The Clinical Audiogram

Its History and Current Use

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This article documents the historical development and evolution of the audiogram through a literature review and describes how audiologists currently use the audiogram. Issues of electronic data collection, privacy, and future developments are briefly discussed.

Introduction

The audiogram has been the banner of the clinical audiologist's work since the profession gained recognition after World War II. Without the data contained on the audiogram, physicians could not properly document pathologic conditions of the ear, nor prepare for otological surgeries. Speech-language pathologists have utilized the audiogram for the purposes of understanding the auditory receptive communication skills of their patients. Audiologists base habilitative and rehabilitative programs on information obtained from the audiogram. Considering the variety of ways that hearing sensitivity of an individual can be recorded, a widespread acceptance of established standards has enabled the audiogram to be universally understood despite variables such as patient-related historical data, types of tests performed, and test conditions/components.

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As facilities and practices grow in a technologically fluid field, the audiologist must remain current in every aspect of his or her practice. Similarly, the audiogram must periodically change to reflect current advances or modifications in clinical protocols and state of the art equipment.

The purpose of this paper, therefore, is to document the historical development and evolution of the audiogram through literature review and to describe how audiologists currently use the audiogram and briefly raise issues about privacy, electronic data collection, and future applications. An Audiometry Time line in Appendix A highlights the landmarks of hearing measurement.

The History of the Audiogram

Since the invention of the audiometer over 100 years ago, the audiogram has become the graphic and/or numerical record of hearing sensitivity for the otologic and audiologic specialties in health care. The audiogram was born out of necessity as the signature tool specific to the hearing scientist's ability to observe, measure, and record hearing behavior (Hedge, 1987). Without the ability to record information retrieved from the test environment, data collection would be circumspect and haphazard. Interestingly, this indispensable tool has received little more than cursory attention throughout the years.

From a historical perspective, as audiology grew into a profession, the audiogram reflected the technologies developed and used in the clinical environment. (See the Audiometry Time Line in Appendix A for an overview of the historical development of these tools.) In 1885, Arthur Hartmann designed an "Auditory Chart" which included left and right ear tuning fork representation on the abscissa and percent of hearing along the ordinate (Figure 1) (Feldmann, 1970).

Although Hartmann's "Auditory Chart" does show similarities to today's pure-tone grid, the standard for recording hearing sensitivity gradually evolved from Max Wien's "Sensitivity Curve" first presented in 1903 (Figure 2). Wien's graph documented results from tuning fork stimuli. Physical sensitivity was indicated along the ordinate and the chart was the first to show the relationship between hearing thresholds and frequency (Feldmann, 1970).

It was not until some 20 years later that a different type of record of hearing measurement was presented for recognition as a standard by Politzer, Gradenigo, and Delsaux (Figure 3). Their proposal, given in 1904 during the 7th International Congress of Otology in Bordeaux, France, was intended to standardize nomenclature such as "auditory horizon" and "auditory area" along with re-

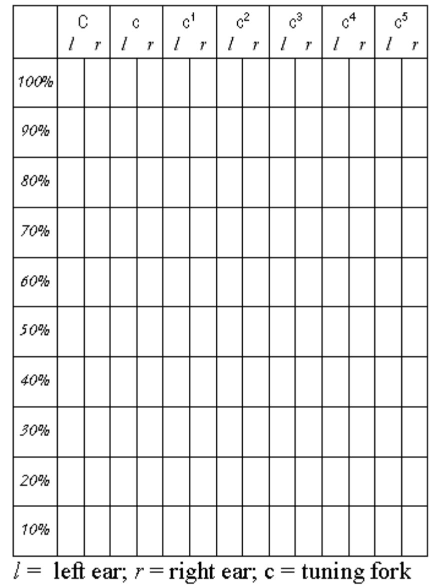
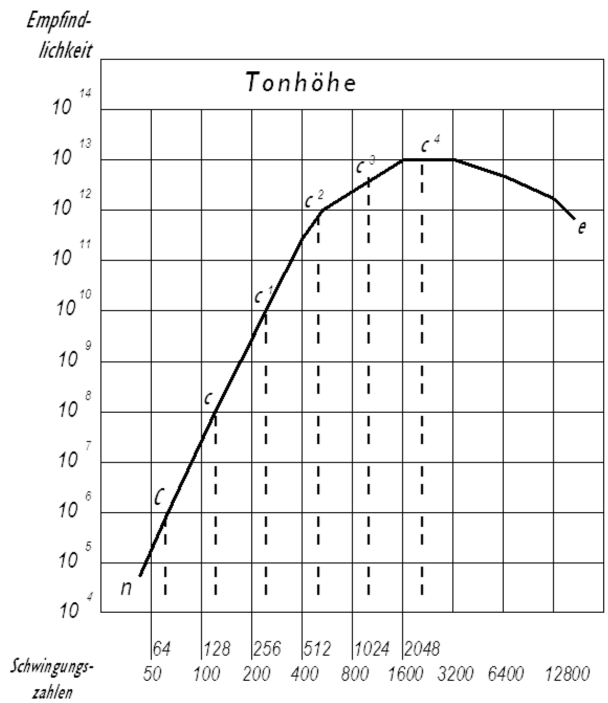


Figure 1. Recreation of Hartmann's Auditory Chart, first conceived in 1885. This was used to document tuning fork responses to the left and right ears.

cording forms for hearing testing. It was finally accepted in 1909 during the 8th International Congress of Otology in Budapest, Hungary. Called an "Acumetric Schema," this attempt at hearing record standardization was never universally accepted (Feldmann, 1970).

