Otoacoustic Emissions:

Some Observations & Applications[1]

by

Marilyn V. Feiner, *M.A.*[2]
Andrew J. Hotaling, *M.D.*[3]
Kathryn M. Pardue, *M.A.*[2]
Gregory J. Matz, *M.D.*[3]
Brian Walkner[4]
and
Michael J.M. Raffin, *Ph.D.*[3, 2]

THIS IS _____'s COPY

DEATH TO PILFERERS!!

---

[1] Synopsis of a Seminar
Presented at the Inaugural {Annual} Convention of the
Puerto-Rico Academy of Audiology
San Juan, Puerto Rico, 2 February 1996.

[2] Department of Audiology, Loyola University Medical Center, Maywood, IL

[3] Department of Otolaryngology, Loyola University Medical Center, Maywood, IL

[4] Strich School of Medicine, Loyola University Medical Center, Maywood, IL..

Caveat Praeambulum

The needs and characteristics inherent to inmates of a Neonatal Intensive Care Unit (NICU) in a tertiary, quaternary and/or decennary health-care environment are likely to differ from those of healthy neonates in a community hospital. By extension, the success experienced through the use of clinical procedures on these populations also may be expected to differ in noticeable, if not always quantified, ways.

In this presentation, we will proceed to review some significant observations which we have reported previously. Specifically, with respect to otoacoustic emissions, we will present data acquired from such interesting entities as patients afflicted with sensorineural hearing loss, syringes, couplers, real-ear simulators and cadavers. Data were obtained under different ambient test conditions characterized primarily by their striking similarity to the Ideal Acoustic Environment — something we have not found to be very prevalent in patient testing conditions. Transient and distortion-product data will be reviewed, with characteristics identified from various instruments. The salient findings indicate that it is possible to interpret a test result as indicating the presence of an otoacoustic emission, even though no emission has been generated. For the purposes of the present paper, such a finding is termed instrument distortion. Instrument distortions whose characteristics approximate what the published research indicates are otoacoustic emissions may result in erroneous interpretations which impact the cost effectiveness of the testing. Distortions have been identified for many instruments currently available. No instrument is completely free of such distortions. Some distortions have step-like input / output functions which indicate that reducing the level of stimulation will not avoid the impact of these distortions. No objective way to compensate for the presence of these distortions has been identified. Thus, a criterion for the identification of emissions must be established such as to minimize confusion with instrument artifact.
These data suggest that professionals perhaps would be well advised to consider several factors before inflicting an instrument or test usage on any patient.

INSTRUMENT AND TEST CONSIDERATIONS

- Capital costs (initial equipment costs, maintenance agreement costs, upgrade costs)
- Supplies — costs, availability, logistics, inventory systems needed and storage
- Expertise needed to operate instrumentation/user friendliness/ease of calibration
- Frequency of occurrence, and characteristics of artifacts
- MTBF of instrument (if available)
- Professional and legal acceptance of instrument and tests it is designed to implement on patient populations
- Duration of test procedure, and its amenability for the target patient population
- ROC characteristic of test outcomes — Hits, false alarms, misses, *etc…*
- Break-even analysis and impact on fee structure
- Cost effectiveness of the entire process based on that test and instrument's performance characteristics in the target population

Examples will be drawn from automated ABR and otoacoustic emissions.

When attempting to implement a new program, many administrators like to analyze the premises underlying the associated staffing model. Most such models will easily accept the notion that a full-time employment (FTE) status entails 2,080 paid hours per year. We believe that not only is it necessary [from the financial analysis of costs standpoint] to include the costs of fringe benefits, but also that it is necessary to deduct all paid-time off in order to arrive at a logistically accurate estimate of time available to test patients [and thus generate revenue]. When these conditions prevail, then illness [or any other anticipated absence] on the part of any employee [as long as it does not exceed appropriate time allocations, in this case Sick Leave] will not necessitate the hiring of float-pool or temporary workers to generate projected revenues. If any given employee mismanages paid time on the job for five minutes each day, and takes all allowed leave time, that employee will have been paid for 17.34 theft hours in the course of a year. A theft in this context does not imply intent only a *fait accompli*. Likewise, employees who do not expend the entire paid-time off to which they may be entitled may be expected to be able to generate more revenue than previously anticipated.

DEPARTMENT OF AUDIOLOGY **Staffing Model**		
Nomenclature	Unit Value (Hours)	Hours Remaining
Total Paid Hours/FTE: 52 weeks x 40 hours/week	2,080	2,080
Paid Holidays (10 days/year x 8 hours/day)	80	2,000
Paid Vacation (3 weeks/year x 40 hours/week)	120	1,880
Paid Sick Leave (10 days/year x 8 hours/day)	80	1,800
Paid Personal Leave (2 days/year x 8 hours/day)	16	1,784
Paid Medical Leave (8 hours/year)	8	1,776
Daily Breaks(30 min/day of remaining paid time)	111	1,665
Meetings/Rounds/Equip.√ (20% of remaining time)	333	1,332
PRODUCTIVE HOURS/YEAR/FTE		**1,332**

At a salary of $37,000 per year (current mid-point of salary range), an audiologist grosses an effective $27.78 per productive hour without benefits after being allowed 8 weeks, 1 day and 5 hours for such activities as continuing education, discharge rounds, meetings and other non patient-contact professional activities which the employer subsidizes.

