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# Epidemiology of Early Hearing Loss Detection in Hawaii

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**ABSTRACT.** *Objective.* Universal Newborn Hearing Screening began in 2 Honolulu hospitals in 1992, and by 1999, all 14 civilian birthing facilities in Hawaii were providing screening. Examination of 1998 Hawaii data indicated that approximately 13% of infants who did not pass initial hearing screening in the hospital did not return for the indicated follow-up. The purpose of this study was to determine the epidemiologic profile of infants who were born in 1999 and did not return for follow-up.

*Methods.* A population-based, cohort study of the hearing screening completion rates among the 13 civilian birthing facilities in Hawaii that provided data to the Department of Health was conducted. Analysis included a bivariate analysis of the demographic characteristics of infants who completed the screening/follow-up process compared with those who did not and logistic regression modeling to ascertain the demographic profile of infants at high risk for being lost to follow-up.

*Results.* Of 12 456 infants, hearing screening data could be linked to the birth certificate file, and a final disposition regarding completion of the screening/follow-up process was determined for 10 328 (83%). Less than 2% ( $n = 176$ ) of the linked infants failed to complete the screening/follow-up procedures. Low birth weight and white infants and infants born to women who had not completed high school were approximately twice as likely not to complete the screening as were their normal birth weight or nonwhite counterparts.

*Conclusions.* Failure to complete the hearing screening follow-up may be related to cultural differences that have been previously reported in other maternal and child health studies of the diverse populations in Hawaii. The results of this study will allow the Hawaii Newborn Hearing Screening Program to target its efforts and limited resources toward infants who are at higher risk of not completing the screening and who may need special attention to encourage their mothers to complete the screening process, and to move quickly with rescreening infants whose initial tests are positive so that infants are not lost to follow-up. *Pediatrics* 2003;111:1202-1206; *universal newborn hearing screening, epidemiology, hearing screening/follow-up.*

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ABBREVIATION. aOR, adjusted odds ratio.

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In 1990, Hawaii legislation mandated that the Hawaii Department of Health develop methods to establish, implement, and evaluate a statewide program for early identification of hearing loss and intervention for children younger than 3 years.<sup>1</sup> Newborn hearing screening began voluntarily in 2 Honolulu hospitals in 1992, and by 1999, all 14 civilian birthing facilities in Hawaii were providing screening. The goal of the program is to provide universal newborn hearing screening/follow-up by 1 month of age; initiate audiological evaluation to confirm infant hearing loss including type, configuration, and degree to infants who screen positive for hearing loss by 3 months of age; and begin intervention for infants identified with a hearing loss by 6 months of age. The specific procedures for newborn hearing screening in Hawaii using otoacoustic emissions screening have previously been described.<sup>1</sup>

"Infants are generally screened within the newborn nursery, or, if the nursery's noise level is unacceptable, in an adjacent room. Best results are obtained after the first 24 hours following the birth. If an initial response is not obtained, several efforts are made to secure a response. If a response still cannot be secured, the infant is scheduled to return for a rescreen as soon as possible. If responses cannot be obtained during the second screening, the infant is referred for a diagnostic auditory brainstem evaluation . . . Parents and pediatricians are informed whenever responses are not obtained from the newborn. For those newborns for whom screening cannot be completed before discharge, parents are notified that the child was not screened and parents are offered the opportunity to return for outpatient screening."

Examination of 1998 Newborn Screening Program data indicated that approximately 13% of infants who did not pass initial hearing screening in the hospital did not return for follow-up to complete the screening process. Although the Newborn Screening Program worked extensively with the birthing hospitals in 1999 to decrease the number of infants lost to follow-up, there was still some concern about what more could be done for the infants who seemed to be "falling through the cracks." Because early intervention has been deemed either to minimize or to prevent the negative effect of hearing loss,<sup>2,3</sup> it is important to identify all children who might benefit from the program. Furthermore, if families who are at risk of not completing the hearing screening/follow-up process can be identified, then more intensive efforts, including health education, can be directed to them. Thus, the purpose of this study was to determine the epidemiologic profile of infants who did not complete hearing screening/follow-up in 1999.