Unfortunately, hearing loss in the eras of Hartmann and Wien could not be specified in quantitative values relative to normal hearing. The tester arbitrarily selected intensity steps. It was not until 1922 that Fletcher, Fowler, and Wegel first employed *frequency* at octave intervals plotted along the abscissa and *intensity* downward along the ordinate as a degree of hearing loss. Fletcher et al. also coined the term "audiogram" at that time (Feldmann, 1970).

Throughout the years, the audiogram has reflected the growth of audiometry from air conduction in the early 1920s (Jacobson & Northern, 1991) to otoacoustic emissions of the 1990s. Virtually every population served by the audiologist, at some point, has its hearing sensitivity recorded on the audiogram. As mid and late 20th century hearing technologies grew, the audiogram moved into a position not only as the standard for displaying recorded data, but also as a counseling tool among audiologists. Its value is currently emphasized by clinical doctoral audiology courses as an important application used to illustrate degrees and types of hearing losses for patients and caregivers (Chial, 1998). Outside the profession of audiology, otologists and speech-language pathologists continue to receive training in audiometrics so they may understand hearing loss (Nodar, 1997).



Tanslation: *Empfindlichkeit* (sensitivity); *Tonhöhe* (frequency);
Schwingungszahlen (number of vibrations)

Figure 2. Re-creation of Wien's sensitivity curve, first conceived in 1903. The graph was the first attempt to mark hearing sensitivity in relation to frequency (Feldmann, 1970).

W	AD S AS	a^1M	a^1A	c^4A	R	H	P	V	v	LI	LS

Figure 3. Recreation of the Acumetric Schema submitted by Politzer et al. in 1904. Although intended to document hearing sensitivity, the schema failed in its attempt at standardize nomenclature. Key: W = Weber test; AD = *auris dextra* (right ear); S = Schwabach test; AS = *auris sinistra* (left ear); a^1M = duration of the auditory sensation with a fork placed on the mastoid; a^1A = same for air conduction; c^4A = same for a c^4 fork and air conduction; R = Rinne test; H = horlogium (distance that a watch may be heard); P = results of Politzer's acumeter; V = *vox* (distance to which conversational speech is understood); v = same for whispered voice; LI = *limes inferior* (lower frequency limit); LS = *limes superior* (upper frequency limit).

The Audiogram and the First Commercially Produced Audiometer

Any discussion of the audiogram must include a discussion of the development of the audiometer. In 1899, Carl E. Seashore introduced the audiometer as an instrument to measure the "keenness of hearing" whether in the laboratory, schoolroom, or office of the psychologist or aurist. The instrument operated on a battery and presented a tone or a click; it had an attenuator set in a scale of 40 steps (Seashore, 1899). Although Seashore's audiometer was not the first attempt to create an instrument for hearing testing, its ability to attenuate intensity logarithmically made it a landmark invention. This device initiated early forms of hearing testing standards, and consequently the otologist's understanding of the need for evaluation protocols and the construction of sound-treated test rooms. The decade of the 1920s propelled hearing testing into a more exacting science with the introduction of audiometers capable of producing pure tones via air conduction and bone conduction, and, to a limited extent, even speech testing capabilities. In the early 1920s, Western Electric developed the first commercially produced electronic audiometer. This instrument was capable of frequency testing via specially designed earphones. The "1A," at a cost of $1500 (a house in the same time period cost only slightly more), could test hearing from 32 Hz through 16,384 Hz (Fowler & Wegel, 1922).

Western Electric later produced the "2A" audiometer which was more portable and tested hearing from 64 Hz through 8192 Hz. As it was less expensive than the 1A, the 2A gained popularity with otologists (Olsen, 1991). With further technologic advances, bone conduction testing capabilities became a standard component of all Western Electric audiometers by 1928 (Jacobson & Northern, 1991). An interesting commentary on the infancy of the hearing testing industry was the prevalence of homemade audiometers during the mid and late 1920s. This was due to the popularity and economics of do-it-yourself radio kits available during that period (Feldmann, 1970).

There is little known about the birth and development of the audiogram although Fowler and Wegel first made reference to it in 1922. They described a chart plotting hearing sensitivity, with frequencies listed along the abscissa, and hearing sensitivity along the ordinate of a graph (Jacobson & Northern, 1991).