One of the areas for which the testing for otoacoustic emissions has been advocated involves the hearing screening of neonates. At Loyola University, we have implemented a Universal Hearing Screening Program for all Neonatal Intensive Care Unit (NICU) patients. When analyzing the potential cost of such a program, it is necessary to consider projected volumes and to detail expected costs. Thus, the equipment must be amortized completely in a reasonable period of time. A reasonable period of time in this context means that any instrument must be completely paid before a replacement is even considered. Administrative and staff-support costs also must be identified, so the associated personnel also may be paid. Finally, ancillary costs including property tax, utilities and all other support must be included.

The Loyola University Medical Center experiences a reimbursement rate of 66.93% of the billed amount for medical fees of NICU patients, across all payors. Thus, in order to stay fiscally viable, a program must bill enough to at least break even. If one plans for break even on the expectation of certain volumes, and these volumes do not materialize, then the program becomes a fiscal liability and must be subsidized from programs which generate a profit, or must be terminated. Thus, in planning a new program, one must plan for break-even [in a not-for-profit institution] plus a margin which will cover anticipated volume-projection errors. When the Program was initiated, a 3.34% projection error was built in. When projected volumes materialize, then this padding for projection error becomes profit, provided all expenses have stayed within their respective projections.

Because the characteristics of our professionals are changing, with a sizeable component anticipating the establishment of a doctoral degree such as the Au.D. as the entry-level requirement, we have included the impact of such a change on the profitability of this program. Because one response to the Au.D. requirement will be to replace M.A.-level professionals [who will be expected to train the first few generations of Au.D., but who themselves may not be eligible for the Au.D. without substantial investment of time and effort into their local or not so local university] with technologists or technicians. Training programs for audiometric technicians are not new, but several professional organizations are reviewing and accelerating standards for the training of such technicians. If a technician generates the same volume as Audiologists currently are generating, the hiring of these technicians may be expected to almost double the profit margin. The hiring of an Au.D. audiologist to accomplish the same job will put the Program into significant deficit, unless fees are augmented. Increased cost for already existing services is not likely to be well received by

consumers. Increases in errors, which may or may not accompany technicians, may take some time to be manifest, and will be recognized only if someone bothers to analyze the data.

DEPARTMENT OF AUDIOLOGY

QPro\wks\fiscal\Nicu

NICU Screening-Program Cost Analysis: Annual Forecast

Staffing: Audiologist / Test: Automated ABR

ASSUMPTION: Annual volume of 436 Tests

					Per Case	Annual
EXPENSES						
FIXED						
	Capital Equipment - 2 instruments @ $12,000				$11	$4,800
	Amortized linearly over 5 years					
	Equipment Maintenance Agreement	$900/year/instrument			$4	$1,200
VARIABLE						
	Administration	(Supervision/TQM/Systems monitoring/Follow-Up)		3 min	$2	$982
	Secretarial Support	4 minutes/case			$1	$436
	Patient-Contact Hours @ 33 min/test		436 x 0.55	240		
	Productive hours needed @ 80% contact time			240		
	Productive Hours for 1 FTE (2,080 minus paid time off)			1,332		
	Clinical FTE needed	Productive hours needed/1332		0.1800		
	Audiologist	$37000/year			$15	$6,661
	Benefits	24.8% of salaries			$5	$2,004
	Disposables ($5.00 per patient)				$5	$2,180
	Apportioned Expenses: 3.82% (240/6277) of Department Total				$9	$3,820
	Utilities/support services (BioMed, Housekeeping, Security, etc…):					
	$100,000/year spread across 6,277 Patient Contact Hours/Year					
COST TO THE MEDICAL CENTER					$52.03	$22,084
BREAK-EVEN ANALYSIS						
	Average Fee Paid to Medical Center for Break-Even (0% profit margin)				$52.03	
	Deductions at 66.93% of gross fee	as of 30 June 1995	(52.03 /[(1-0.6693) x 0.6693]		$105.30	
	Gross Fee for Break-Even Bottom Line		52.03 / (1-0.6693)		$157.32	**$58,593**
PROPOSED FEE:						
	Gross Fee Per Test				$175.00	$76,300
	Deductions	@ 66.93% of Gross Fee			$117.13	
	Average Fee Paid to the Medical Center				$57.87	$25,232
	NET PROGRAM PROFIT/(LOSS) PER YEAR				$5.85	$2,549
	PROFIT MARGIN		[(57.87 - 52.03) / 175] x 100		3.34%	

