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Auditory Brainstem Response Pass Rates Correlate with Newborn Hour of Life and Delivery Mode

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Objective To determine whether hour of life and mode of delivery affect auditory brainstem response (ABR) results in healthy infants with a gestational age of >35 weeks.

Study design This retrospective cohort study reviewed 31 984 infants tested during a standard birth hospitalization from 2014 to 2016 at Prentice Women's Hospital of Chicago. Per policy, ABRs were performed after 6 and 12 hours of life for vaginally and cesarean-delivered infants, respectively. Testing was repeated before discharge for infants who were referred once. For those infants who referred again, a third ABR was offered at no cost to families 10-14 days after discharge starting in 2016.

Results ABR pass rates consistently and significantly increased with advancing hour of life at testing, starting at 10-11 hours of life for vaginally born infants and 30-32 hours for cesarean-born infants. This steady, incremental increase in the pass rate was maintained overall until the vaginal and cesarean groups reached plateaus at 42-44 and 48-52 hours of life, respectively. In 2016 and beyond, a third hearing screen after discharge lowered the referral rate to just 0.77%.

Conclusions This study of the results of ABR tests in over 30 000 well newborns demonstrates that delaying hearing screening until 10-11 hours for vaginally born infants and 30-32 hours for cesarean-born infants results in a statistically significant improvement in hearing pass rates. *(J Pediatr 2021;230:100-5)*.

Congenital hearing loss affects 2-3 of every 1000 live born infants worldwide, with known risk factors only identifiable in 50% of cases.[1,2] Delayed diagnosis can lead to significant long-term speech, language, social, and emotional developmental delays.[3,4] Early identification and referral can help to maximize the developmental potential of these children.[5-7] In the US, all 50 states have established Early Hearing Detection Intervention programs, of which universal newborn hearing screening (UNHS) during birth hospitalization is a core component and >98% of newborns are screened in the US before discharge from the birth hospital.[8]

UNHS is conducted by an evoked otoacoustic emissions (OAE) or auditory brainstem response (ABR) test. These tests, although highly sensitive, still result in 2%-4% of all infants across the country failing, or "refer," on their hearing screens. These false referrals occur at almost 10 times the true incidence of hearing loss.[9,10] Unnecessary referrals cause undue anxiety for parents, exacerbate the wait times for formal audiology testing, and increase costs.[11,12] Almost 35% of infants who do not pass initial screening fail to follow-up with formal audiologic testing within the recommended period of 3 months.[13] Strain on the current health care system may render these attrition rates higher.

The Joint Committee on Infant Hearing recommends delaying newborn hearing screening to as close to discharge as possible, while still allowing for repeat testing to be done should the initial test refer.[2] Short hospital stays and other newborn screening practices often present operational challenges to implementing this recommendation successfully. In addition, although hour of life and mode of delivery have been shown to affect referral rates of OAE screening, there have been no comparative studies confirming the same effect to be true for the ABR testing.[14] This study aimed to investigate the relationships between hour of life and mode of delivery on ABR pass and referral rates.

Methods

At Northwestern Prentice Women's Hospital, hearing screening is performed via the ABR test using the ALGO screener in a quiet environment with a calm or sleeping infant. Skilled hearing technicians use this clinically validated cart-based system that screens at 35 dB hearing loss and must detect that the electrodes are detecting the stimulus with high statistical confidence (>99%) to determine that a response is present, or that the infant "passes" the ABR test. Per hospital protocol, screenings

ABR	Auditory brainstem response
OAE	Evoked otoacoustic emissions
UNHS	Universal newborn hearing screening

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are delayed until ≥6 and ≥12 hours of life for vaginally and cesarean-delivered infants, respectively. If an infant refers on their ABR in 1 or both ears, a repeat ABR is performed bilaterally before discharge, consistent with current recommendations of the Joint Committee on Hearing.[15] Referral rates from the newborn hospital stay have historically ranged between 3% and 4%. Before 2016, if a baby failed the screening a second time, the infant was referred for formal diagnostic testing at the audiology department at our affiliated children's hospital, Ann & Robert H. Lurie Children's Hospital of Chicago. However, starting in January 2016 in an effort to lower false referrals, a third ABR was offered 10-14 days after hospital discharge at no cost to parents.

