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Efficacy of the Speech Intelligibility Index as an intervention tool with pediatric cancer patients

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EFFICACY OF THE SPEECH INTELLIGIBILITY INDEX AS AN INTERVENTION TOOL WITH PEDIATRIC CANCER PATIENTS

By

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Abstract*:** ***This study evaluates the Speech Intelligibility Index (SII) as a tool to describe hearing loss and predict when hearing aids would be appropriate for pediatric oncology patients who have received or are currently receiving cisplatin. The efficacy of the SII is compared to the Brock grade which is commonly used for patients with ototoxic hearing loss secondary to cisplatin treatment. The SII is a discrete measure that precisely reflects the patient's functional hearing status and is highly correlated with the need for audiologic intervention.

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LITERATURE REVIEW

Cisplatin ototoxicity in pediatric oncology patients has been well documented and currently several scales exist to classify the high-frequency hearing loss associated with this treatment.[1-10] Although there are many ways to classify ototoxicity, it is most commonly defined by one of the three following classification systems—Brock Grade[1], American Speech Language Hearing Association (ASHA) hearing loss classification[2], and the National Cancer Institute Common Terminology Criteria for Adverse Events version 3.0 (NCI CTCAEv3)[11]. Most recently, the Chang grading scale was introduced as a modification of the Brock grade to classify ototoxicity.[12] Each of these four scales serves a somewhat different purpose.

The Brock grade was specifically designed to characterize platinum-induced high-frequency hearing loss.[1] This system is based on severity of high-frequency hearing loss for the better hearing ear, with grades from 0 to 4 with grade 4 representing the most severe hearing loss (see Table 1). Recently, Chang and Chinosornvatana developed a modified Brock grade designed to more accurately reflect the patient's need for a frequency modulation (FM) system and/or hearing aids.[12] The Chang grading scale is more sensitive to functional deficits than the Brock grade due to inclusion of hearing thresholds less than 40 dB HL and thresholds at the interoctaves 6000 and 3000 Hz (see Table 1). It is proposed that the Chang grading scale is more useful in predicting the need for hearing aids and/or FM systems than the NCI CTCAEv3.0 scale; however, further research is warranted.[12]

The NCI CTCAEv.3 scale was specifically designed for patients involved in an ototoxicity monitoring program and to identify the presence of hearing loss that could affect a person's ability to communicate.[11] This four-level system combines threshold information, including threshold shifts, with subjective judgments (see Table 1). The NCI CTCAEv.3 is the standard toxicity scale used in large-scale clinical pediatric trials and is often the basis for subsequent dose reductions within a study.[11]

The ASHA scale was designed for early detection of threshold shifts to potentially minimize or prevent hearing loss.[2] This scale classifies ototoxicity into three groups relative to the baseline audiogram (see Table 1). Thresholds at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, and if possible, ultra-high frequencies (9000, 10,000, 11,000, 12,000, 14,000, 16,000, 18,000 and 20,000 Hz) are considered. Any decrease or loss of response must be confirmed by repeat testing within 24 hours of the test session.[2] The utility of the ASHA scale in monitoring patients and adjusting ototoxic therapy such as platinum agents in cancer patients has not been clearly established. (personal communication, Robert J. Hayashi)

Significant differences among these classification systems make comparisons difficult.[3,9] The Brock grade is based on a medical model of grades to represent severity of loss of the better ear. The Chang grading scale, also based on a medical model of grades, prefers that each ear be graded individually. In the event that only one grade is to be given, then the grade would be based on the worse ear (personal communication, Kay W. Chang). The grading scales of Brock and Chang are familiar to oncologists due to their design, which is tailored for platinum ototoxicity, with increasing grades tracking the characteristic declines in hearing in this patient population. In contrast, the ASHA and NCI CTCAEv.3.0 scales can be used with unilateral or bilateral changes, typically classifying loss based on the worse ear. Both ASHA and NCI CTCAEv.3.0 are designed to alert clinicians to the onset of mild hearing loss due to ototoxicity. The Brock grade is based on thresholds $\geq$ 40 dB HL; whereas, NCI CTCAEv.3.0 and ASHA are based on threshold shifts of 10, 20, and 25 dB.

An important issue for clinicians is determining when the severity of the loss warrants intervention. None of the three most commonly used and researched scales addresses the functional hearing status of the patient, which would help guide intervention strategies such as hearing aids, FM systems and classroom accommodations. In contrast, the Chang grading scale attempts to account for functional hearing status. However, there are currently no reports further validating the scale and assessing its application within clinical settings.

A tool that accurately reflects functional loss and can assist clinicians in conveying its impact to patients and families is the speech intelligibility index (SII). The SII was created in 1997 as a major revision of the 1986 Articulation Index (AI).[13] The AI is a physical measure developed by communication engineers to quantify the relationship between the portion of the average speech spectrum that remains audible in the presence of filtering, noise distortion and low speech level.[13] It was originally developed to assist engineers in the design of telephone communications systems but has been more recently used as an audiologic counseling tool[14], a means for selecting various amplification systems[15-16] and the prediction of speech intelligibility[16-18]. Like the AI, the SII is also a physical measure highly correlated with the intelligibility of speech under a variety of adverse listening conditions such as noise, filtering and reverberation. Critical to the study of ototoxic hearing loss, the SII has more emphasis on the high frequencies (6000 and 8000 Hz.) than the AI.[19] The SII is interpreted as the total number of speech cues to reach the listener. If all speech cues reach the listener the SII is 1.0; whereas, if no speech cues reach the listener the SII is 0.0.[20] According to the ANSI 1997 standard, a good communication system has a SII >.75 and a poor communication system has a SII <.45.[20]

The SII is computed as a product of the frequency band importance function (Ii, a numerical value characterizing the relative significance of the frequency band to speech intelligibility) and the band audibility function (Ai, a number between 0 and 1 specifying the effective proportion of the speech dynamic range within the band that contributes to speech intelligibility under less than optimal conditions) summed over the total number of frequency bands in the computations.[20]

$$SII = \sum_{i=1}^{n} I_i A_i$$

There are four methods to calculate the SII: 1) Critical Frequency Band (21 bands), 2) One-Third Octave Frequency Band (18 bands), 3) Equally Contributing Critical Band (17 bands), 4) Octave Frequency Band (6 bands). The basic steps of the four computations are essentially the same. The formulas differ only in the number and the size of the frequency bands. Since more frequency bands increase accuracy, the Critical Frequency Band method is the most precise of the four listed.[20]

Research involving the SII and the pediatric population is sparse. The SII has been used with normal hearing adults to predict speech intelligibility under realistic conditions[21] as well as to predict speech reception thresholds for sentences in fluctuating noise.[22] The SII has also been used to study hearing impairment and hearing aids as well as automated calculations with manufacturers probe microphone equipment in children and adults.[23] To the author's knowledge, no published accounts use the SII to classify ototoxic hearing loss.