DEPARTMENT OF AUDIOLOGY — **QPro\wks\fiscal\Nicu**

NICU Screening-Program Cost Analysis: Annual Forecast

Staffing: Technician / Test: Automated ABR

ASSUMPTION: Annual volume of 436 Tests

					Per Case	Annual
EXPENSES						
FIXED						
	Capital Equipment - 2 instruments @ $12,000				$11	$4,800
	Amortized linearly over 5 years					
	Equipment Maintenance Agreement	$900/year/instrument			$4	$1,200
VARIABLE						
	Administration	(Supervision/TQM/Systems monitoring/Follow-Up)		3 min	$2	$982
	Secretarial Support	4 minutes/case			$1	$436
	Patient-Contact Hours @ 33 min/test		436 x 0.55	240		
	Productive hours needed @ 80% contact time			240		
	Productive Hours for 1 FTE (2,080 minus paid time off)			1,332		
	Clinical FTE needed	Productive hours needed/1332		0.1800		
	Technician	$26000/year			$11	$4,681
	Benefits	24.8% of salaries			$3	$1,513
	Disposables ($5.00 per patient)				$5	$2,180
	Apportioned Expenses: 3.82% (240/6277) of Department Total				$9	$3,820
	Utilities/support services (BioMed, Housekeeping, Security, etc…):					
	$100,000/year spread across 6,277 Patient Contact Hours/Year					
COST TO THE MEDICAL CENTER					$46.36	$19,612
BREAK-EVEN ANALYSIS						
	Average Fee Paid to Medical Center for Break-Even (0% profit margin)				$46.36	
	Deductions at 66.93% of gross fee	as of 30 June 1995	(46.35 / [1-0.6693] x 0.6693		$93.82	
	Gross Fee for Break-Even Bottom Line		46.36 / (1 - 0.6693)		$140.19	$61,119
PROPOSED FEE:						
	Gross Fee Per Test				$175.00	$76,300
	Deductions	@ 66.93% of Gross Fee			$117.13	
	Average Fee Paid to the Medical Center				$57.87	$25,232
	NET PROGRAM PROFIT/(LOSS) PER YEAR				$11.51	$5,020
	PROFIT MARGIN		[(57.87 - 46.36) / 175] x 100		6.58%	

DEPARTMENT OF AUDIOLOGY

QPro\wks\fiscal\Nicu

NICU Screening-Program Cost Analysis: Annual Forecast

Staffing: Au.D. Audiologist / Test: Automated ABR

ASSUMPTION: Annual volume of 436 Tests

					Per Case	Annual
EXPENSES						
FIXED						
	Capital Equipment - 2 instruments @ $12,000				$11	$4,800
	Amortized linearly over 5 years					
	Equipment Maintenance Agreement	$900/year/instrument			$4	$1,200
VARIABLE						
	Administration	(Supervision/TQM/Systems monitoring/Follow-Up)		3 min	$2	$982
	Secretarial Support	4 minutes/case			$1	$436
	Patient-Contact Hours @ 33 min/test		436 x 0.55	240		
	Productive hours needed @ 80% contact time			240		
	Productive Hours for 1 FTE (2,080 minus paid time off)			1,332		
	Clinical FTE needed	Productive hours needed/1332		0.1800		
	Au.D. Audiologist	$60000/year			$25	$10,802
	Benefits	24.8% of salaries			$7	$3,031
	Disposables ($5.00 per patient)				$5	$2,180
	Apportioned Expenses: 3.82% (240/6277) of Department Total				$9	$3,820
	Utilities/support services (BioMed, Housekeeping, Security, etc…):					
	$100,000/year spread across 6,277 Patient Contact Hours/Year					
COST TO THE MEDICAL CENTER					$63.88	$27,251
BREAK-EVEN ANALYSIS						
	Average Fee Paid to Medical Center for Break-Even (0% profit margin)				$63.88	
	Deductions at 66.93% of gross fee	as of 30 June 1995	(63.88 / [1-0.6693]) x 0.6693		$129.28	
	Gross Fee for Break-Even Bottom Line		63.88 / (1 - 0.6693)		$193.16	$84,219
PROPOSED FEE:						
	Gross Fee Per Test				$175.00	$76,300
	Deductions	@ 66.93% of Gross Fee			$117.13	
	Average Fee Paid to the Medical Center				$57.87	$25,232
	NET PROGRAM PROFIT/(LOSS) PER YEAR				($6.01)	($2,619)
	PROFIT MARGIN	[(57.87 - 63.88) / 175] x 100			-3.43%	

DEPARTMENT OF AUDIOLOGY

NICU - Hearing Screening: Protocol[5]

1 ***Scope***: All (100%) of NICU patients are subject to the hearing screening

2 ***Current Population*** — Based on daily census reports.

2.1 **Daily census outcomes**

2.1.1 **Old Patients**

2.1.1.1 *Patients with completed screening* — Appropriate follow-up tickler exists?

2.1.1.2 *Patients eligible for screening*

2.1.1.2.1 Coordinate logistics to implement screening

2.1.1.2.2 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7 and 3 through 4.