This institutional review board-approved (STU00205901-CR001) retrospective chart analysis was conducted on all 36 223 infants born at Northwestern Prentice Women's Hospital from January 2014 to December 2016. Because our intent was to analyze referral rates in otherwise healthy term infants, infants were excluded for being preterm (born <35 weeks of gestation) or for being tested while in the neonatal intensive care unit. Additionally, infants who had their initial hearing screening performed on day of life ≥5 were removed from the analysis because a stay of this duration may not reflect a normal newborn nursery course. Last, infants with incomplete ABR data were excluded from the analysis. The sample studied can be seen in **Figure 1**.

For our sample, the core data of time and date of birth, time and date of ABR testing, results of said testing, and mode of delivery were gathered. All birth times were rounded to the nearest hour. Statistical analysis was performed by using R (The R Project for Statistical Computing, The R Foundation) 3.6 software for Mac OS X. Because our goal was to determine whether the mode of delivery and age of the newborn influenced the results of ABR testing, the 2-proportions z-test was used for analysis comparing pass rates at different hours of life at testing for infants born vaginally and via cesarean delivery. After considering several different epochs for analysis, we found that 10-hour epoch intervals provided the greatest sensitivity and were not subject to the extremes of variances given differing sample sizes that other intervals were. Additionally, the Yates' correction was applied to prevent overestimation of statistical significance with small sample sizes. Pass rates at a given hour of life were compared with the pass rates of infants tested in the 9 hours preceding and after that hour. A 95% CI was set and statistical significance was defined when the proportion test for a group had a *P* value of <.05 using a 2-sided alternative hypothesis.

Results

Of the 31 984 newborns screened, 4943 (15.5%) failed their initial screening. Consistent with current Joint Committee on Infant Hearing position statement goals, all infants who failed underwent a second screening before discharge. Of those infants retested, 3711 (75%) passed their repeat hearing screening during the birth hospitalization. This process resulted in referral rates at our institution during the birth hospitalization of 3.63% in 2014, 3.73% in 2015, and 4.2% in 2016. The ultimate referral rates did not differ significantly between those infants born vaginally vs via cesarean delivery. The addition of the postdischarge third hearing screen lowered the referral rate from 4.2% to just 0.77% of infants in 2016. There were 378 false referrals detected and only 72 infants ultimately needed referral for formal diagnostic testing.

Overall, our program had a very low attrition rate of referred infants during this period of time with just 23 infants in 2014 (5.8% of infants who referred) in 2014 and 16 infants in 2015 (4.2%) being lost to follow-up. After the addition of the third hearing screen in 2016, the attrition rate increased to 12.5%, but this equated to only 9 infants not following up as scheduled. The average number of days to diagnosis of congenital hearing loss in these groups was 92 days in 2014, 122 in 2015, and 60