This study aims to evaluate the Speech Intelligibility Index (SII)[20] as a tool to describe hearing loss and predict when hearing aids would be appropriate for pediatric oncology patients who have received or are currently receiving cisplatin. In particular, the following questions have been examined: 1) Is there a specific value of the SII that would serve as a criterion for hearing aids? 2) Do the SII values correspond to hearing aid recommendations of audiologists?

3) Is the SII better than the Brock Grade for describing the impact of hearing loss on every day function?

SUBJECTS

The study was approved by the Washington University School of Medicine Human Research Protection Office. Retrospective chart analysis was performed on pediatric oncology patients treated between August 1990 and April 2007 at St. Louis Children's Hospital. This review generated a list of 160 patients treated with the chemotherapeutic drug cisplatin. Eligibility criteria required that patients were treated with the chemotherapy agent cisplatin, have an audiogram obtained at least six months after the last cisplatin administration and all conductive hearing losses were excluded. To distinguish a platinum-induced, high-frequency sensorineural hearing loss from a conductive loss, the air-bone gap was evaluated. If results indicated an air-bone gap ≥15 dB above 1 kHz, the ear was excluded from entry. Ears for which there was decreased hearing with no bone conduction measures were excluded if tympanometry indicated a static admittance of ≤ .2 mmho. Patients were also excluded if the pure tone thresholds were not obtained bilaterally at the following test frequencies: 500, 1000, 2000, 4000 and 8000 Hz. Seventy-eight patients met eligibility criteria; however, patient number fifty-one was excluded from analysis due to extreme asymmetric hearing loss (i.e., profound loss in the left ear and normal hearing from 500 to 4000 Hz with a severe loss above 6000 Hz in the right ear). Variables recorded included the following: age, gender, diagnosis, first and last day of cisplatin treatment, cumulative cisplatin dosage, and audiometric thresholds.

PROCEDURES

Audiologic assessments were performed at St. Louis Children's Hospital by licensed audiologists. The age, physical status and cooperation of the patient determined whether visual reinforcement audiometry (VRA), conditioned play audiometry (CPA) or conventional audiometry was used. Due to the nature of pediatric audiologic assessment, not all frequencies were tested for each patient. If the audiometric thresholds tested did not include 6000 Hz, it was interpolated based on the average of 4000 and 8000 Hz rounded up to the nearest five dB.

Both Brock grade and SII values were recorded for both ears. (see appendix D) SII values were calculated by the Verifit Audioscan (Audioscan) using 1/3 octave bands, and expressed as a number ranging between 1.0 (full reception) and 0.0 (no reception). Audioscan uses linear interpolation for bands between entered audiogram points. For those frequencies external to the entered audiogram: the SPL threshold at the lowest entered frequency is used for each 1/3 octave band between this point and 200 Hz (inclusive); the SPL threshold at the highest entered frequency is used for each 1/3 octave band between this frequency and 8000 Hz (inclusive). (personal communication, Chris Stokes Rees)

The need for hearing aids was based on judgments from three pediatric audiologists with an average of 15 years of experience fitting/managing hearing aids in a practice of approximately 500 active patients. Based on patient age and audiometric data the three audiologists independently evaluated the need for hearing aids. The audiologists judged the extent to which hearing aids would be recommended based on the following ranking: 1) Definitely would not recommend hearing aids, 2) Most likely would not recommend hearing aids, 3) Could go either way, 4) Most likely would recommend hearing aids, 5) Definitely would recommend hearing aids. Comments were solicited from the ranking audiologists regarding the type of information they would like to have at their disposal when making a decision on whether or not to fit a child with hearing aids. Additionally, they were also asked to comment on the reasoning behind choosing to fit a child with hearing aids and any additional intervention methods (FM system, speech and language evaluation, preferential seating, etc.) they may have recommended.

STATISTICAL METHODS

Descriptive analysis with mean, standard deviation and proportion was used to describe patient characteristics, SII and Brock grade data. Kappa value and intra-class correlations (ICC) were calculated to test agreement among the three audiologists. Sensitivity and specificity of SII with a < 0.8 cut-off value were calculated for SII compared to Brock grade. SAS version 9.1 software was used for statistical analyses.

RESULTS

Patient characteristics are listed in Table 2 for age, gender, diagnosis and cumulative cisplatin dosage. The SII (minimum, maximum, average and standard deviation) is compared to the Brock grade for both ears in Table 3. Data for individual ears are displayed in Figure 1, with a scatter plot comparison between Brock grade and the SII.

Figure 2 displays the mean ranking of each audiogram from the panel of three audiologists as a function of the SII value of the worse ear. Figure 3 displays the mean ranking of each audiogram from the panel of three audiologists as a function of the SII value of the better ear. In general, the audiologists were in agreement as to which patients were in need of amplification and those that did not. Furthermore, the SII values correlated with the audiologists' consensus for the need of amplification with patients with a value < 0.8 receiving recommendations from all three audiologists. The Kappa value for audiologists one and two was

.95. Kappa statistics could not be calculated for agreement involving audiologist three because audiologist three never used category three (could go either way) in their hearing aid rankings. Because Kappa statistics could not be performed for agreement involving audiologist three, intra-class correlations (ICC) were calculated for the remaining agreement statistics. ICC for audiologists one and three was .96 with a 95% confidence interval (.93-.97). ICC for audiologists two and three was .97 with a 95% confidence interval (.94-.98). Thus, agreement among the three audiologists was consistently high.