2.1.1.3 *Patients not eligible for screening*

2.1.1.3.1 Daily Tickler

2.1.1.3.2 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7 and 3 through 4.

2.1.2 **New Patients**

2.1.2.1 *Patients eligible for screening*

2.1.2.1.1 Coordinate logistics to implement screening

2.1.2.1.2 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7 and 3 through 4.

2.1.2.2 *Patients not eligible for screening*

2.1.2.2.1 Daily Tickler

2.1.2.2.2 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7 and 3 through 4.

2.1.3 **Discharged Patients**

2.1.3.1 *Un-screened patients*

2.1.3.1.1 Obtain demographics

2.1.3.1.2 Send notice to parents

2.1.3.1.3 Check tickler to implement screening

---

[5] Fiscal analysis to implement this system fully allows for 40 [33 professional, 3 admin., 4 support] minutes across all Department of Audiology staff involved

2.1.3.1.4 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7.

2.1.3.2 *"Refer" patients*

2.1.3.2.1 Parents notified?

2.1.3.2.2 Check tickler for one-month visit

2.1.3.2.3 Ascertain adequate documentation for TQM, per JCAHO requirements 2.1 through 2.4.

2.1.3.3 *"Pass" patients*

2.1.3.3.1 Parents notified of follow-up rec.?

2.1.3.3.2 Check tickler for yearly follow-up

2.1.3.3.3 Ascertain adequate documentation for TQM, per JCAHO requirements 2.1 through 2.4.

3 ***Previous population (tickler systems)***

3.1 **Daily tickler**

3.1.1 **Inpatient**

3.1.1.1 Coordinate logistics to implement screening

3.1.1.2 If patient not eligible due to age, but discharge is imminent, attempt screening.

3.1.2 **Discharged**: Mail notice to parents and coordinate for one-month follow=up screening.

3.2 **One-month follow-up screening** (tickler systems)

3.2.1 **Coordinate logistics to implement screening**

3.2.1.1 Confirm appointment with parent

3.2.1.2 Confirm appointment with MD

3.2.2 **Implement screening**.

3.3 **Yearly check**

3.3.1 Implement logistics for annual screen.

3.3.2 Implement screening

4 ***Eligibility for Screening***

4.1 Patient's physical, physiological and medical condition preclude testing?

4.2 Patient's medications contraindicate valid test?

4.3 Nurse's O.K.?

4.4 Patient's gestational age $\geq$ 33 weeks?

5 ***Implement Screening***

5.1 **Patient eligible?**

5.1.1 If not, because of age, then implement Daily Tickler for appropriate date.

5.2 **Screen Outcomes**

5.2.1 **Pass**

5.2.1.1 Insert note in medical record and in envelope for parents

5.2.1.2 Tickler for yearly follow-up

5.2.1.3 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7.

5.2.2 **"Refer" — from patient's first screen**

5.2.2.1 Insert note in medical record

5.2.2.2 Schedule for follow-up monitoring

5.2.2.2.1 If "*Refer*" status is on patient < 33 weeks gestational-age, then schedule follow-up for appropriate date.

5.2.2.3 *Inpatients*: Daily Tickler, Attempt re-screen before discharge if possible.

5.2.2.4 *Outpatients*: One-month follow-up.

5.2.2.5 Ascertain adequate documentation for TQM, per JCAHO requirements 1.1 through 1.7.

5.2.3 **"Refer" — from patient's second, or subsequent, screen as inpatient**

5.2.3.1 Insert note in medical record

5.2.3.2 Insert notice in envelope for parents

5.2.3.3 Tickler for one-month follow-up screening

5.2.3.4 Ascertain adequate documentation for TQM, per JCAHO requirements 2.1 through 2.4.

5.2.4 **"Refer" — from patient's one-month follow-up screening**

5.2.4.1 Counsel parents

5.2.4.2 Notify physician(s)

5.2.4.3 Refer to ENT

5.2.4.4 Schedule diagnostic evaluation if ENT exam. indicates it

5.2.4.5 Ascertain adequate documentation for TQM, per JCAHO requirements 2.1 through 2.4 and 3 through 4 as appropriate.

5.2.5 **Could not complete**

5.2.5.1 Insert note in medical record

5.2.5.2 Schedule for follow-up monitoring prior to discharge if possible

5.2.5.3 Daily tickler

6 ***TQM*** — Ascertain compliance with specifications promulgated by JCAHO (JCAHO nomenclature) through written documentation of considerations outlined in Sections 6.1 through 6.4 (below).

6.1 Patient physical assessment to document readiness of patient for screen (JCAHO-1.1) in accordance with the scope of the screening program (JCAHO-1.2 - 1.5) within the appropriate time frame (JCAHO-1.7).

6.2 Patients are reassessed (JCAHO-2) at times appropriate to the patient's treatment (JCAHO-2.1) and when a change in the patient's status occurs (JCAHO-2.3, 2.4).