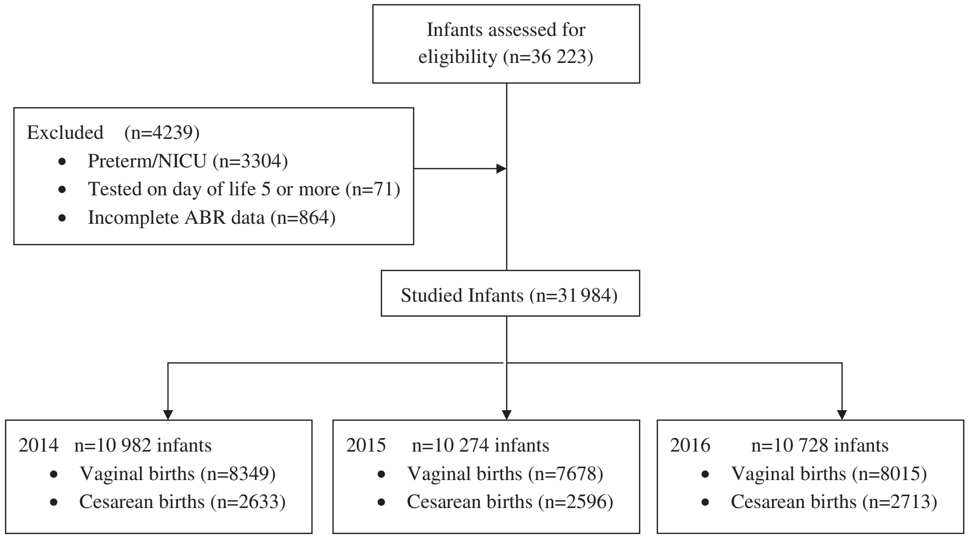

Figure 1. Flow diagram for the sample studied. *NICU*, neonatal intensive care unit.

Table. Ten-hour epoch analysis for vaginal and cesarean delivery births

Hour	Pre-hour count	Pre pass, %	Post-hour count	Post pass, %	*P* value
Vaginal births in 2015					
8	366	0.781	3064	0.804	.477391
9	616	0.779	3007	0.804	.147863
10	876	0.78	3064	0.805	.034708*
11	1118	0.783	3202	0.809	.00659*
12	1378	0.792	3349	0.809	.003604*
13	1662	0.792	3445	0.810	.023794*
14	1956	0.794	3551	0.813	.000001*
15	2247	0.796	3577	0.823	.000001*
16	3202	0.809	3555	0.831	.000001*
17	2774	0.808	2964	0.843	.000001*
…					
39	872	0.858	364	0.89	.026812*
40	750	0.864	346	0.899	.013536*
41	655	0.86	318	0.896	.011995*
42	583	0.87	281	0.897	.079175
Cesarean deliveries in 2015					
28	1099	0.834	753	0.833	.8889
29	1169	0.835	734	0.831	.7056
30	1217	0.832	719	0.85	.0494*
31	1234	0.832	725	0.854	.0193*
32	1196	0.832	751	0.852	.0186*
33	1132	0.837	763	0.853	.0365*
34	1021	0.834	762	0.848	.0424*
35	896	0.831	747	0.853	.0002*
36	809	0.843	727	0.855	.01384*
37	761	0.837	683	0.858	.0000*
38	753	0.833	624	0.861	.0001*
39	734	0.831	560	0.862	.0001*
…					
47	683	0.858	173	0.908	.0420*
48	624	0.861	153	0.895	.1943

*Statistical significance $P < .05$.

in 2016. The true positive incidence of congenital hearing loss as evidenced by the formal audiologic diagnostic testing during our study period was 0.89 per 1000 live births in 2014, 0.92 per 1000 in 2015, and 0.63 per 1000 in 2016, excluding those infants who were lost to follow-up.

With regard to the relationship between age at testing and pass rate, both vaginally and cesarean-delivered infants had increased pass rates at advancing hour of life at first testing. However, as shown by the aberrant points at certain hours, the data were easily skewed when the number of infants tested was small at that point in time, and thus data were analyzed by comparing the pass rates in the 9 hours preceding with the 9 hours post any certain hour of testing, as noted. We were able to demonstrate a continued statistically significant increase in pass percentage in the vaginal groups starting at hour of life 10 for the 2014 and 2015 populations and hour of life 11 for the 2016 group. This steady incremental increase in the pass rate was maintained overall until the group reached a plateau at 42-44 hours of life (**Figure 2** and **Table**). For those infants born via cesarean delivery, a statistically significant and consistent increase in the pass rate was achieved after 30 hours of life in 2015 and 32 hours in 2014 and 2016 as shown in **Figure 3** and the **Table**. The plateau was achieved and there was no statistically significant increase in pass rate after 48-52 hours of life for infants born via cesarean delivery.

Discussion

Our study presents compelling data from a large sample demonstrating that hour of life and mode of delivery affect ABR hearing screen pass referral rates and that delaying testing until ≥10-12 hours of life for vaginally born and ≥30-32 hours of life for cesarean-delivered infants results in a significant reduction in false referrals. These data support earlier studies from OAE testing that mode of delivery affects newborn hearing referral rates.[14] These data also demonstrate that a third screen within 2 weeks significantly decreases the overall refer rate.