Sensitivity, specificity and efficiency are shown in Table 4 for SII and Brock grade for both the better and worse ear using several criteria. A cutoff criterion for hearing aids or intervention has not been specified for the Brock grade. To optimize the sensitivity and specificity measures for the Brock grade two logical cutoff scores were evaluated: Brock grade 2 as passing and Brock grade 2 as failing. As reflected in the data, the SII was associated with a high sensitivity, specificity and efficiency for both ears.

DISCUSSION

This report supports the use of the SII to describe the functional hearing status of pediatric patients with ototoxic hearing loss secondary to chemotherapeutic treatment with cisplatin. In contrast to the Brock grading system, the SII gives a more precise measurement of the clinical impact of the hearing loss for the patient. Of particular interest are the large range of SII scores for Brock grades 2 and 3. Patients with Brock grade 2 had SII scores ranging from .59 to .86. Patients with Brock grade 3 had scores ranging from .37 to .59. In fact, some patients with Brock grades of 2 or 3 had SII scores that varied by more than 25%, indicating that the SII, by its numeric calculation, provides a more precise numeric value of the patient's hearing loss. The wide range of scores suggests that the SII is better than the Brock grade at representing the nuances of functional hearing status and would be more sensitive to subtle progression of hearing loss.

Sensitivity, specificity and efficiency were calculated for a variety of conditions for both SII and Brock grade (see Table 4) in an attempt to optimize criteria for each scale. For the patients studied, the SII with a <.8 criterion for the worse ear provided the best match to the hearing aid recommendations of the three audiologists, with 100% sensitivity, specificity and efficiency. The Brock grade for the better ear with a criterion of grade 2 as the indicator of the need for hearing aids also provided excellent agreement with the audiologists with 95% sensitivity, specificity and efficiency.

The Chang grading scale was developed to improve upon the Brock grade by adding subcategories for Brock grades 1 and 2 and modifying grade 3. Grade 4 remains unchanged. (see Table 1) Although the Chang grading scale begins to address the issue of correlating audiologic measures with the need for FM systems and/or hearing aids, it does not account for individual variation to the same extent as the SII. The SII is a more precise measure than the Chang grading scale or Brock grade because the audiogram is converted into a dynamic index, which accounts for individual variation in functional hearing status.

According to the 1997 SII ANSI standard, a good communication system for an adult has an SII in excess of .75. Published data for a good communication system for children are lacking. Data from the current study with cisplatin treated pediatric cancer patients support an SII cut-off of <.8 to differentiate children in need of hearing aids from those not needing hearing aids.

It is known that children with hearing loss have greater difficulty hearing in noise[23-25] and that schools typically have poor acoustic environments. Children spend the majority of their time in classrooms, which often exhibit excessive levels of background noise that can negatively affect their speech perception.[26] This is especially true for children younger than fifteen years of age, who tend to be in the noisiest classrooms.[26-28] For children to take advantage of both structured lessons and incidental learning they need to have a communication system that is appropriate for their age, language ability and acoustical environment. In recognition of these factors, the three audiologists often recommended the use of FM systems to improve the signal to noise ratio within the school setting. (see appendices—A to C—for the comments of the audiologists)

In addition to environmental obstacles, children are at a disadvantage relative to adults because they have not fully developed speech and language skills and therefore, they are not as capable of filling in inaudible information to complete the message appropriately. Thus, a slightly more conservative SII for children seems justified. The judgments of the three experienced audiologists suggested that a SII of <.80 is appropriate for children compared to the <.75 SII value commonly used for adults. Further validation with other audiologists at other centers serving pediatric oncology patients is needed.

The three audiologists all commented that recent advances in hearing aid technology with frequency compression and frequency transposition enable audiologists to aid children with high frequency losses that previously would not have benefited from a hearing aid. Two examples are depicted in Figures 4 and 5. Figure 4 is an example of a patient who received an audiologist ranking of three (could go either way regarding recommendation of hearing aids). Additional recommendations for this patient by the audiologists were the use of a FM system, and a speech and language evaluation. Figure 5 is an example of a patient who received an audiologist ranking of four (most likely would recommend hearing aids). Additional recommendations by the audiologists for this patient included use of a FM system, speech and language evaluation and preferential seating. Examining the rankings and comments of the audiologists suggests that they frequently gave a ranking of three when the hearing loss was present at 4000 Hz and a ranking of four when the loss began to impact 3000 Hz.

An advantage for the SII relative to the Brock grade and Chang grading scale is that future advances in technology enabling the fitting of even milder hearing loss can be accommodated by merely changing one number, the cut-off score within the index, rather than creating a new scale.

The audiologists participating in the study stated that case histories would have been beneficial in making hearing aid decisions. This is particularly true for oncology patients. The medical team, which has worked closely with the patient and family, are in the best position to know whether the timing is appropriate to begin audiologic intervention. In clinical practice the audiologists would have access to thorough case histories and parent reports. Clinical decisions are most often based primarily on the audiogram but other factors such as parent commitment, realistic expectations, the motivation/desire of the child, academic performance, speech and language evaluations, perceived difficulties and in the case of this special population the medical prognosis are considered. Having a reduced SII does not guarantee a successful hearing aid fitting. All intervention options should be discussed with the family and children who are old enough should be included in the counseling sessions.

Based on the comments from the audiologists, even with a ranking of one (definitely would not recommend hearing aids), the audiologists would have recommended preferential seating, investigated the need for speech and language evaluation, and considered the use of a FM system. For audiograms receiving a ranking of 5, the audiologists would definitely have recommended preferential seating, a FM system and a speech and language evaluation. Preferential seating tends to be a universal recommendation regardless of hearing loss or audiologist ranking. In the study, recommendations were made depending solely on age of the patient and threshold information. The audiologists often made the comment that in clinical practice recommendations would be based on patient concerns or problems observed by the audiologists or other professionals working with the child and family. Again, these observations support the need for a team approach when working with these patients.

