingly demanded by the patients....It does not seem feasible to use the audiometer for testing the hearing in all patients. Still there is a greater number that should be tested with the audiometer. The test requires from fifteen to thirty minutes. It is felt that if Mrs. [Margaret] Thomas [a Registered Nurse in the ENT section at the time] could be trained to do the routine audiometer test it would save the time of the consultants and fellows. Naturally, the fellows must be familiar with audiometer testing and will be required to become familiar with the test.” (Page 5) Staff consultants and fellows continued to complete many of the necessary hearing tests in that Mrs. Thomas’s duties as an audiometrist was listed as 2 hours daily in the 1945 Annual Report, and increased to 3 hours daily in the 1946 Annual Report.

The 1947 Annual Report mentions that arrangements had been made for the construction of a sound treated room for audiometric testing. To wit, “Arrangements have been made to reconstruct room 630 into a partially soundproof one in order to meet the criticism of not having conducted hearing tests in such a room. There is still much controversy in the otologic profession concerning the necessity for a soundproof room for the testing of hearing, but an institution such as the clinic is expected not to oppose attempts at progress in research.” (Page 3) Also in this report it was noted that, “…it has been arranged for Doctor Sheard and his associates to give lectures and demonstrations important to new developments in the testing of hearing. More importance is now placed on the basic physics and electronic influence of sound interpretation in relation to adequate testing of hearing. This fundamental knowledge will be increasingly important to the Fellows and Staff in understanding of new developments in the discussions appearing in the current literature.” (Page 6) (Charles Sheard, Ph.D. was the Founder and Chair of the Section of Biophysics and Biophysics Research at Mayo Clinic. He also devised an artificial larynx that was used at Mayo Clinic for many years.)

**Audiology 1949-1970**

Mayo Clinic’s first “consulting audiologist” as described in the 1949 Annual Report, was one of the authors (LDH). LDH joined the staff in September 1949 with perquisites equal to the physicians and other Ph.D. staff employed at Mayo Clinic at that time. LDH’s audiological experience stemmed from a Bachelor of Arts degree in deaf education from the Central Institute for The Deaf and Washington University in 1936, a Masters Degree in secondary education from the University of Northern Colorado in 1939, Ph.D. in speech pathology from the University of Wisconsin in 1948,
interspersed with employment at Indiana School for the Deaf, 1936-1938, New Jersey School for The Deaf 1938-1942, and as a faculty member at the University of Indiana, 1943-1946, and the University of Minnesota, 1946-1949. [It must be remembered that the first academic program in audiology was begun at Northwestern University in 1947 by Raymond Carhart (whose Ph.D. in 1936 also was earned in speech pathology, psychology and speech science), following his experience from 1944-1946 in the Army Medical Corps as an acoustic physicist and Director of the Acoustics Clinic at the Veterans Rehabilitation Center at Deshon Hospital in Butler, PA.] At the University of Indiana and the University of Minnesota LDH taught classes in speechreading and audiometry to speech pathology students and completed speech and hearing evaluations. At both institutions the practice of borrowing hearing aids from local hearing aid dealers to complete hearing aid demonstrations and evaluations was initiated by LDH.

In addition to his role in the conduct of hearing evaluations and hearing aid demonstrations and evaluations, from 1949 to 1955 LDH also provided service in speech pathology for patients who had undergone laryngectomies at Mayo Clinic. In 1955 the Department of Neurology at Mayo Clinic employed its first speech pathologist who also worked with ENT patients who had had laryngectomies, or had other speech or voice problems.

In 1951 and some subsequent years during the 1950s, temporary personnel were hired to assist LDH during the busier summer schedule. By 1952 Mrs. Thomas’s time as an audiometrist had increased from half days to full days. Audiometric screening of ENT patients “...to eliminate the need for the consultant to develop this information by the use of tuning forks” was noted in the 1958 Annual Report. (Page 4) A full time audiologist (Master’s Degree) also was added at the end of the 1950s.

Prior to 1954 all tests of vestibular function were conducted by the ENT consultants and fellows. The 1954 Annual Report notes that a paramedical office assistant had taken on the additional duty of assisting in special testing of the function of the vestibular labyrinth.

Further additions to the audiology personnel continued in the 1960s. The 1964 Annual Report mentions the initiation of plans for development of additional space for the audiology program in an area immediately adjacent to ENT. In this same Annual Report it is noted that, “To accommodate the Department of Neurology, a sound-insulated booth is being installed in the space adjacent to the Ear, Nose, and Throat consultation room at St Mary's [Hospital]. This will allow routine audiometry to be done there and will be of considerable benefit to the evaluation of neurologic patients hospitalized at St. Mary’s [Hospital].” (Page 23) Although this consultation room has been moved twice and new test booths have been installed at St. Mary’s Hospital since 1964, the immediate adjacency of the two facilities has been maintained and is staffed by ENT and audology each weekday morning.