The etiology for this variation owing to mode of delivery remains unclear. In previous studies, failure on OAE has been posited as being due to a combination of persistence of both external and middle ear canal secretions. However, external ear debris is unlikely to contribute to failure in this population screened via ABR, because the ABR is much less dependent on the status of the external ear canal than the OAE testing. ABRs do not rely on sound being able to travel from the hair cells back through the external ear canal to an external recording device as in OAE testing. Thus, it is more likely that persistent middle ear fluid or edema contributes to the difference seen in our sample. Fluid status overall differs significantly in vaginally vs cesarean-born infants, who are more likely to retain fluid at birth and experience more precipitous weight loss after birth.[16,17]

Limitations of our study include evaluation of 1 hearing screening modality (ABR) at a single institution with trained and skilled hearing technicians. Other institutions may have different staffing demands and time restraints for their audiologists, and recommendations based on this study may not be practical for their institutions. Additionally, UNHS, conducted by whatever modality, is limited in that it can only detect hearing loss present at birth. Many conditions, such as congenital cytomegalovirus, can lead to hearing loss later in infancy and may have a more insidious and delayed onset.

Cost containment as well as accurate and timely detection are of the utmost importance during times of limited global health care resources. At our institution, the cost of formal diagnostic audiology evaluation is >10 times the cost of a screening newborn ABR, requires subspecialty referral, and often has wait times ranging from 2 to 6 weeks. Hospitals are constantly looking for new ways to optimize efficient and reliable care. Those with sufficient resources to institute a third screening opportunity for referred infants after discharge at 10-14 days of life should consider establishing this practice to make sure that the infants with true congenital hearing loss are being referred, diagnosed, and intervened on in a timely manner.

The success of UNHS is due in part to the captive audience of newborns during the birth hospitalization. Although optimizing exact hour of life may not always align with hours when hearing technicians will be available, birth institutions should evaluate their policies and make modifications to delay the timing of