6.3 The information obtained through the analysis of screening data is integrated to identify and promote adequate prioritization of the patient's needs for care or treatment (JCAHO-3) and treatment decisions are based on the identified patient's needs (JCAHO-3.1).

6.4 The activities that comprise the screening program are specified in writing, as in the above Sections 1 and 3 and Department of Audiology Protocols (JCAHO-4) as is its scope (JCAHO-4.1) and the implementation of the screening program is undertaken by appropriately licensed practitioners (JCAHO-4.2).

Thanks to the persistent and continued efforts of the senior author, Loyola University Medical Center has made the universal hearing screening of NICU patients a reality. Even with almost one FTE completely dedicated to the Program, some patients are not screened. We have tried to identify reasons and have implemented changes in procedures to minimize this occurrence. The next analyses and summary describe our most current results.

What is *universal* on paper may not be quite so *universal* in practice

At Loyola University Medical Center, for a one-year period ending 30 November 1995, using automated ABR:

- 561 Babies were admitted to the NICU
  - 57 died [504 babies survived]
  - 436 were tested
  - 66 were discharged then *lost to follow-up*
  - 2 still inpatients and untestable due to medical condition
- Of the 436 receiving the **initial screening**:
  - 365 were identified as a *PASS* on the first screening and were "tickler'd" for one-year follow-up.
  - 71 either were identified as a *REFER* from the initial screening and were "tickler'd" for follow-up screening, or could not be tested (primarily due to persistent myogenic interference) on first screening and were "tickler'd" for screening.
- Of the 71 referred for **re-screens**:
  - 37 were identified as a *PASS* on the re-screening and were "tickler'd" for one-year follow-up.
  - 23 were identified as a *REFER* from the follow-up screening and were referred for medical and/or audiological work up.
  - 11 were *lost to follow-up*.
- of the 23 referrals for **medical and/or audiological work-up**:
  - 5 were identified as afflicted with sensorineural hearing loss.
  - 8 were diagnosed as otitis media with effusion with conductive hearing loss.
  - 3 had hearing within normal limits after ENT exam.
  - 5 have been notified multiple times in writing and have not responded.
  - 2 have ENT and ABR appointments pending.

UNIVERSAL NEWBORN SCREENING IN THE NICU
SUMMARY STATISTICS

- 86.51% of babies were tested [436 / 504].
- 5.95% were discharged from NICU in less than 48 hours [30 / 504].
- 7.14% were discharged without test [36 / 504].
- 0.397% remain inpatients.
- 13.49% total babies were not tested [68 / 504].
- 86.51% of babies attempting test were actually screened [436 / 504].
- 83.72% of babies screened passed on initial screen [365 / 436].
- 92.89% of babies screened eventually passed [{365 + 37 + 3} / 436].
- 1.15% of babies screened had sensorineural hearing loss [5 / 436] .
- 1.83% of babies screened had conductive hearing loss [8 / 436].
- 3.17% of babies attempted were lost to follow-up or did not respond to multiple contact attempts [{11 + 5} / 504].

UNIVERSAL NEWBORN SCREENING IN THE NICU
REASONS FOR "*LOST TO FOLLOW-UP*

- Parental discretion/Choice
- Geography/Commuting logistics
- Patient deceased
- Followed-up elsewhere
- Lost in follow-up/*e.g.* changes in custody/adoption
- No forwarding address

UNIVERSAL NEWBORN SCREENING IN THE NICU
The Loyola University Medical Center Criteria for DPOAE

To avoid representing "instrument" distortions as emission when measurements are obtained on clinical entities capable (at least theoretically) of generating emissions, the following criteria were developed[6]:

I. The measured response must be:
   A. greater than 0-dB SPL
   B. more than 15 dB greater than the noise floor
   C. sustained over a minimum of one-half octave (4 or more consecutive data points with a 6 points per octave resolution).

II. The frequency range of analysis need span only 2 kHz through 4 kHz.

---

[6] Hotaling, A.J., Blank, C.R., Park, A.H., Matz, G.J., Yost, W.A. & Raffin, M.J.M.: *Distortion-Product Otoacoustic Non-Emissions: A discourse on distortion products, acoustic distortion products, electronic distortion products, electroacoustic distortion products, otoacoustic distortion products and otoacoustic distortion-product emissions.* Paper presented at the 20th. Annual Meeting of the American Auditory Society, Halifax, Nova Scotia, Canada, 3 July 1994, Page 42.