Limitations to the current study were restricted age range due to audiologic criteria, the small number of audiologists used to determine the validation measure, and not formally asking about intervention strategies other than hearing aids. Including a variety of audiologists from several medical centers and surveying all of the common intervention strategies (e.g. hearing aids, FM, speech/language evaluation/therapy, preferential seating, auditory training) are needed to validate the criterion and to learn more about intervention options. Obtaining complete testing for all required audiometric frequencies is a challenge, particularly for children under three years of age. Therefore, future research is needed to determine the best ways of interpolating and extrapolating from incomplete data to accommodate inclusion of these younger patients.

In summary, the SII, which can be easily generated from conventional audiograms, results in a discrete measure that precisely reflects the patient's functional hearing status and is highly correlated with the recommendation for hearing aids. The SII has the potential to have great utility in the clinical arena as an easy to interpret measurement to guide clinicians and counsel families. Although it is beyond the scope of this paper, the SII may also be useful for children with hearing loss who are not receiving cisplatin. Further investigation is needed to validate the cut-off criterion and to demonstrate efficacy of the SII in clinical practice.

Table 1:

Overview of the four scales available to track ototoxicity

The Brock Grade		The Chang Grading Scale	
0	< 40 dB HL at 250 to 8000 Hz	0	≤ 20 dB HL at 1000, 2000 and 4000 Hz
1	≥ 40 dB HL at 8000 Hz	1a	≥ 40 dB HL at any frequency 6000 to 12000 Hz
		1b	> 20 dB HL and < 40 dB at 4000 Hz
2	≥ 40 dB HL at 4000 Hz and above	2a	≥ 40 dB HL at 4000 Hz and above
		2b	> 20 dB HL and < 40 dB at any frequency below 4000 Hz
3	≥ 40 dB HL at 2000 Hz and above	3	≥ 40 dB HL at 2000 or 3000 Hz and above
4	≥ 40 dB HL at 1000 Hz and above	4	≥ 40 dB HL at 1000 Hz and above

National Cancer Institute (NCI) Common Terminology Criteria for Adverse Events Version 3.0 (CTCAEv3)

Category	
Level 1	Threshold increase of 15 to 25 dB in relation to the initial audiologic exam for two or more sequential frequencies in at least one ear or a subjective change in the absence of a level one shift
Level 2	Threshold increase of 25 to 90 dB in two sequential frequencies in at least one ear
Level 3	Hearing loss sufficient to indicate therapeutic intervention, including hearing aids (i.e. threshold shift in the speech frequencies equal to or greater than 20 dB bilaterally or 30 dB unilaterally)
Level 4	Bilateral hearing loss requiring a hearing aid or cochlear implant

American Speech Language Hearing Association (ASHA) Hearing Loss Classification

Category	
A	20 dB decrease at any one test frequency
B	10 dB decrease at any 2 adjacent frequencies
C	Loss of response at 3 consecutive test frequencies for which responses were previously obtained

Table 2:

Patient Information

Number of Patients	77
Gender	
Males	40 (52%)
Females	37 (48%)
Age Range at Test Date (years)	2.68 to 19.42
Average Age at Test Date (years)	10.78
Diagnosis:	
Adrenal Cortical Carcinoma	2
Astrocytoma	1
Ependymoma	4
Germ Cell Tumor	9
Hepatoblastoma	3
Medulloblastoma	14
Neuroblastoma	13
Osteosarcoma	25
Pineoblastoma	1
PNET	4
Thymoma	1
Cisplatin Cumulative Dose Average (mg/m^2)	392.99
Cisplatin Cumulative Dose Range (mg/m^2)	90 to 800

Table 3:

Comparison of Brock grades and the Speech Intelligibility Index (SII)

Brock Grade	Number of Ears	Avg. SII	Min. SII	Max SII	Standard Deviation
0	53	0.99	0.85	1	0.025
1	49	0.94	0.86	1	0.042
2	29	0.74	0.59	0.86	0.077
3	23	0.48	0.37	0.59	0.058
4	0	0	0	0	0

Figure 1

Comparison of Brock Grades and the Speech Intelligibility Index (SII) for all ears.