Prior to the installation of 7 prefabricated sound suites in an area designated for audiology in 1966, the custom built sound treated rooms were mixed in with other ENT examining rooms, first in the Plummer Building, and then in the Mayo Building of Mayo Clinic. The 1966 Annual Report states: “The Audiology Section has recently been moved to newly remodeled space in the L-5 region [an area on the 5th floor of the Mayo Building; ENT occupies West-5 of Mayo Building]. One room in the north module of West -5B has been reserved for auditory screening...” (Page 26) The report goes on to state that, “The function of the Department of Audiology has been modified somewhat with the move to the new area and with the institution of the current system of auditory screening of patients. A bank of four automatic audiometers has been installed. These can be operated by a single technician [not an audiologist] who can thereby determine a pure tone threshold simultaneously on four patients. Standards have been set by which the patient is either referred to the otologist for consultation or to the audiology section for further testing on the basis of the screening test. It is anticipated that this system will
allow more efficient use of the consultant's time and avoid the delay of secondary appointments for the patient. Up to the present time the method is under close observation to determine the most effective procedure of patient scheduling in this unit. It is of interest that the improved sound insulation provided by the new audiology unit has resulted in a distinct improvement in the auditory thresholds determined on the average patient. The results indicate greater accuracy of testing in the new environment.” (Page 27)

1970-1986

In 1970 one of the authors (DER) joined the audiology staff as director of audiology at Mayo Clinic. Direct referral to audiology followed, as noted in the 1971 Annual Report. “In order to try and facilitate the referrals of patients from the Internal Medicine department with minor hearing complaints, a pilot program of auditory screening of patients from a few [Internal Medicine] sections on the fifteenth floor of the Mayo Building was started officially in the latter part of February of 1971. The purpose of the trial period was to determine if L-5 could handle the additional case load with present available facilities and staff personnel. This direct referral allows for a patient to be seen in Audiology for a screening hearing test as well as additional audiologic testing if deemed necessary. This also included hearing aid orientation. It was anticipated that this would not relieve the patient load for the otolaryngologist but would allow patients with minor hearing complaints to be seen with dispatch. Ordinarily with the long delay in appointments many of these patients would not wait for otolaryngologic and audiologic consultations. In the middle of May results to that point were analyzed and it was determined that such a referral program could be expanded to other areas of the Clinic without additional staff personnel in the Audiology Section. These conclusions were based on the fact that one additional masters (sic) level audiologist trainee would be added through the assistance of funds from the Allied Health Professional Training Program....The direct referral program was announced through the Clinic Newsletter....In approximately 54% of cases (275 of 514), it was determined that no E.N.T. examination was necessary and as such the patients were given audiologic information...and dismissed without an E.N.T. examination....Approximately 46% (239 of 514) of the direct referrals failed the screening test and had problems which were felt to be of a degree that...E.N.T....should see them. Of this number several have had otological surgery.” (Pages 1-3)

More formal recognition of audiology was announced in the 1972 Annual Report. “During 1972, audiology was officially made a Section in the Department of Otolaryngology, and Darrell Rose, Ph.D. was appointed Head of the Section of Audiology.” (Page 41) Also noted in this report was that, “In June of 1972, the Section of Audiology arranged and co-sponsored with the Department of Otorhinolaryngology, University of Minnesota, a Symposium on Middle Ear Impedance. Many authorities from the United States and Foreign (sic) countries participated. Approximately 200 attended the two day symposium. The proceedings of the symposium are scheduled to be published in the latter part of March of 1973.” (Page 42)

During the summer of 1972 a program was initiated in which graduate students nearing completion of their studies in academic audiology programs spent 2 to 6 weeks with the audiology group in a busy, fast-paced clinical setting. In like manner the first Clinical Fellowship Year at Mayo Clinic for audiology graduates was inaugurated in the fall of 1972. Every year since then one or two recent graduates from various academic programs have completed their Clinical Fellowship Year experience with audiologists at Mayo Clinic. Further expansion of the audiology section personnel and space continued throughout the 1970s. LDH retired from the Mayo Clinic in 1978.