Before jumping on the OAE bandwagon with alacrity, an experiment was carried out thanks to the timely assistance of a "volunteer" medical student [BW]. Only Babies which had passed Automated ABR Screening were assessed with DPOAE. Our results may be summarized as follows:

UNIVERSAL NEWBORN SCREENING IN THE NICU
Preliminary DPOAE Outcomes in Screening

- Protocol Synopsis
  - All babies tested in NICU under same conditions prevailing during automated ABR screening.
  - DPOAE were measured at 1/6th. octave with 128 sweeps or time averages (instrument maximum limits) and 2 spectral averages between 2 and 4 kHz.
  - When transient noise levels (such as alarms) interfered with the test, as noted on the real-time FFT display, the test was halted and begun again for that ear (restart).
  - If no DPOAE was identified [in accordance with the LUMC criteria], test was repeated either upon reduction of background noise levels or within a day (retest).
  - Each ear was tested twice. If ear passed either test [by meeting the LUMC Criteria], it was considered to be a *PASS* on the initial screening.
- Results summary
  - DPOAE required 12 to 59 minutes per baby to administer [including immediate restarts but not retests].
  - Ambient noise levels ranged from 42- to 73-dBA rms with a maximum transient peak level of 79-dBA noted on one occasion.
  - Of the 242 ears which had passed automated ABR:
    - 41 passed DPOAE (16.94214%, *approximately*)
      - 5 on the first test representing 4 babies
      - 36 required a retest spread across 21 babies
      - the 41 ears represented both ears for 8 babies
      - Restarts were not tracked
    - 201 failed DPOAE screening (83.05785%, *approximately*)
  - Of the 121 babies who had passed automated ABR, 112 (92.56%) did not pass with DPOAE [by failing one or both ears].

Before the impact of these results were fully analyzed or comprehended, a preliminary cost analysis of a program based on this technique was carried out in a manner parallel to that used for automated ABR.