In their paper presented during the 28th Annual Meeting of the American Laryngological, Rhinological, and Otological Society of 1922, Fowler and Wegel discussed the audiogram as a curve which demonstrated the threshold of audibility to pure tones of various frequencies. At that time, the abscissa spread from 8 to 32,768 cycles per second, and the ordinate of the audiogram showed an increase from low to high in rms pressure change in grams per square centimeter. This presentation was landmark in its mention of the use of logarithmic scales for both frequency and sensation. It was argued in the paper that an audiogram plot may be misleading without the use of a logarithmic scale. These two scientists understood the need for standardization of both hearing testing units and recording methods (Fowler & Wegel, 1922). The increasing popularity and need for hearing testing spontaneously generated the audiogram as a method of recording pure tone information. At the 30th annual meeting of the American Laryngological, Rhinological and Otological Society, Jones and Knudsen (1924) discussed the need for recording hearing test findings on a chart that included questions about symptoms, right and left ear measurements with an amplifier, bone conduction measurements, and percentages of deafness for eight different pure tones.

It may be surmised that the advent of the audiogram did not result from any preconceived design born out of scientific necessity; rather, it became the sum of hearing technology's evolutionary parts. Scientists in the early years were focused on exploring diseases of the ear, how the auditory system functioned, and finally, how it could be assessed. The excitement of exploring the fundamentals of bone conduction overshadowed the need to create a standard method for plotting these findings (Fowler, 1925). When audiograms first appeared, they were employed as illustrations in scientific journal articles. These works influenced the audiogram's development rather than pre-existing standards for clinical recording. The student of audiology may conclude that the lack of standards forced clinicians to unsystematically document hearing test data in patient chart notes. As the technology grew to include bone conduction and speech testing, it was only natural for the otologist to condense the findings of these tests on the same piece of paper as the original pure tone grid. In retrospect, it is understandable that reporting standards were absent in a field more concerned with burgeoning advances in anatomy and treatments of pathology. At that time, the importance a governing body could have in the development of audiometry was not apparent. Consequently, reporting audiometric results lacked the same scientific precision needed to document the developing surgical techniques of otologists.

Perhaps reflecting on this lack of precision, otologists eventually demanded standardization for audiometers with regard to frequency and intensity. Curiously, it was the Council on Physical Therapy of the American Medical Association that organized the first attempt at standardization by releasing tentative findings in 1937 (Bunch, 1941, 1943).

Coincidental to the need for audiometric standards, Western Electric's D-5 audiometer was introduced in 1937. This was the first unit enabling the selection of "0" decibels for each frequency. The significance of this advance meant that audition could be tested in hearing level (HL) without the need for documenting hearing through a calibration curve (Feldmann, 1970). Despite this innovation, it was not until 1951 that the American Standards Association (ASA) introduced audiometric zero based on normative values (Berlin, 1963).

The Post World War II Years

The 40-to-50 year period following World War II reflected the sophisticated technologic advances that have earned a permanent placement on the audiogram. Along with the first established norms for pure-tone recorded information, the following test results eventually became standard on the audiogram: speech audiometry, tympanometry, acoustic reflex testing, and sound field audiometry.

The introduction of automatic audiometry by von Békésy in the late 1940s caused the audiogram to be transcribed by the audiometer (Békésy, 1947). Attempts were made later to demonstrate the importance of automatic audiometry in diagnosing auditory disorders by categorizing the audiometer's tracings (Jerger, 1960); however, its popularity was relatively short lived, having all but disappeared from clinical diagnostic settings by the mid 1990s. Despite its short life in the clinical community, automatic audiometry remains to this day an effective means for group hearing testing in occupational hearing conservation programs.

During the 1960s and 1970s, the audiogram also provided a means for recording popular test results such as the Short Increment Sensitivity Index (SISI) test, the Alternate Binaural Loudness Balance (ABLB) test, the Monaural Loudness Balance (MLB) test, and the tone decay test (TDT) (Liden, 1969).

The Audiogram Today

Current use of the audiogram in the United States complies with the most recent standards set by the American Speech-Language Hearing Association (ASHA) in 1992 and the American National Standards Institute (ANSI) in 1996. Along with pure tone information, audiograms often display data such as results from acoustic immittance measures inclusive of tympanograms and acoustic reflex thresholds, speech audiometric information, and include a legend explaining the symbols used. One of the most notable changes over the past decade has been a decreased dependence upon the Liden/Jerger classification system of tympanograms, replaced by a unit-specific notation of static admittance in cubic centimeters, peak middle ear pressure in decapascals (daPa), tympanogram width in daPa, and ear canal volume in cubic centimeters (Stach, 1998). Although manufacturers of hearing testing instruments are moving toward generating audiometric result printouts from their units, there are many facilities that desire to present hearing test findings on one integrated sheet. Practitioners have customized audiograms to include historical notes, otoscopy findings, hearing aid information, sound field data, and areas designated to record a description of findings and recommendations.