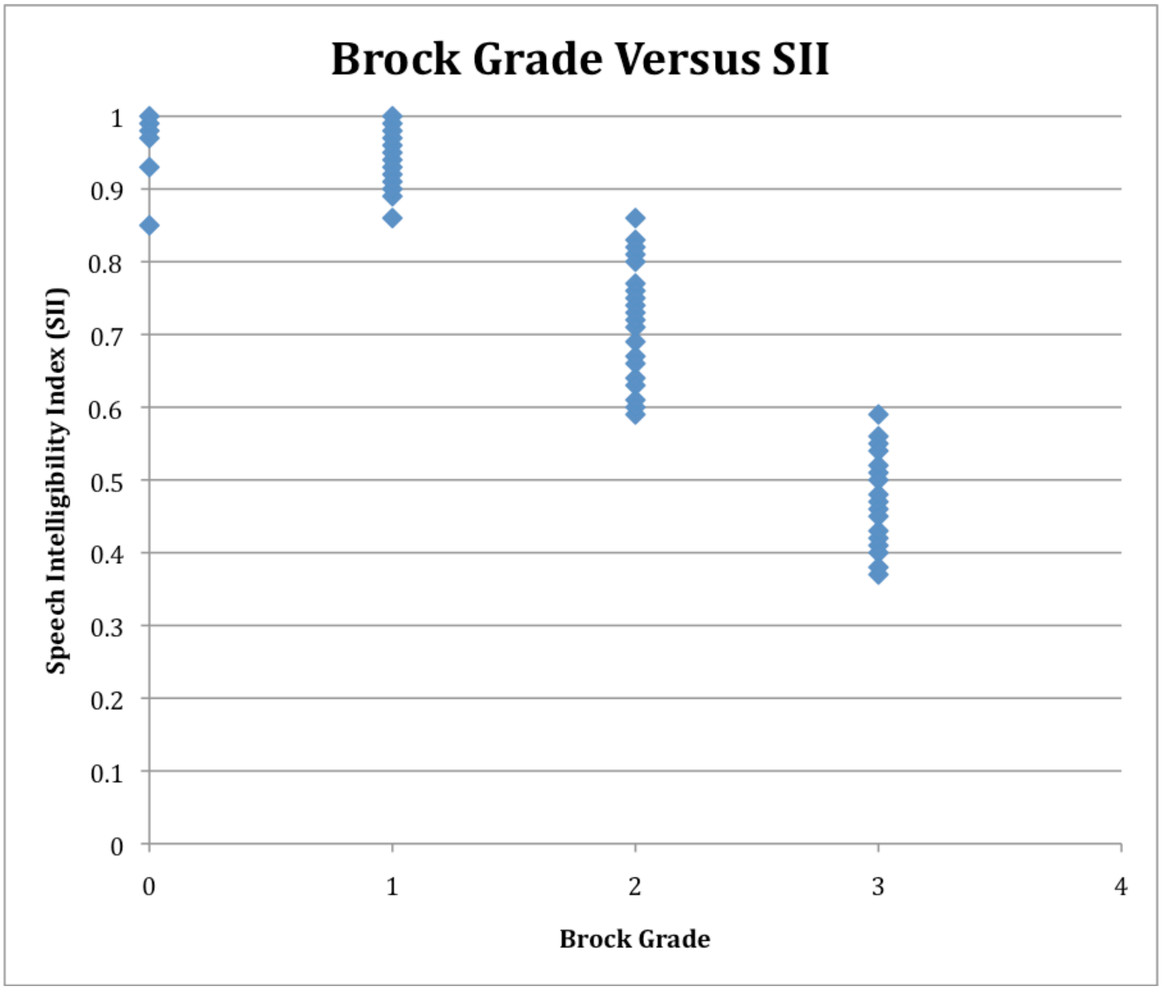
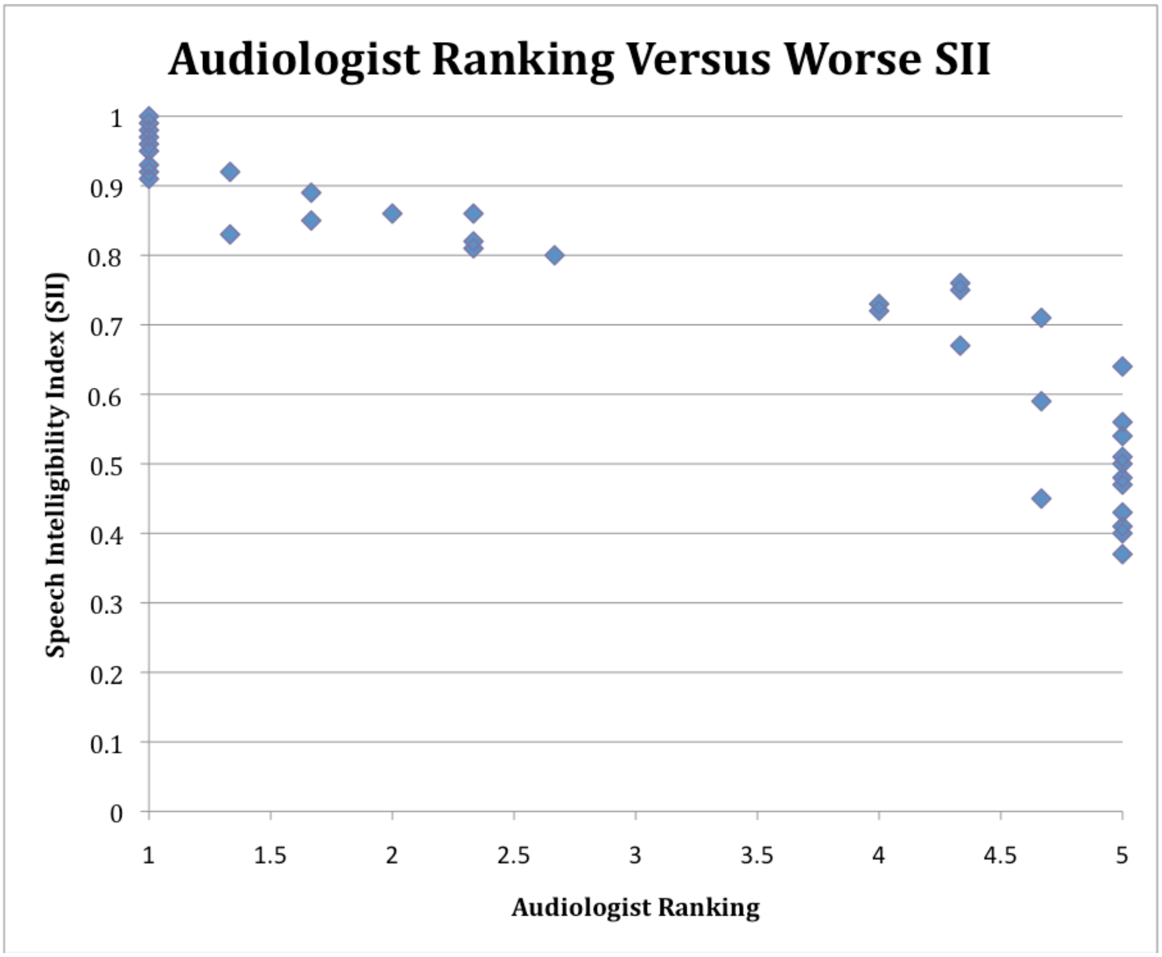