DEPARTMENT OF AUDIOLOGY

QPro\wks\fiscal\Nicu

NICU Screening-Program Cost Analysis

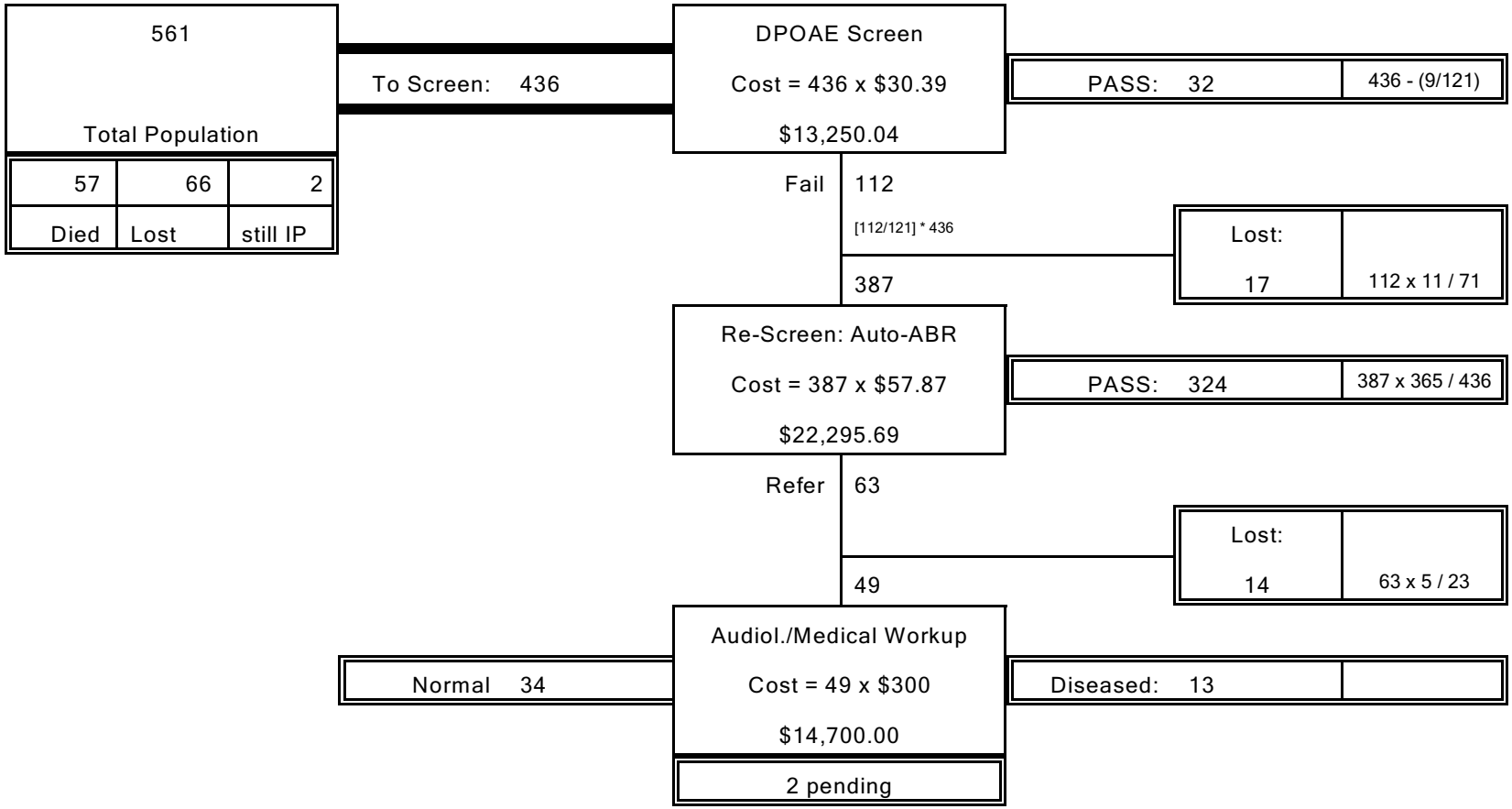
Staffing: Audiologist / Test: DPOAE

ASSUMPTION: Annual volume of 436 Tests

EXPENSES					Per Case	
FIXED						
	Capital Equipment - 1 DPOAE instrument @ $14,000				$11	$4,667
	Amortized linearly over 3 years					
	Equipment Maintenance Agreement	$600/year/instrument			$1	$600
VARIABLE						
	Administration	(Supervision/TQM/Systems monitoring/Follow-Up)		2 min	$2	$655
	Secretarial Support	4 minutes/case			$1	$436
	Patient-Contact Hours @ 12 min/test		436 x 0.2	87		
	Productive hours needed @ 80% contact time			87		
	Productive Hours for 1 FTE (2,080 minus paid time off)			1,332		
	Clinical FTE needed	Productive hours needed/1332		0.0655		
	Audiologist	$37000/year			$6	$2,422
	Benefits	24.8% of salaries			$2	$871
	Disposables ($2.00 per patient)				$2	$872
	Apportioned Expenses: 1.39% (87/6277) of Department Total				$3	$1,389
	Utilities/support services (BioMed, Housekeeping, Security, etc…):					
	$100,000/year spread across 6,277 Patient Contact Hours/Year					
COST TO THE MEDICAL CENTER					$27.32	$11,912
BREAK-EVEN ANALYSIS						
	Average Fee Paid to Medical Center for Break-Even (0% profit margin)				$27.32	
	Deductions at 66.93% of gross fee	as of 30 June 1995	(27.32 / [1-0.6693]) x 0.6693		$55.30	
	Gross Fee for Break-Even Bottom Line		27.32 / (1 - 0.6693)		$82.62	**$36,022**
PROPOSED FEE:						
	Gross Fee Per Test				$91.90	$40,068
	Deductions	@ 66.93% of Gross Fee			$61.51	
	Average Fee Paid to the Medical Center				$30.39	$13,251
	NET PROGRAM PROFIT/(LOSS) PER YEAR				$3.07	$1,338
	PROFIT MARGIN	[(30.39 - 27.32) / 91.90] x 100			3.34%	

Having identified the anticipated fiscal performance of the Program through the foregoing analysis, it was now possible to determine the Program's cost based on actual performance. An OAE hearing screening protocol typically calls for the administration of an OAE test as a first screening, followed by automated ABR for those patients who do not pass the OAE. Based on actual volumes, the performance of OAE screening in the foregoing experiment, and the actual performance of automated ABR, we can illustrate the Program's anticipated cost. In an optimistic attempt to illustrate the benefits of OAE testing, test time was taken as 12 minutes [for both ears], even though our experience in the NICU indicates a range of 12 to 59 minutes. Nine of 121 patients passed OAE screening in our experiment, and we applied that ratio to the 436 patients who would have been tested in the year ending 30 November 1995. Eleven of 71 patients were lost to follow up, for reasons we have already identified, following the initial ABR screening. There is no reason to expect that this loss would change due to a change in test technique. Thus, out of the 112 who failed the OAE screen, 17 may be expected to become lost to follow up. 365 patients out of 436 patients tested passed the initial ABR screening and this ratio is applied here as the result of the expected re-screen. Five of 23 patients who had failed re-screens were lost to follow up, and this ratio also is applied here to estimate loss following re-screen. We further assumed that OAE who have no misses – an assumption that is not documented in the literature. If an artifact is erroneously interpreted as an emission, then the probability of missing a patient with hearing loss increases.