Since Fausti, Frey, Erickson, Rappaport, and Cleary (1979) reported the advantages of high-frequency testing, the need for an audiogram to serve this purpose has emerged. Many audiologists routinely performing established protocols to monitor ototoxicity in at-risk patients (Fausti, Frey, Henry, Olson & Schaffer, 1993). Indeed, the need for developing an extended high-frequency grid to record data has not been formally established although ANSI does briefly make recommendations for its design in the 1996 standards. By surveying manufacturers of ultra high-frequency testing equipment, it can be seen that the plotting of high-frequency information should extend upward to 20,000 Hz.

Prior to the widespread availability of desktop computers, facilities wishing to create an audiogram needed to commission its design and production to graphic designers at a high cost, or draw one by hand and photocopy or print it. Presently, audiograms can be designed on easily accessible word processor or spreadsheet software and even produced cheaply with inexpensively priced laser and inkjet printers. Manufacturers of audiometers have also initiated capabilities for generating audiograms from their equipment; however, there appears to be little agreement regarding standardization from this sector of the industry.

Everyday use of the word "audiogram" may bear only some resemblance to the graph's original intention. Initially, during the first half of the 20th century, "audiogram" referred to the graph/grid used to plot pure tone information. Now, the term has come to represent all aspects of hearing measurement documented on the same sheet of paper in which pure tone information is recorded. Although there has been no standardized heading at the top of this sheet of paper, many audiologists prefer using terms such as Audiology Assessment, Audiologic Evaluation, Audiologic Record, Audiology Report, and even Record of Audiometric Evaluation as a title for the test page. To date, no governing body (i.e., the American Academy of Audiology, the Academy of Dispensing Audiologists, or the American Speech-Language-Hearing Association) has taken steps to formally name this record of hearing sensitivity. In *Terminology of Communication Disorders*, "audiogram" is broken down as "audio" from the Latin *audire* "hear" plus the Greek word *gramma*, a drawing, and defined as the "standard graph used to record pure-tone hearing thresholds" (Nicolosi, Harryman, & Kresheck, 1996). No longer does the sheet of data strictly refer to the drawing of a plotted curve.

Audiogram Standards

During the 1949 International Congress of Audiology in London, Fowler and Luscher proposed standards for audiogram charts. Approved during the International Congress, Fowler's and Luscher's work was accepted with regard to 0.0002 dynes/cm^2 as being the standard value for sound pressure at 1000 Hz, and remaining frequencies were set to Fletcher and Munson's equal loudness contours. Furthermore, abscissa intervals of one octave and ordinate intervals of 20 dB were to be equal (Feldmann, 1970). This proposal served as the basis for subsequent ANSI specifications.

Over the years, audiologists in most clinical settings including universities, hospitals, and private practices have generally adopted these standards. The issue regarding symbol use and graph spacing has been discussed in publications following those generated by ASHA and ANSI in the 1970s.

ANSI Standards

ANSI periodically releases recommendations for audiograms in the publication, "Standards for Audiometers." In addition to the grid and symbol standards, ANSI recommends the following be placed on the audiogram form: name, age and gender of test subject, test site, the test subject's number, time and date of test, manufacturer's name, type and serial number of the audiometer, and tester's name (ANSI, 1996).

Specific to the grid, ANSI standards indicated the need to notate "Hearing Level—dB" and "Frequency—Hz" set in the vertical and horizontal spaces, respectively. With regard to grid spacing, ANSI continued to recommend in 1996 the initial proposal made during the 1949 London Audiology Congress, requiring that each octave should equal the same spacing as for any 20 dB of intensity. The spacing between octave and interoctave would therefore be equal to the spacing of 10 dB of intensity (Figure 4). Addressing the issue of high-frequency testing above 8000 Hz, ANSI recommended that one-sixth of an octave on the frequency scale be linearly equivalent to the length of 10 dB along the hearing level scale. This would mean that the grid from 8000 Hz to 16,000 Hz would have six divisions with each division equal to the same space allotted to 10 dB.

Symbols and legends for testing are similar for the two standards. ANSI went several steps further in the 1987 recommendations to include symbols for acoustic admittance, conductance, susceptance, impedance, resistance, and reactance. However, these symbols are not in common use by today's audiologists.

ANSI and ASHA indicated that threshold information could be recorded either in numerical entry or in the form of a graph. However, regardless of the format, reference level of the most recent audiometer calibration was recommended for inclusion on the audiogram.