Figure 2

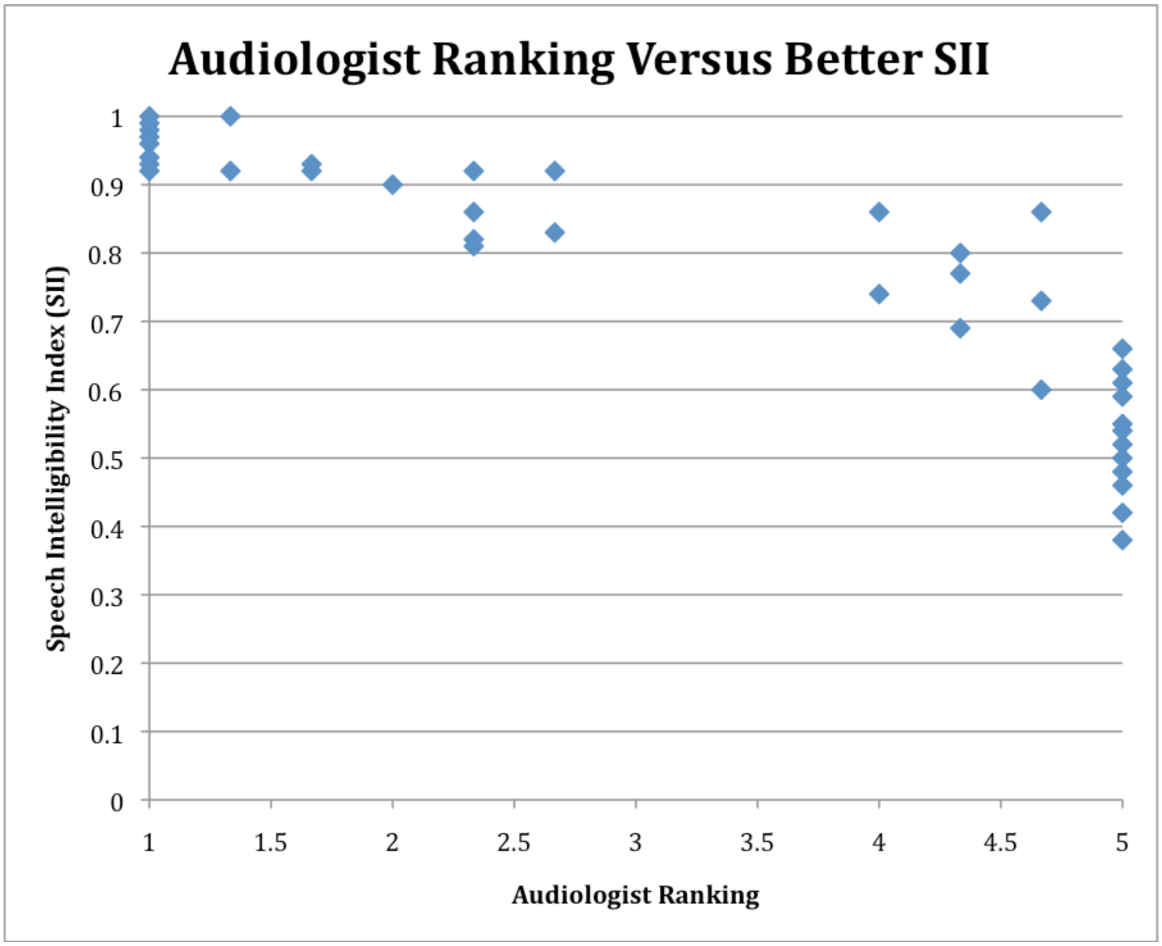
Audiologists average ranking as a function of SII from the worse ear.



Audiologist Ranking	
1	Definitely would not recommend hearing aids
2	Most likely would not recommend hearing aids
3	Recommendation could go either way
4	Most likely would recommend hearing aids
5	Definitely would recommend hearing aids

Figure 3

Audiologists average ranking as a function of SII from the better ear.



Audiologist Ranking	
1	Definitely would not recommend hearing aids
2	Most likely would not recommend hearing aids
3	Recommendation could go either way
4	Most likely would recommend hearing aids
5	Definitely would recommend hearing aids

Table 4

Correlation of various test conditions for the SII and Brock grades with the recommendation of hearing aids by 3 experienced audiologists.

Condition	Sensitivity	Specificity	Efficiency
SII (Worse Ear) <.80 criterion	100%	100%	100%
SII (Better Ear) <.80 criterion	86%	100%	96%
Brock Grade (Worse Ear) ≥ Grade 3 criterion	59%	100%	88%
Brock Grade (Better Ear) ≥ Grade 3 Criterion	45%	100%	84%
Brock Grade (Worse Ear) ≥ Grade 2 Criterion	100%	89%	92%
Brock Grade (Better Ear) ≥ Grade 2 Criterion	95%	95%	95%

Figure 4:

Audiogram of Pt. #49 (4.51 years)