## METHODS

We conducted a population-based, cohort analysis of the hearing screening/follow-up completion rates among 13 of 14 civilian birthing facilities in Hawaii. We compared the infants who were not screened or were screened but did not pass the hearing screening and did not complete the follow-up procedures with infants who did not pass the initial newborn hearing screening and completed the follow-up process. Because the necessary demographic data were not consistently reported in the tracking system, we linked the 1999 hearing screening and tracking data from the Department of Health's *HI\*TRACK* system to the birth certificate file.<sup>4</sup>

A bivariate analysis of the demographic characteristics of infants who completed the screening/follow-up process compared with those who were lost to follow-up was conducted using  $\chi^2$  test statistics. To assess the independent effects of the sociodemographic variables on the outcome, we constructed a logistic regression model adjusting for education (<12 years, 12+ years), ethnicity of the mother (white, Asian, Filipino, Hawaiian, all others), infant birth weight (<2500 g,  $\geq$ 2500 g), and location of birth (obstetric level 2 or 3 medical center on Oahu; community hospital on Oahu; community hospital on the islands of Kauai, Maui, Molokai, and Hawaii, referred to as "neighbor islands"). We estimated model coefficients by using unconditional maximum likelihood methods, and we estimated relative risks by calculating adjusted odds ratios (aORs).

## RESULTS

Of the 17 091 births in Hawaii in 1999, 12 456 infants were born in the 13 civilian hospitals that provide hearing screening data to the Hawaii Department of Health. (Although the 1 civilian hospital not

included in this study did conduct hearing screening in 1999, the results were not transmitted to the Hawaii Department of Health.) Hearing screening tracking data could be linked to the birth certificate file for 10 328 (83%) of these infants. The age and marital status of the mother, and gender and screening/follow-up rates of the infants whose birth certificates could not be linked to *HI\*TRACK* files were similar to those of infants whose files could be linked. However, some differences were noted between the infants with linked files and those with unlinked files when birth weight, hospital of delivery, maternal education, and maternal race were examined (Table 1).

This study included 1013 infants who missed the hearing screening in the hospital, had an inconclusive initial result, or were referred for follow-up. All of the potential outcomes of the initial screening are provided in Fig 1. Sociodemographic characteristics of the mothers and infants are presented in Table 2. No significant differences in age or marital status of mother or gender of infant were noted between the infants who failed to complete the hearing screening/follow-up process and those who completed it. However, infants born weighing <2500 g were less likely to complete the hearing screening than were infants weighing 2500 g or more ( $P < .05$ ). Infants

**TABLE 1.** Characteristics of Mothers and Liveborn, Singleton Infants Born in Selected Hospitals in Hawaii, 1999\*

Characteristic	Linked Files† ( <i>n</i> = 10 328)		Unlinked Files ( <i>n</i> = 2263)	
	<i>n</i>	%	<i>n</i>	%
Age (y)				
10–19	1146	11.1	247	10.9
20–24	2374	23.0	502	22.2
25–29	2585	25.0	539	23.8
30–34	2389	23.1	554	24.5
$\geq$ 35	1834	17.8	421	18.6
Birth weight‡				
< 2500 g	791	7.8	222	9.8
$\geq$ 2500 g	9525	92.3	2033	90.2
Gender				
Male	5356	51.9	1132	50.0
Female	4971	48.1	1130	50.0
Hospital of delivery‡§				
Oahu Medical Centers	5432	52.7	1529	72.3
Oahu Community Hospitals	1164	11.3	168	8.0
Neighbor Island Hospitals	3722	36.1	417	19.7
Education (y)‡				
<12	1245	12.1	259	11.5
12	4327	42.2	884	39.3
$\geq$ 13	4681	45.7	1109	49.3
Marital status				
Married or cohabiting	6362	61.6	1420	62.8
Not married or cohabiting	3964	38.4	843	37.3
Ethnic origin‡				
Asian	2609	25.3	614	27.1
White	1542	15.0	335	14.8
Filipino	2315	22.5	494	21.8
Hawaiian	3112	30.2	701	31.0
Other	732	7.1	118	5.2
Passed initial screening	9315	90.2	1913	92.6

\* Percentages may not add to 100.0 because of rounding.

† The 1999 Department of Health's hearing screening and tracking data were linked to the birth certificate file.

‡  $P < .05$ .

§ Some of the 2263 infants whose files were not linked were not born in hospitals. Ten of the 10 328 infants whose files were linked were missing the hospital of delivery on their birth certificate.

|| 1913 divided by 2065 unlinked records in *HI\*TRACK*.