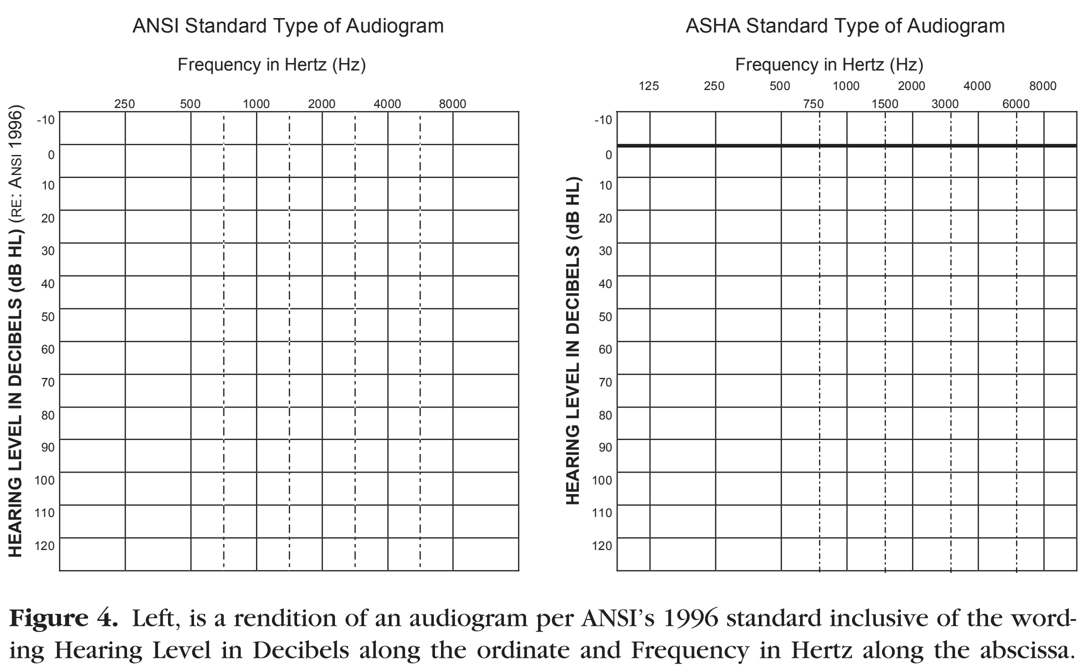


Figure 4. Left, is a rendition of an audiogram per ANSI's 1996 standard inclusive of the wording Hearing Level in Decibels along the ordinate and Frequency in Hertz along the abscissa. ASHA's 1990 standard for audiogram design (right), recommended that 750, 1500, 3000, and 6000 Hertz be placed slightly offset between frequencies to account for a truer arithmetic interoctave scale.

ASHA Standards

In 1990, ASHA's Committee on Audiological Evaluation met and released results similar to their own earlier recommendations (ASHA, 1990). These new recommendations were not necessarily in complete agreement with previously released ANSI standards. The ASHA 1990 committee report acknowledged the absence of standards for audiogram data no matter how sounds are delivered, that is, type of transducer, ultrahigh-frequency stimulation or sound field stimulation. ASHA recommend that 0 dB HL be listed on all audiograms in order to establish a common reference level. Furthermore, ASHA indicated that the 0 dB line should have a prominent place on the graph in order to stand out from other levels on the grid. The ASHA committee felt the inclusion of 125 Hz to 8000 Hz was appropriate for the abscissa, and the ordinate should include hearing levels from -10 dB to 120 dB HL.

ASHA also addressed the issue of high-frequency testing for those evaluations performed at frequencies from 8000 Hz through 16,000 Hz. They advised that spacing for these frequencies be accurately represented as "an octave interval, and equal in spacing to all other octave intervals on the form." Curiously, ASHA points out the following in the 1990 recommendations:

> While 750, 1500, 3000, and 6000 Hz are often represented and used as geometrically centered interactive [*sic*] frequencies, these representations are technically Incorrect [*sic*]. The errors are small and probably not of clinical significance; however, clinicians should be aware that the arithmetic average between octave frequencies does not represent the true semioctave frequency.

ASHA's audiogram example specifically indicated that interoctaves were not evenly spaced between test octaves (see Figure 4). This recommendation complicated audiogram design. Perhaps in an attempt to show less restrictive recommendations, ASHA left patient demographics to the discretion of the individual practitioner and clinic.

Notably, ASHA's 1990 recommendations for audiometric symbols used on the audiogram remained inconclusive regarding the use of bone conduction symbols. The disagreement was stated as a concern for misinterpretation of left versus right mastoid placement during masked audiometric conditions. Several solutions were proposed (Herer, 1967), however, there does not remain to this day any general consensus regarding this issue. In 1976, Jerger proposed a system of symbol use in scholarly publications that has yet to be universally adopted. Jerger's recommendations emphasized the need for "(1) minimization of symbols, and (2) separate graphs for each ear" (Jerger, 1976).

Current Audiogram Usage

A review and comparison of audiograms publicly available through textbooks, list serves, Web sites, and collaborative sharing at conferences and conventions, on commonalities of content and design was undertaken. A summary of these results follows.

Audiogram Analysis Method

Thirty-five various audiograms were reviewed to appraise common and unique components from various clinical sites including hospitals, universities, and private practices. These audiograms were acquired through announcements on professional list serves between January 10, 2003 and June 30, 2003. Commonalities among these audiograms were broken down into eight components (Table 1) including: demographics, grid, speech audiometry, immittance measures, history/comments, technical area, miscellaneous use area and total page use.