The first cochlear implant surgery at Mayo Clinic was performed by George Facer at Methodist Hospital in 1982. At
that time the devices were single channel units with the single active electrode placed on the round window or inserted just through the round window. Because benefits seemed to be limited only a few such units were implanted at Mayo Clinic. Approval granted by the Food and Drug Administration of the multi-channel intra-cochlear devices for adults in 1986, and for children in 1990, led to greater patient benefits and increased demand, necessitating additional personnel and space for the cochlear implant program. Space was provided for another sound suite, offices, observation room, etc., in the Eisenberg Building of Methodist Hospital in 1990. Another move, within the Eisenberg Building, in 2001 allowed the installation of 2 sound suites, offices and necessary ancillary space. The audiology component of the cochlear implant team currently consists of 3.0 full time equivalent (FTE) clinical audiologists, a .5 FTE educational audiologist, a part-time speech-language pathologist, and a developmental psychologist, as needed, led by Jon Shallop.

In anticipation of his move to join the new Mayo Clinic facility being built in Jacksonville, FL, DER resigned his position as Head of the Section of Audiology in 1984. Another of the authors (WOO) was appointed Head of the Section of Audiology at that time. However, WOO very much disliked that role and successfully recruited Martin Robinette to be Head of the Section of Audiology in Rochester.

Mayo Clinic Expansion

Upon completion of a new Mayo Clinic facility in Jacksonville, FL in 1986, DER joined the Department of Otorhinolaryngology there as its sole audiologist. During that same year, hearing aid dispensing as part of the practice of audiology was initiated at the Mayo Clinic in Jacksonville, the first Mayo Clinic facility to do so. A second audiologist was added to the audiology practice in 1987. Upon the retirement of DER in 1994, David Hawkins joined the Mayo Clinic in Jacksonville as Head of the Section of Audiology and the audiology group has continued to grow. Currently it is staffed by 6 FTE audiologists, a 4th year Au.D. extern, and an office manager for the hearing aid dispensing segment of the practice. Space for the audiology group includes 4 sound suites, 2 ENG rooms, separate rooms for a posturography unit and a rotary chair, a cochlear implant room, a designated area for hearing aid services consisting of display space for assistive listening devices, 2 hearing aid fitting rooms, a repair laboratory, and ancillary space for waiting areas, offices, and storage.

Another Mayo Clinic facility was completed in Scottsdale, AZ in 1987 with Michael Cevette as its audiologist. A technician to assist with hearing aid services was added a few months later, and a second audiologist was added in 1988. Currently the Section of Audiology is made up of 9.5 FTE audiologists, a pediatric speech-language pathologist, and 3 FTE technicians (1.5 FTE for hearing aid services, 1 for cochlear implant activities, .5 for the executive hearing screening program). Five sound suites, (1 designated for hearing aid services, 1 for the cochlear implant program), 2 rooms for cochlear implant mapping and counseling, 1 room for speech pathology, 1 room for ENG, 1 large room for posturography and rotary chair testing, and 3 rooms dedicated to hearing aid services, offices, and ancillary space for patient waiting areas, etc., constitute the space for the Section of Audiology at the Mayo Clinic in Scottsdale.

1986-1994

In 1986 Martin Robinette joined Mayo Clinic as Head of the Section of Audiology in Rochester. Under his direction a two-day audiology symposium encompassing 21 presentations was held in Rochester in 1987. The following year another two day symposium on audiology topics was held under the guidance of DER and the Video Communications Section of Mayo Clinic. It was telecast live via satellite to 40 receiving sites across the United States. Although shortened to one day, similar satellite transmitted video symposiums have been conducted by the Mayo Clinic audiology group each year, with the exception of one, since 1988. A wide variety of audiology topics has been presented by internationally
known guest speakers.

Use of this satellite linkage also has allowed teleconferences among the three Mayo Clinic sites. Monthly teleconferences among the Mayo Clinic audiology groups for discussion of various topics, case study presentations, etc. were initiated in 1989 and continue to be held.

The late David Cyr joined the Section of Audiology in Rochester in 1989 to develop and direct a new facility for assessment of vestibular function. Under his direction additional equipment for electronystagmography (ENG) and Mayo Clinic's first units for posturography and rotary chair testing were purchased and installed. Upon Cyr's resignation and return to Boys Town Research Hospital in 1990, Robert Brey was hired to replace him. Once again demand for these audiology services, “This program has grown 117% in the last two years” (1991 Annual Report, page 7), necessitated additional personnel and space. The Vestibular/Balance Laboratory moved to larger space in the Eisenberg Building in 1993 and was expanded again in 2001. Currently the Vestibular/Balance Laboratory consists of 4 rooms for ENG and associated tests and maneuvers, 2 posturography rooms, 2 rotary chair rooms, a reception and waiting area, and offices staffed by 4.3 FTE audiologists. A room for vestibular rehabilitation staffed as needed by physical therapists and occupational therapists, is also available.