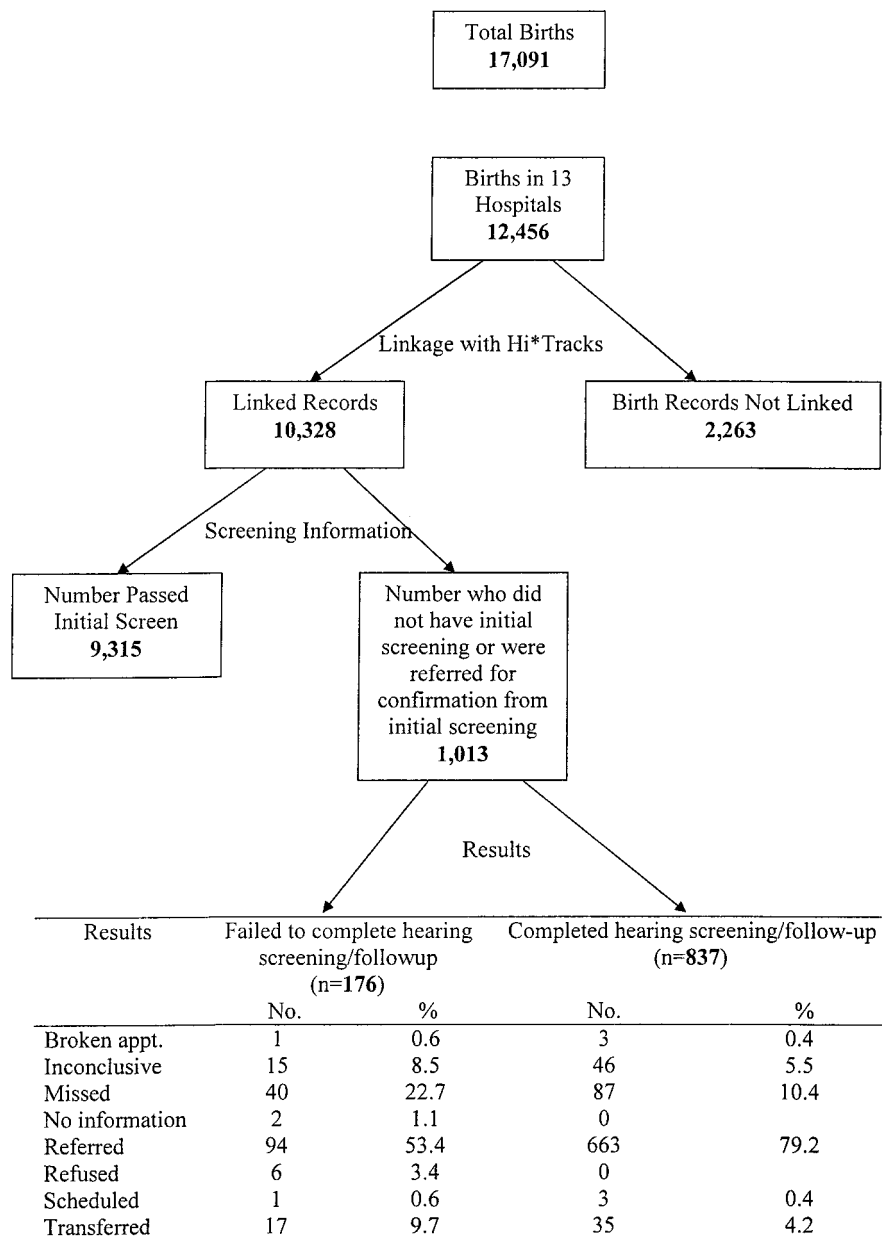


Fig 1. Hawaii newborn hearing screening flow chart, 1999.

who were born in community hospitals throughout the state were less likely to complete the screening than were infants who were born in the medical centers on the island of Oahu designated as obstetric level 2 or 3 ( $P < .05$ ), although these latter hospitals delivered the majority of the births in the study and in the state. Significantly lower completion rates were also noted for lower educational levels as well as for white mothers.

We entered maternal education, infant birth weight, maternal ethnicity (white versus other), and hospital of delivery in the logistic regression models (Table 3). Women who had not completed high school were less likely to have their infant complete the hearing screening/follow-up than were more educated women (aOR: 1.8; 95% confidence interval [CI]: 1.2–2.8). Low birth weight infants were twice as likely not to complete the screening/follow-up compared with their normal birth weight counterparts

(aOR: 2.0; 95% CI: 1.2–3.4). White infants were also more likely not to complete the screening/follow-up compared with nonwhite infants (aOR: 1.8; 95% CI: 1.2–2.7). After adjustment, infants who were born in rural, community hospitals were not different with respect to completing the screening/follow-up process when compared with infants who were born in major medical centers on Oahu.

#### DISCUSSION

The review of newborn hearing screening surveillance data in Hawaii revealed several interesting results. First, the age of the infant's mother was not a significant predictor of failing to bring the infant in to complete the hearing screening/follow-up process. Often in maternal and child health programs, the youngest mothers, notably teenagers, are at the highest risk for adverse reproductive and parenting outcomes.<sup>5</sup> However, in our study, we found that moth-

**TABLE 2.** Characteristics of Mothers and Liveborn, Singleton Infants Needing Follow-up\* to Hearing Screening in Selected Hospitals in Hawaii, 1999†