Guess-timated DPOAE-based Program Cost



TOTAL COST OF PROGRAM: $50,245.73

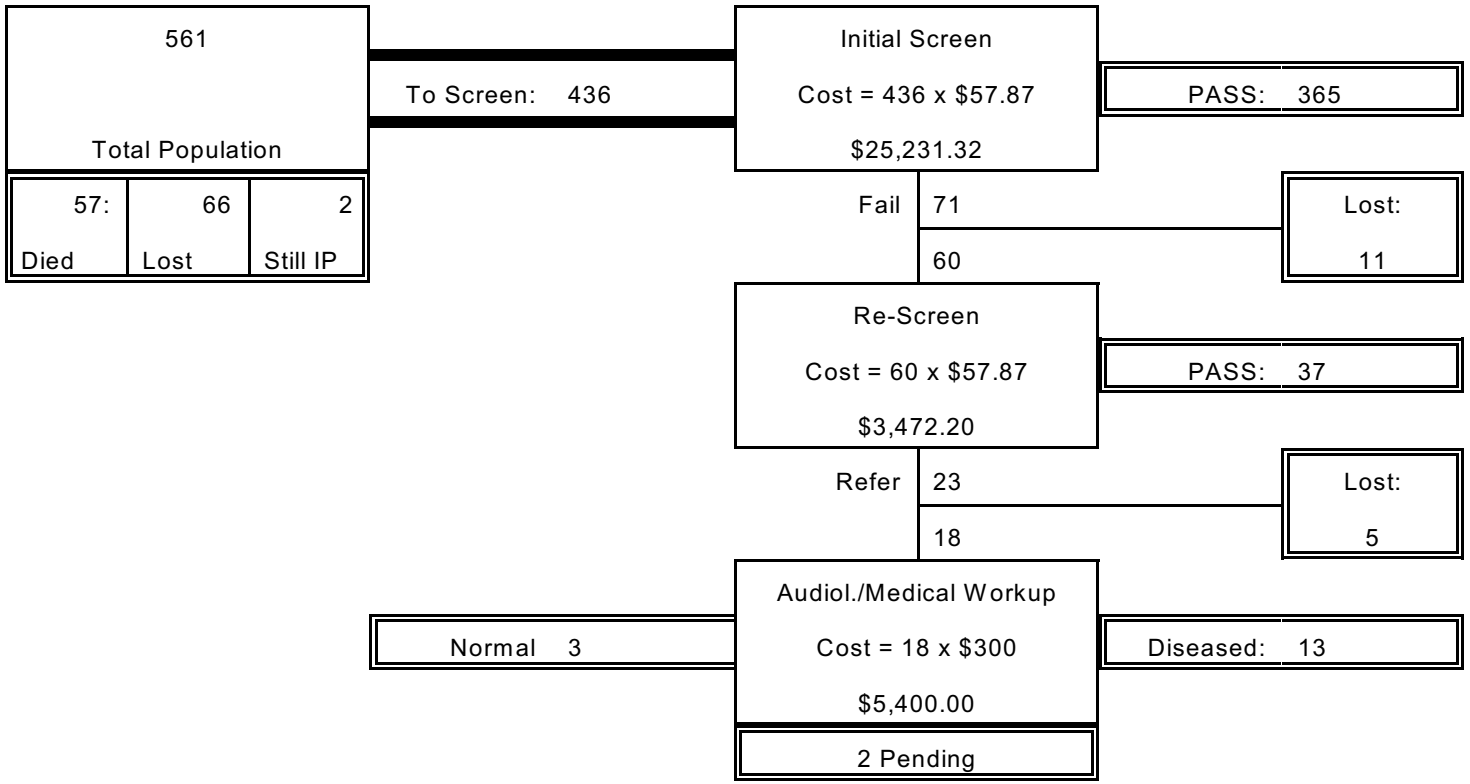
Guess-timated DPOAE-based Program Outcomes with Auto-ABR Re-Screen

		Disease		Total
		Yes	No	
Screen Refer	n	13	34	47
	Row %	28	72	
	Col%	100	9	12
Screen Pass	n		356	356
	Row %	0	100	
	Col%	0	91	88
Total	n	13	390	403
	Row %	3	97	

Efficiency:	91.6
Sensitivity:	100.0
Specificity:	91.3
False Alarm:	8.7
False-Negative:	0.0
Positive Predictive:	27.7
Negative Predictive:	100.0

In like manner, we are now in a position to identify the costs associated with an entirely automate ABR hearing screening program. The total cost of $34,104 per year compares favorably with the OAE-based program cost of about $50,246. This cost savings is accompanied by improved performance in several categories. The ABR-based Program yields an overall efficiency of 99.3% which is somewhat better than OAE's otherwise spectacular 91.6% efficiency. ABR reduces the false alarm rate from 8.7% to 0.7%. This 8% reduction reduces unnecessary testing to almost negligible levels. Finally, the positive predictive value of an ABR-based program is 81.3% compared to the 27.7% achieved by OAE. Positive predictive value is important when one values the confidence with which one can state that a given patient has a disease as a result of failing the screening process. These results have led us to conclude that an ABR-based hearing screening program is the most cost-effective [it not only costs less, but it is more efficient than alternative approaches], and that it improves the outcomes-based Total Quality Management system which the Department already has adopted.

Automated ABR-based Program Cost



TOTAL PROGRAM COST: $34,103.52

UNIVERSAL NEWBORN SCREENING IN THE NICU
Automated ABR-based Program Outcomes

		Disease		Total
		Yes	No	
Screen Refer	n	13	3	16
	Row %	81	19	
	Col%	100	1	4
Screen Pass	n	0	402	402
	Row %	0	100	
	Col%	0	99	96
Total	n	13	405	418
	Row %	3	97	

Efficiency:	99.3
Sensitivity:	100.0
Specificity:	99.3
False Alarm:	0.7
False-Negative:	0.0
Positive Predictive:	81.3
Negative Predictive:	100.0