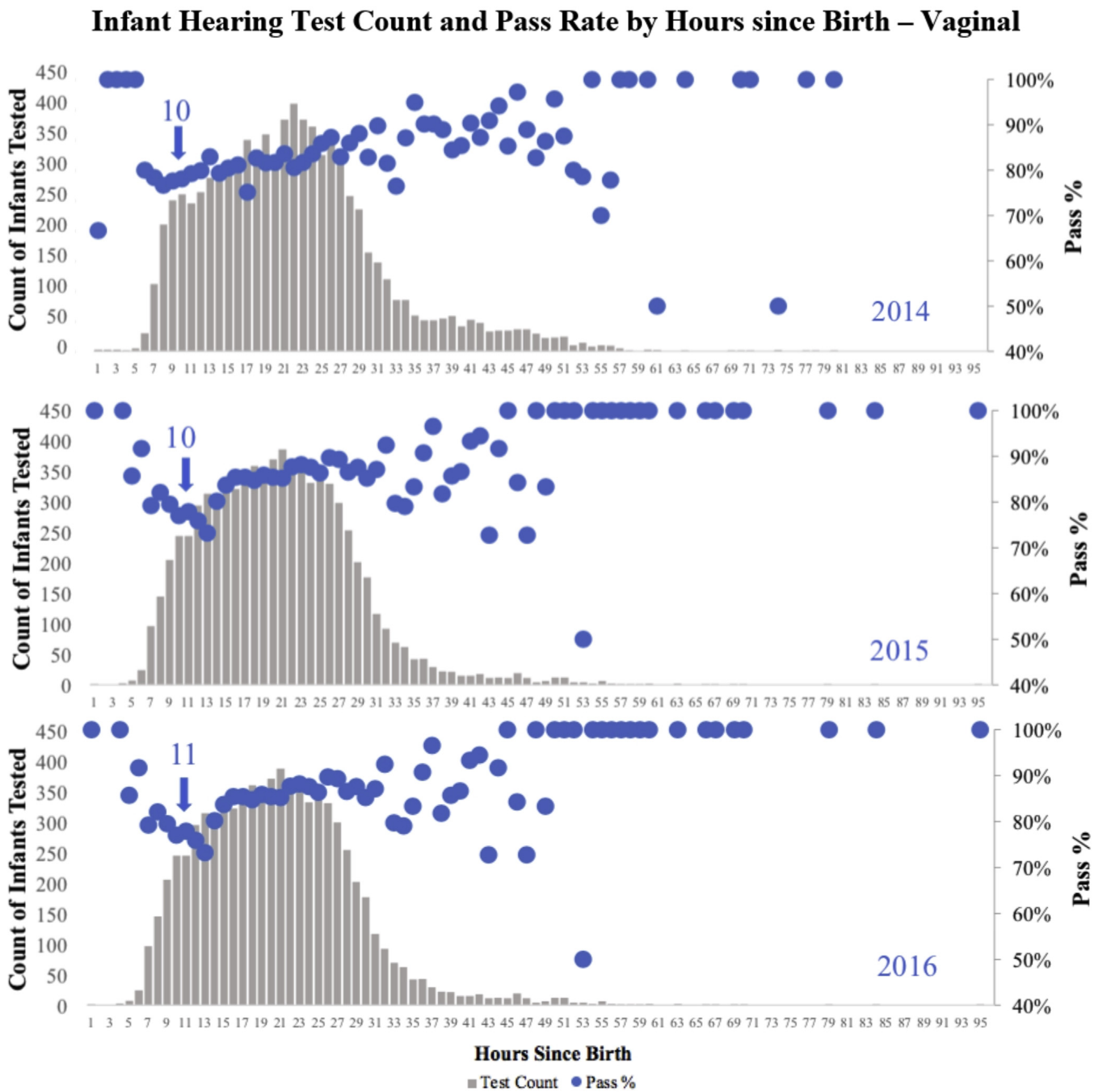

Figure 2. Vaginal pass rates increase with increasing hour of life. The *x* axis denotes hours of life since birth at testing. *Gray bars* on the *y* axis denote number of infants tested during that hour. *Blue dots* on the *y* axis denote pass rate percentage.

hearing screening to decrease false referral rates. If successfully implemented, a decrease in referral rates would not only serve to ameliorate family anxiety and decrease health care costs, but also result in improved and more rapid detection and interventions for those with true congenital hearing loss.

This large study of the results of ABR tests in >30 000 well newborns at a large academic urban institution demonstrates that delaying hearing screening until ≥10-12 hours for vaginally born infants and ≥30-32 hours for infants born via cesarean delivery results in a statistically significant improvement in hearing pass rates. Given that >98% of US newborns are screened for congenital hearing loss, the implications of using this screening in an effective and appropriate manner are profound. Additionally, this study demonstrates that the time to confirmatory diagnosis of congenital hearing loss improved by 1-2 months when referral rates more appropriately mirrored the true incidence of hearing loss. Further studies should be conducted to evaluate the impact of changing hearing screening policies to reflect this evidence on referral rates and timing of formal diagnosis of hearing loss. ■