Results of Audiogram Analysis

Audiograms were generally found to show fairly good design especially when attempting to condense a variety of information onto the front of a single form. Not surprisingly, the audiogram graph required the largest area with the average grid using slightly more than one-fifth of space on a given 8½" x 11" sheet of pager. This was followed by facility header/footers and patient demographics at an average of slightly less than one-fifth of space per page. Remaining results can be seen in Table 2.

There are two interesting and innovative presentations on the assessment sheet. Although most audiograms do not have space dedicated for otoscopy (60%), more than several allowed for this important aspect of the audiologic evaluation. One practitioner included a symbolic representation of the left and right tympanic membranes, allowing the audiologist to draw information on it. The second innovative presentation was in the form of graphed SRT/SAT results. This method enabled a visual comparison of pure tone to SRT/SAT findings. Here, the practitioner placed another narrow three-column grid alongside the pure tone graph. The abscissa stated SRT and SAT, and the ordinate carried

Table 1. Eight Common Components on Audiograms.

Section	Description
Demographics—Header/Footer	Audiograms typically have space allotted here indicating patient demographics and the facility's or practice's essential information such as logo, address, etc., and sometimes the clinician's signature.
Audiogram Grid	Space used to graph the pure tone findings.
Speech Audiometry	Area designated for entering essential speech audiometric information.
Immittance Audiometry	Complete tympanometric findings, acoustic reflexes, etc. are assigned to this section, usually in numerical form.
History/Comments	Brief narrative related by the tester is designated here. This includes historical information, findings and recommendations.
Technical Area	Items such as key/symbol legend, patient reliability, transducer information, and test site are assigned to this section.
Miscellaneous Usage	An area containing information not universally found on most audiograms, i.e., otoacoustic emissions, otoscopic comments, hearing aid information, etc. The information in this section often increases the value of the audiologic record as it shows unique information particular to the practitioner and/or facility's professional profile.
Total Page Use	This section shows the total percentage of space used on a sheet of paper for entering all essential pieces of information.

Table 2. The Eight Sections of Reviewed Audiograms

Area on Page Section of Audiogram	Largest	Smallest	Average
Demographics & Header/Footer	33.93%	12.46%	**19.88%**
Audiogram Grid	35.0%	12.3%	**21.2%**
Speech Audiometry	23.2%	3.8%	**10.5%**
Tympanometry	28.6%	3.7%	**12.3%**
Comments	32.1%	1.5%	**16.8%**
Legends/Technical	16.8%	1.5%	**6.3%**
Miscellaneous	30.9%	2.3%	**10.1%**
Total Page Use	99.8%	72.1%	**89.6%**

over the same decibel levels as the pure-tone grid. This allowed the clinician to indicate the thresholds for either speech reception or speech awareness similarly to the pure-tone graph markings.

Discussion and Conclusions

Future Audiogram Development

The audiogram is on the brink of change, as health insurance carriers more frequently require audiometric data for review before appropriating reimbursement for audiologic services. Because the Health Insurance Portability and Accountability Act of 1996 (HIPAA) requires application of privacy standards, audiograms will need to be electronically recorded and forwarded safely and securely without compromise of the patient's privacy. Another modification for electronic audiograms may be seen as facilities move toward the paperless chart. Measurements of hearing sensitivity, traditionally shown in graphic form, may need to be transferred through an electronic system while complying with HIPAA regulations (Hester, 2003). Because of the diversity of audiometers and available software, there does not appear to be any consensus regarding how to approach the electronic audiogram at this time.

Issues raised about the electronic audiogram focus on capture of numerical data transfer versus the graphic picture file created by scan. Although numerical data transfer would be a logical mechanism to employ, there appears to be resistance in the use of digits representing pure-tone threshold information. The difficulties of electronic transfer are multiple: (1) a method to transfer hearing test information from patient to database with no error needs to be created, (2) a standard agreeable to clinicians and manufacturers of equipment must be implemented, and, (3) an agreement regarding where data are going must be made. In this regard, information received in-house for the purpose of paperless charts may find a solution simply by scanning the audiogram into an electronic picture format. Conversely, an individual clinician or institution wishing to transfer information electronically for billing purposes would have to abandon the electronic scan protocol for numerical data transfer. Ideally, the best mechanism to transfer data would be through the audiometer itself. Here, the benefit would be minimal extra steps needed for the clinician to complete the task. Should a mechanism be created in which the audiologist must manually input data after threshold acquisition, there would be an increase in the likelihood of error.

Further benefits of an electronic audiogram may lie in exploring the possibilities of recording serial audiometrics for the purpose of tracking hearing loss trends in individuals. This may be possible through layered color schemes in some software programs; however, it is unknown if this area has been explored.