With the introduction of an industrial audiology program in 1990 and further additions of personnel to the Section of Audiology in the early 1990s, more space was needed. Consequently the L-5 area in the Mayo building was renovated and additional space was allocated for additional sound suites and office space in 1993.

1994-2002

Following an evaluation of auditory brainstem response and transient otoacoustic emissions (TEOAEs) for hearing screening of at-risk infants in the neonatal intensive care unit (NICU) at St. Mary's Hospital (see Robinette, et al. in this issue) routine screening of infants in the NICU with TEOAEs was begun in 1994. Prior to that time behavioral observation auditory testing and/or auditory brainstem response testing had been completed for NICU patients upon request. Currently otoacoustic emission and/or auditory brainstem response tests are scheduled for all infants prior to discharge from the NICU. Otoacoustic emission testing of newborns in the well-baby nursery prior to discharge began in 1999 and continues as one of the tasks for the audiology assistant, a new position created in the Section of Audiology in 2001.

In 1994 dispensing of hearing aids became a part of the practice of the Section of Audiology in Rochester also. Initially this service was staffed by 1.5 FTE audiologists and a hearing aid technician in space providing two hearing aid fitting rooms and an area for display of assistive listening devices in the Siebens Building of Mayo Clinic. At this time this service is staffed by 1.8 FTE audiologists and 1.7 FTE hearing aid technicians.

Martin Robinette resigned as Head of the Section of Audiology in Rochester in 1994. (It is Mayo Clinic policy that appointments as Department Chairs or Section Heads are finite terms of appointments, renewable up to 10 years or so, only occasionally longer. Upon completion of such appointments, former Department Chairs or Section Heads continue as members of their respective Departments or Sections.) David Fabry was named as his successor.

In 1998 Martin Robinette transferred from the Section of Audiology in Rochester to the Section of Audiology in Scottsdale where he assumed the responsibility for the audiology practice at the Mayo Arrowhead Clinic, an outreach family practice clinic. Audiology space in this facility consists of a sound suite, a hearing aid fitting room, a laboratory, and an office. In this setting he provides a wide range audiologic diagnostic and hearing aid services, assisted by a hearing aid technician.

The Section of Audiology in Rochester was renamed the Division of Audiology in the Department of Otorhinolaryngology in
2001. In 2002 David Fabry resigned his position as Head of the Division of Audiology in Rochester and was succeeded by Christopher Bauch. At this time, in mid-2003, the Division of Audiology at the Mayo Clinic in Rochester is made up of 3.0 FTE clinical audiologists and a .5 FTE educational audiologist in the cochlear implant program, 1.8 FTE audiologists and 1.7 FTE technicians in the hearing aid dispensing segment of the practice, 4.3 FTE audiologists in the Vestibular/Balance Laboratory (in spaces described above), and 8.6 FTE clinical audiologists and one audiology assistant for the hearing evaluation and diagnostic segment of the audiology practice at L-5 in the Mayo Building. Currently L-5 consists of 9 sound suites and separate rooms for otoacoustic emissions tests and hearing aid measurements.

In 1990 the Section of Audiology in Rochester completed almost 29,000 audiological procedures and consultations. That total increased to nearly 52,000 in 2001 with a high of over 53,500 in 1998. Across the sites in Rochester, Jacksonville, and Scottsdale, audiological procedures and consultations exceeded 763,000 in the 12 year period from January 1990 through December 2001. Also during that time period, Mayo Clinic audiologists had 122 publications in the form of articles in refereed journals, book chapters, or published proceedings of professional meetings, and made 438 presentations at professional meetings.

From the discussion above it is apparent that the growth of the audiology practice at Mayo Clinic, since 1949 in Rochester, and since 1986 and 1987 in Jacksonville and Scottsdale, respectively, has been substantial. The need for additional personnel and new services has outpaced the availability of space in the Mayo Building in Rochester. Consequently, the Division of Audiology in Rochester is housed in three separate but connected buildings. Even as this brief history of audiology at Mayo Clinic is being written, renovations of the space for audiology are under way in conjunction with a major expansion of other medical facilities in Rochester. A long-term goal of the “Practice Integration Project” as this expansion is called, is to obtain contiguous space for the various Departments and Sections of Mayo Clinic (including the Division of Audiology), and to allow room for further expansion as the numbers in personnel and services continue to grow.