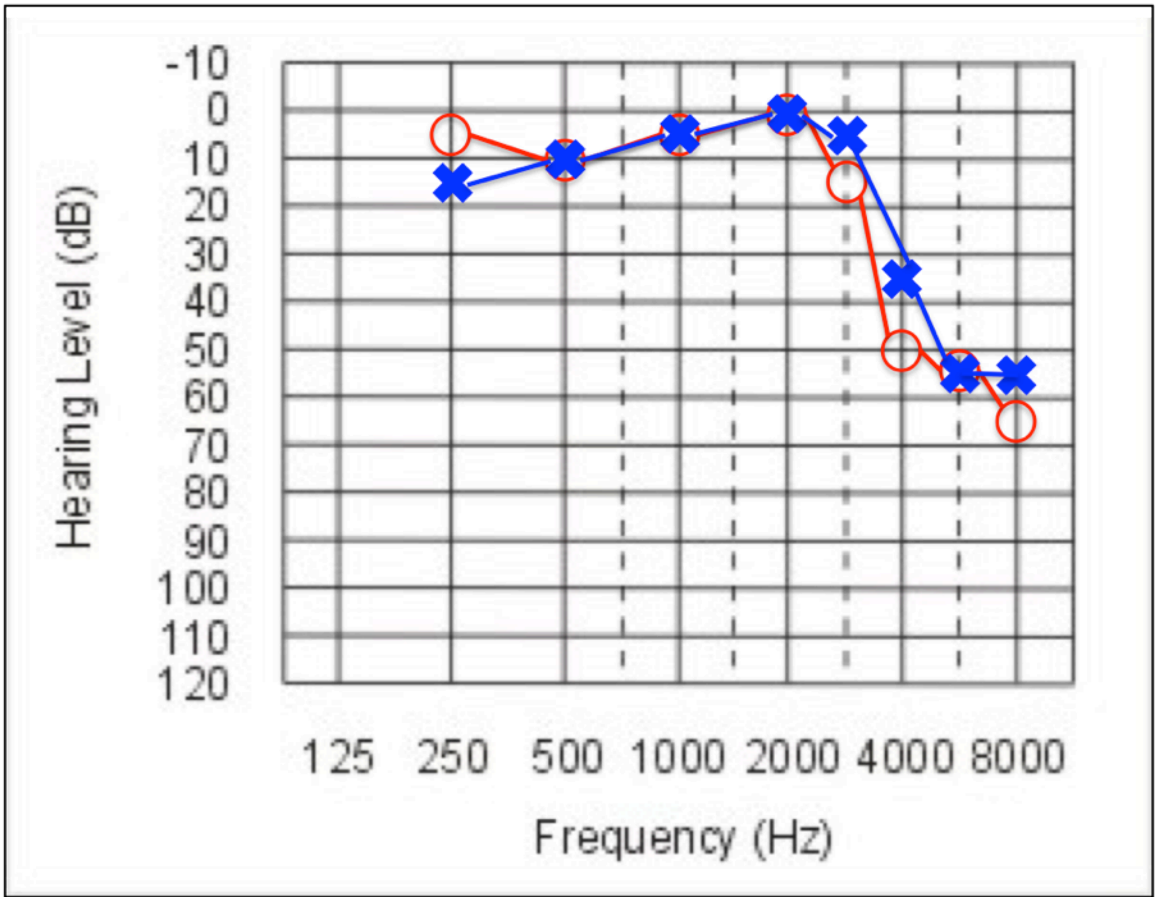
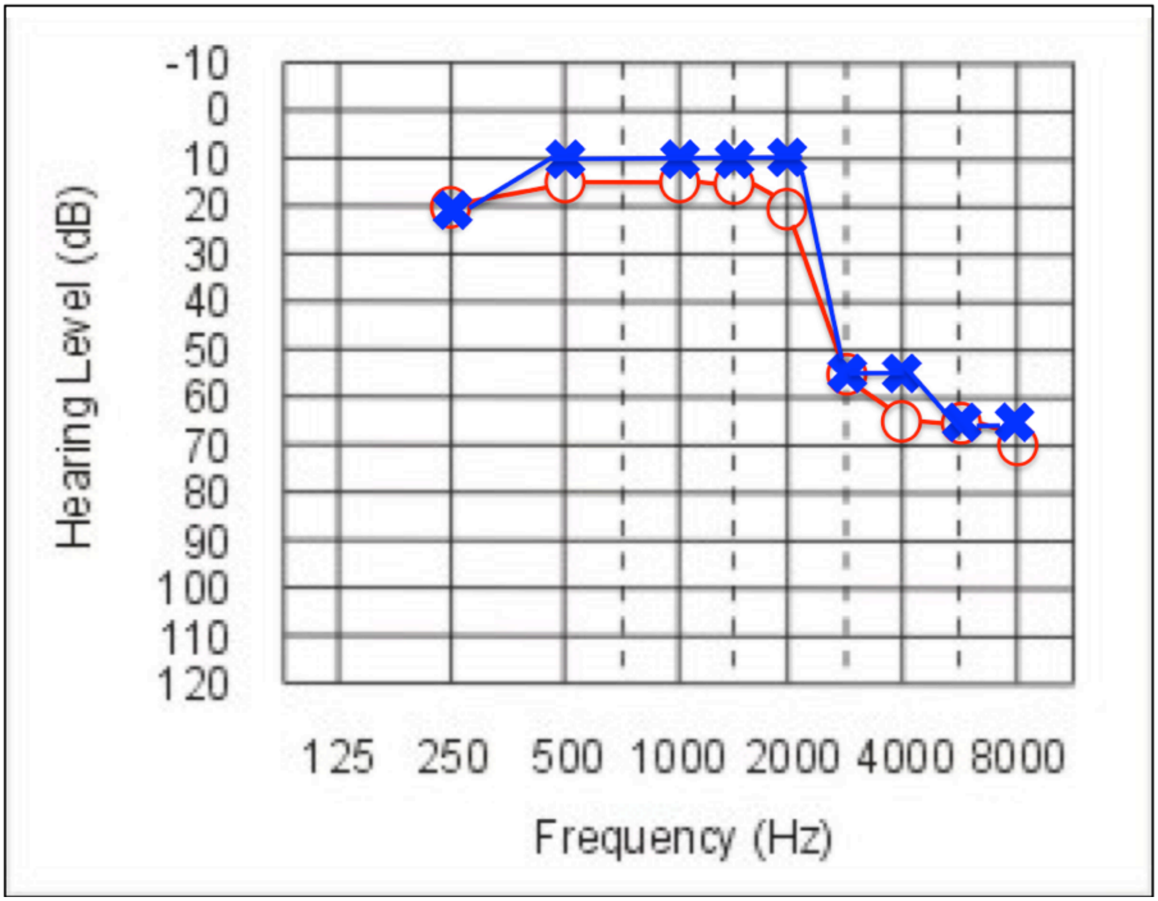


Figure 5:

Audiogram of Pt. #93 (5.62 years)



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Appendix A

Additional recommendations organized by averaged ranking

Ranking	Comments
1	Preferential seating if issues arise or when school aged Sit in front of auditorium classes at college Speech and language evaluation if warranted FM system if concerns arise when school aged Counseling with family on potential of progression of hearing loss Only pursue amplification if patient is having issues and wishing to pursue amplification
2	Preferential seating FM system Speech and language due to age Trial with frequency compression/transposition depending on motivation and school performance Recommendations would depend on family and child motivation ENT consultation due to asymmetry between ears
3	
4	Preferential seating Speech and language evaluation FM system Trial with frequency compression/transposition depending on motivation and school performance ENT consultation due to asymmetry between ears Counseling with family on potential of progression of hearing loss
5	Preferential seating Speech and language evaluation FM system Frequency transposition/compression hearing aid