Aside from the electronic data transfer question, the audiogram is increasing its usefulness as a counseling tool among audiologists. At this time, audiology doctoral programs are emphasizing and developing the importance of counseling for audiologists through formal coursework. The audiogram may be seen as part of the growth in new counseling approaches (Clark & Martin, 1994). Some audiologists overlay what is called the "speech banana" or articulation index on the audiogram in an effort to demonstrate to patients and relatives the positive effects that hearing aids or cochlear implants can have on the speech spectrum. This configuration, initially conceived by Daniel Ling and further developed by others assists in visualizing the target areas of audibility (Berlin, 2006, Olsen & Matkin, 1991)

Audiogram Revisions

There does not appear to exist a standard regarding the frequency for audiogram revision. Although left to the individual facility's or practitioner's discretion, the assessment sheet may best be suited for redesign whenever a facility acquires significant and technologically advanced hearing testing equipment.

Four aspects may be considered when proposing a new audiogram:

1. *What population is being served?* Review of patient demographics may help to shape the style of a new assessment sheet.
2. *What tests are normally performed at each facility that typify the audiometric standard?* All patients must be given the benefit of being provided with optimal audiologic care: pure tone audiometry, immittance testing, speech audiometry, otoscopy, otoacoustic emissions, and hearing aid check.
3. *Who is going to read the audiogram?* Audiometric reports are typically read by otolaryngologists, audiologists, speech-language pathologists, physicians and nurses of other medical specialties, early intervention *specialists, and educators.*
4. *Does the audiogram have a professional appearance?* The audiogram should reflect the quality of care normally accorded by the clinician and institution it represents. Aside from prosaic design, audiograms are often photocopies of photocopies, losing the crisp look of professionally printed documents.

Revision of a facility's current audiogram comes under the decision of the designer. An appraisal regarding currency and usefulness of a facility's audiologic assessment sheets may be initiated utilizing the same eight categories identified in the earlier audiogram review. This will allow for more effective use of the form for purposes of recording and relating data.

CONCLUSIONS

The audiogram has a worldwide history originating in the field of otology during the late 19th century and migrating to the profession of audiology after World War II. It typically offers a visual base by which hearing sensitivity is presented, judged, and compared to previous other recordings. As a tool documenting hearing sensitivity, only the audiogram grid component must adhere to one of two formal standards which are dictated by ANSI or ASHA.

After reviewing and analyzing audiograms used in the United States, it was concluded that the convention of most facilities is to post the following information across the top of an audiogram page: institution name/logo, patient demographics inclusive of date of birth/age, medical record number, test date, and referral source. This is often dictated by standards set by a facility's Medical Records department and Forms Committees. Although the size of the pure-tone grid varied from sheet to sheet, it was clearly the dominant feature on every record. With few exceptions, the grid was usually placed on the left side of the audiogram.

Design and features of the clinical audiogram are often reflective of how the clinician employs the tool, who reads it, and even the types of equipment used in the setting. Just as its birth and development were directly linked to the available hearing testing equipment and protocol of its day, so too will today's audiogram evolve as the industry creates new technologies and applications of hardware and software. Indeed, the audiogram will continue to profile human hearing sensitivity, but under the harnesses of voluntary standards and regulations, systems of electronic recording, data transfer, and even government privacy guidelines.

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APPENDIX A

AUDIOMETRY TIME LINE

Events Relevant to Audiology	Audiometric-Related Events
550 BC — Pythagoras explained that vibrations in the air made sound (Gerritsen, 2003)	377 BC — Hippocrates reported clinical findings of hearing loss, first case history involved deafness from skull trauma (Feldmann, 1970)
	50 AD — Celsus reported clear etiologic differentiation of hearing disorders, especially those involving the outer and middle ears (Feldmann, 1970)
1543 — Vesalius described middle ear anatomy (Feldmann, 1970)	600 AD — Alexander of Tralles reported physicians making noises with bells for the purpose of investigating the auditory system (Feldmann, 1970)
1561 — Fallopio discovered the cochlea (*Sound From Silence*, National Academy of Sciences, 2003)	1550 — Cardano described method of transmitting sound to the ears by placing a hard object between one's teeth (Feldmann, 1970)
	1578 — Capivacci differentiated between conductive hearing loss and a nerve loss by use of zither string attached to the patient's teeth (Feldmann, 1970)
	1711 — Shore invented the tuning fork (Feldmann, 1970)
	1804 — Psfingsten divided speech sounds into classifications of vowels, voiced consonants, and voiceless consonants (Feldmann, 1970)
	1821 — Itarod used a tuning ring of copper to test hearing; first to systematically test hearing in a scientific manner (Feldmann, 1970)
	1820 — Wallaston reported the upper and lower limits of hearing with regard to frequency (30–18,000 Hz) (Feldmann, 1970)
	1834 — Weber described cochlear anatomy and his Weber Test (Feldmann, 1970)
	1855 — Rinne reported the findings of differentiating tuning fork sounds to the ear from bone conduction versus air conduction (Feldmann, 1970)
Telephone invented; commercial development and widespread use of electricity	1875 — Bing introduced an alarm clock–shaped "acumeter" with built-in tape measure for measuring distance between patient and sound source (Feldmann, 1970)
	1877 — Politzer invented an "acumeter" which assisted in bone conduction testing (Feldmann, 1970)
	1879 — Richardson coined use of the word audiometer (Feldmann, 1970)
	1885 — Hartmann created the "Auditory Chart" (Feldmann, 1970)
	1899 — Seashore used induction coils to create an electric acumeter with logarithmic intensity regulation (Seashore, 1899)
	1903 — Wien created graphs to show sensitivity curves in relation to hearing threshold (Feldmann, 1970)
	1907 — Zwaardemaker described construction of a "noise-proof" test room (Feldmann, 1970)