Characteristic	Total Hearing Screening/Follow-up (n = 1013)	Completed Hearing Screening/ Follow-up (n = 837)	
	n	n	%
Age (y)			
10–19	135	110	81.5
20–24	246	199	80.9
25–29	250	215	86.0
30–34	228	191	83.8
≥35	152	121	79.6
Unknown	2	1	50.0
Birth weight‡			
<2500 g	82	59	72.0
≥2500 g	924	772	83.6
Unknown	7	6	85.7
Gender			
Male	597	486	81.4
Female	414	350	84.5
Unknown	2	1	50.0
Hospital of delivery‡			
Oahu Medical Centers	218	188	86.2
Oahu Community Hospitals	232	187	80.6
Neighbor Island Hospitals	563	462	82.1
Education (y)‡			
<12	137	102	74.5
12	467	388	83.1
≥13	402	343	85.3
Unknown	7	4	57.1
Marital status			
Married or cohabiting	568	480	84.5
Not married or cohabiting	443	356	80.4
Unknown	2	1	50.0
Ethnic origin‡			
Asian	174	153	87.9
White	195	148	75.9
Filipino	242	208	86.0
Hawaiian	333	277	83.2
Other	66	50	75.8
Unknown	3	1	33.3

\* Follow-up includes infants who either missed the initial screen or were referred from initial screen.

† Percentages may not add to 100.0 because of rounding.

‡  $P < .05$ .

**TABLE 3.** Adjusted Odds Ratios for Failing to Complete Newborn Screening for Hearing Loss in Selected Hospitals in Hawaii, 1999

Exposure	OR	95% CI
<12 y education	1.8	1.2–2.8
<2500 g	2.0	1.2–3.4
White	1.8	1.2–2.7
Neighbor Island Hospitals*	0.8	0.5–1.2
Oahu Community Hospitals*	1.0	0.7–1.6

\* Compared with obstetric level 2 or 3 medical centers on Oahu as reference group.

er's lack of a high school education was a more reliable predictor of infants who might fail to complete the hearing screening follow-up. Second, white infants were more likely to have an incomplete hearing screening profile, similar to findings in an earlier study in Hawaii that reported that white pregnant women were less likely to receive prenatal care.<sup>6</sup> These authors speculated that a small percentage of white women may choose "alternative lifestyles," preferring nontraditional health care rather than traditional services.<sup>6</sup> If this speculation is true, then it

could explain the increased odds of failing to complete hearing screening follow-up among white infants in our study.

One of the strengths of our study is that it is population-based, including births from 13 of the 14 civilian birthing facilities in the state. Nevertheless, the findings are limited by the fact that the 2 hospitals not included in the study, 1 civilian (11.1% births) and 1 military (15.4% births), accounted for more than one fourth of the live births in Hawaii in 1999. Another limitation was the lack of information in the surveillance data about the medical status of the infants screened. It is likely that infants who were low birth weight were more medically fragile than their normal birth weight counterparts and were unable to complete the screening/follow-up process. Furthermore, more of the infants whose *HI\*TRACK* files could not be linked with birth certificates were low birth weight compared with those in the study (9.8% vs 7.8%). However, we have no reason to believe that the infants who were excluded from the study had a higher risk of experiencing hearing loss

than infants who could be linked, because 93% of the excluded infants passed their initial hearing screening tests (compared with 90% of the included infants).

Although we were unable to link 2128 (17%) of the birth certificates of the 12 456 infants who were born in the 13 hospitals in our study, we have no reason to suspect that any nondifferential biases were introduced. Less than 2% of infants (176 of 10 328) whose records were linked failed to complete the screening/follow-up procedures. The percentage was the same among the 2065 infants whose records could not be linked.

Hawaii's newborn screening law was amended by the 2001 State Legislature to mandate that "all newborn infants shall be screened for hearing impairment for early identification of children with hearing loss and for the promotion of language and communication." The new law further allowed the Hawaii Department of Health to clarify roles and responsibilities for agencies involved in service delivery to these newborns. Because of this law, all the hospitals in the state must now report surveillance data to the Hawaii Department of Health. Thus, it is anticipated that the findings from this study can be updated to include births in the additional 2 hospitals in Hawaii.

Hearing loss is a serious problem that affects 4.3 of every 1000 infants born in Hawaii in 1999. Early identification, diagnostic evaluation, and intervention services are important for a child's acquisition of the fundamental language and communication skills needed for school success.<sup>7,8</sup> Activities to refine further Hawaii's system of early hearing detection and intervention will continue. A major change will be

updating the data management information system at birthing facilities statewide to improve data collection.

The results of this study will allow the Hawaii Newborn Hearing Screening Program to target its efforts and limited resources toward ensuring that pediatricians are aware that infants who are at higher risk of not completing the follow-up testing may need special attention to encourage their mothers to complete the process. Moreover, efforts must be made to move quickly with rescreening infants whose initial tests are positive so that a final disposition can be determined and infants who need intervention are not lost to follow-up.

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