Audiologist Ranking	
1	Definitely would not recommend hearing aids
2	Most likely would not recommend hearing aids
3	Recommendation could go either way
4	Most likely would recommend hearing aids
5	Definitely would recommend hearing aids

Appendix B

General comments organized by audiologist

Audiologist	Comments
1	Hearing loss at 3000 Hz automatic hearing aid 6 yrs or younger always got a speech and language evaluation First ID, ENT consult Case by case, need full history
2	FM and preferential seating for any patient with any amount of hearing loss Retest hearing ASAP if change Done with treatment, annual testing Still on treatment, per protocol First ID, ENT consult Case by case, need full history
3	Hearing loss at 2000 Hz, automatic hearing aid FM systems for all patients with a hearing loss No preferential seating for hearing loss at 8000 Hz only Loss at 4000-8000 Hz does not automatically qualify for a hearing aid based on audiogram alone Loss in the speech frequencies 500-4000 Hz, recommendation was hearing aid, FM system and preferential seating Any hearing loss should have an ENT evaluation Case by case, need full history

Appendix C

Instructions Provided to Audiologists

Author met with each audiologist
Recommendations for a hearing aid were based on a scale from 1-5:

1: Definitely would not recommend

2: Most likely would not recommend

3: Could go either way

4: Most likely would recommend

5: Definitely would recommend

Assume normal middle ear function and speech discrimination that is in accordance with pure tones.

Provide comments to support your rating, particularly for ratings of 2, 3 or 4. Note any additional recommendations that you would consider. Note any additional information that you would want to consider prior to finalizing your recommendations.

Please Circle One

1 2 3 4 5

Comments: □FM System □Preferential seating
□Speech and Language Evaluation □ENT consult

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Appendix D

Raw data

Pt. ID #	Worse Brock Grade	Better Brock Grade	Worse SII	Better SII	Audiologist (1)	Audiologist (2)	Audiologist (3)	Average Audiologist Ranking
1	2	2	0.59	0.6	5	4	5	4.67
2	3	3	0.5	0.54	5	5	5	5
3	1	1	0.93	0.98	1	1	1	1
5	1	1	0.89	0.92	1	3	1	1.67
11	3	3	0.4	0.48	5	5	5	5
15	1	1	0.93	0.98	1	1	1	1
17	1	0	0.98	0.99	1	1	1	1
18	1	1	0.92	0.92	1	1	1	1
19	1	0	0.99	1	1	1	1	1
20	3	2	0.45	0.86	4	5	5	4.67
22	0	0	0.97	1	1	1	1	1
26	1	0	0.97	0.99	1	1	1	1
27	3	3	0.41	0.42	5	5	5	5
28	0	0	1	1	1	1	1	1
29	3	3	0.37	0.38	5	5	5	5
34	0	0	1	1	1	1	1	1
36	3	3	0.54	0.55	5	5	5	5
37	1	1	1	1	1	1	1	1
39	1	1	0.92	0.92	1	1	1	1
40	2	2	0.64	0.66	5	5	5	5
41	0	0	1	1	1	1	1	1
43	1	1	0.92	0.92	1	2	1	1.33
44	2	1	0.8	0.92	3	3	2	2.67
46	0	0	1	1	1	1	1	1
47	2	2	0.81	0.81	3	3	1	2.33
48	3	3	0.48	0.5	5	5	5	5
49	2	1	0.82	0.86	3	3	1	2.33
52	3	2	0.51	0.63	5	5	5	5
56	2	2	0.71	0.73	5	5	4	4.67
62	1	1	1	1	1	1	1	1
64	0	0	1	1	1	1	1	1
65	2	2	0.81	0.82	3	3	1	2.33
66	2	2	0.75	0.77	5	4	4	4.33
72	0	0	1	1	1	1	1	1
76	0	0	1	1	1	1	1	1
77	3	3	0.47	0.59	5	5	5	5
78	3	3	0.43	0.46	5	5	5	5
79	0	0	0.99	1	1	1	1	1
80	3	3	0.5	0.52	5	5	5	5
82	2	0	0.83	1	2	1	1	1.33
84	2	2	0.76	0.77	5	4	4	4.33
87	0	0	1	1	1	1	1	1
88	0	0	0.99	1	1	1	1	1
89	0	0	1	1	1	1	1	1

93	2	2	0.67	0.69	5	4	4	4.33
95	2	2	0.8	0.83	4	3	1	2.67
97	1	1	0.97	0.98	1	1	1	1
102	1	1	1	1	1	1	1	1
106	1	1	0.98	0.99	1	1	1	1
107	2	2	0.73	0.74	5	3	4	4
108	1	0	0.95	1	1	1	1	1
113	0	0	1	1	1	1	1	1
116	1	1	0.96	0.96	1	1	1	1
117	0	0	1	1	1	1	1	1
118	3	3	0.47	0.48	5	5	5	5
119	1	1	0.86	0.92	3	3	1	2.33
121	1	1	0.91	0.94	1	1	1	1
125	1	1	0.86	0.9	3	2	1	2
126	0	0	1	1	1	1	1	1
127	2	2	0.76	0.8	5	4	4	4.33
129	0	0	1	1	1	1	1	1
130	1	0	0.99	0.99	1	1	1	1
131	0	0	1	1	1	1	1	1
132	1	0	0.93	1	1	1	1	1
134	1	0	0.99	1	1	1	1	1
136	0	0	0.85	0.93	2	2	1	1.67
137	1	1	0.92	0.97	1	1	1	1
138	1	1	0.93	0.94	1	1	1	1
140	3	2	0.56	0.61	5	5	5	5
141	1	1	0.93	0.93	1	1	1	1
142	1	1	0.91	0.93	1	1	1	1
146	1	0	0.92	0.98	1	1	1	1
147	0	0	1	1	1	1	1	1
151	0	0	0.99	1	1	1	1	1
152	0	0	0.98	1	1	1	1	1
153	2	1	0.72	0.86	4	4	4	4
154	0	0	0.97	0.99	1	1	1	1