Events Relevant to Audiology	Audiometric-Related Events
First commercially manufactured hearing aid (League for the Hard of Hearing, 1998)	1909 — Congress of Otology adopted the Politzer et al. proposal to standardize nomenclature and record forms for hearing testing (Feldmann, 1970)
1918 - American National Standards Institute was founded (ANSI)	1910 — Bárány attempted to test one speech sound per test word (Feldmann, 1970)
	1919 — Schwarz presented an electronic audiometer – "Otaudion." This included the "Otosklerometer" which attempted to involve the Wheatstone-Gelle phenomenon (occlusion effect) (Feldmann, 1970)
	1922 — Fletcher et al. initiated the convention of recording hearing with frequency shown along the abscissa and intensity downward on the ordinate (Fletcher, Fowler & Wegel, 1922)
	1923 — Fowler and Wegel reported use of the Western Electric 1A Audiometer — the first commercially available hearing testing instrument and use of a "sound-proof" room for testing was first employed (Fowler & Wegel, 1922)
	1924 — Jones and Knudsen included speech transmission through their instrument, the "audio-amplifier" (Feldmann, 1970)
Penicillin was discovered	1928 — Fowler employed the use of binaural loudness balance testing to test the perception of intensity, later, recruitment; Western Electric audiometers were routinely equipped with bone conduction vibrators; otologic journals included instrucitons for building audiometers (Feldmann, 1970)
	1937 — Manufacturer Western Electric introduced D-5 audiometer enabling the selection of "0" for each frequency, and dispensed with the need for calculating hearing loss via calibration curve (Feldmann, 1970)
	1938 — ASA (later, ANSI), AMA, and manufacturers of audiometers — initiated standards for hearing instruments (Feldmann, 1970)
WWII: Military showed interest in hearing rehabilitation	1939 — Davis reported on human brain activity after acoustic stimulation (Galambos, 1992)
1946 – International Standards Organization (ISO) was found_ (Netlingo, 2003)	1946 — Hudgins et al. developed spondee word lists in English. Word lists in other languages were concurrently under development during the same period (Feldmann, 1970)
	1947 — Békésy introduced the semiautomatic self-testing audiometer which enabled the graphing of a diagram of hearing (Békésy, 1947)
	1949 — International Congress of Audiology — accepted proposals for standardization of audiogram charts (Feldmann, 1970)
	1951 — ASA introduced the standard for audiometric "0" (Berlin, 1963)
Introduction of transistorized Behind The Ear hearing aids (League for the Hard of Hearing, 1998)	1956 — Zwislocki initiated use of narrow-band noise for purposes of masking (Feldmann, 1970)
	1958 — Matzker used a "central synthesis" of signals to be received binaurally in order to judge central auditory function (Feldmann, 1970)
	1960 — Madsen presented the first commercially available electroacoustic bridge for impedance audiometry (Palmu, 2001)

Events Relevant to Audiology	Audiometric-Related Events
	1963 — Zwislocki introduced the first commercial use of the acoustic impedance bridge (Palmu, 2001)
	1964 — International Standards Association introduced its standard for audiometric zero (de Jonge, 2003)
	1969 — ANSI released its standard for audiometric zero (ANSI, 1969)
	1970 — Jerger introduced classification of tympanograms (Jerger, 1970)
	1974 — ASHA published “Guidelines for Audiometric Symbols” (ASHA, 1974)
First cochlear implant	1978 — ANSI published “Methods for Manual Pure-Tone Threshold Audiometry” — included audiogram specifications (ANSI, 1978)
	Kemp reported on acoustic emissions from within the human auditory system (Kemp, 1978)
Widespread availability of desktop computers	1979 — Fausti et al. indicated the need for ultrahigh-frequency testing to monitor ototoxic medication exposure (Fausti et al. 1979)
	1990’s — Manufacturers marketed instruments capable of producing audiograms directly from their audiometers; the appearance of paperless charts in hospitals
	Universal newborn hearing screening programs become widespread initiating the delivery of economical hand-held OAE screeners
	1996 — ANSI published most recent audiometric standards (ANSI, 1996)
Health Insurance. Portability and Accountability Act of 1996 (HIPAA)	