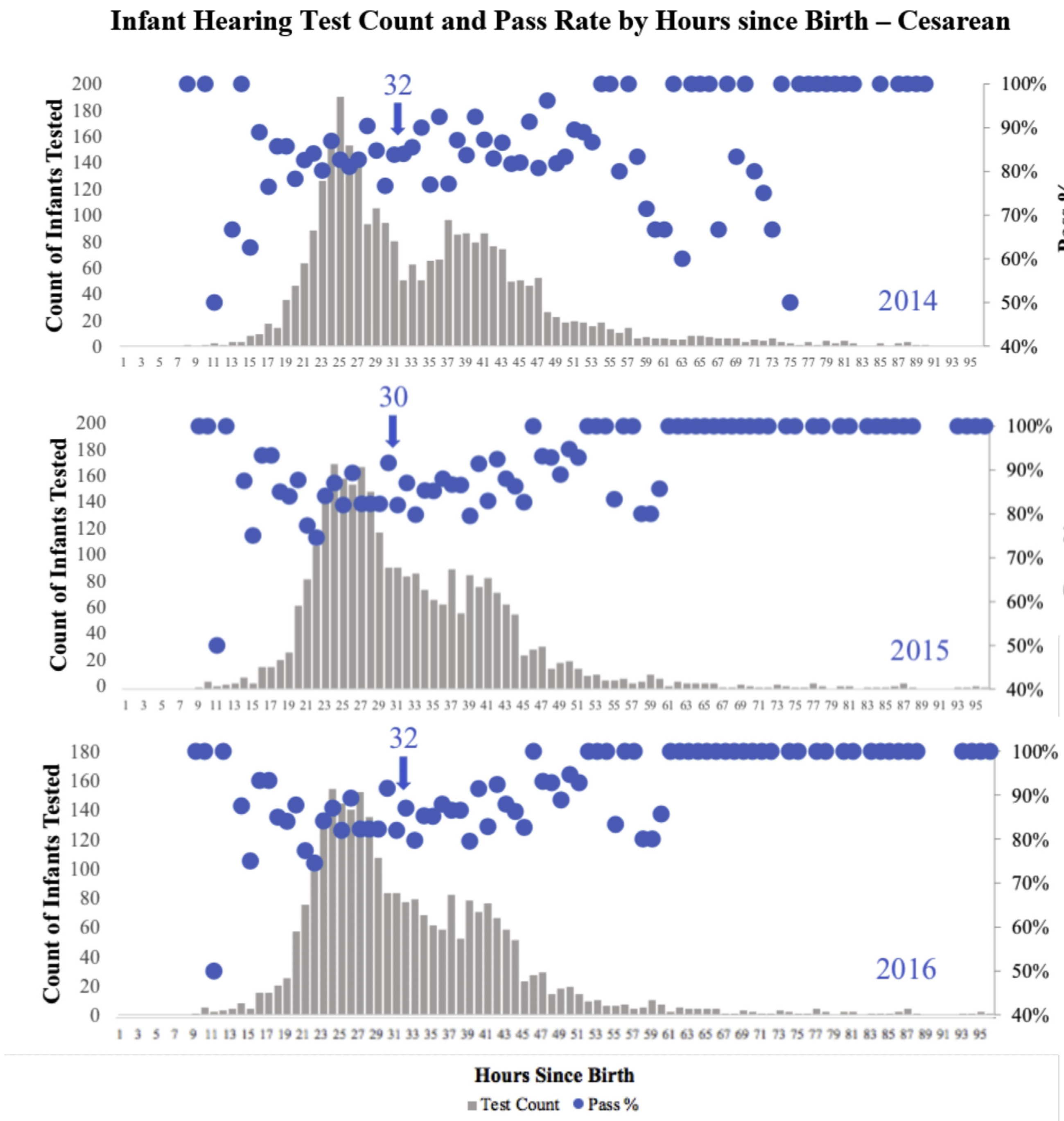

Figure 3. Cesarean pass rates increase with increasing hour of life. X axis denotes hours of life since birth at testing. Gray bars on the Y axis denote number of infants tested during that hour. Blue dots on the Y axis denote pass rate percentage.

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50 Years Ago in *The Journal of Pediatrics*

Pediatric Lower Respiratory Pathogens: What Has Changed Throughout the Years

Glezen WP, Loda FA, Clyde WA Jr, Senior RJ, Sheaffer CI, Conley WG, et al. Epidemiologic patterns of acute lower respiratory disease of children in a pediatric group practice. J Pediatr 1971;78:397-406.

Cold weather viruses have been a common cause of consultation in the pediatric practice for many years. The respiratory syncytial virus (RSV) is responsible for an estimated 3.4 million worldwide hospitalizations annually in children younger than 5 years of age.[1] Fifty years ago, Glezen et al published a study with more than 3000 cases in which they demonstrated (by culture medium) that almost 75% of the pathogens were associated with RSV, parainfluenza virus, or *Mycoplasma pneumoniae*. Needless to say, times (and pathogens) have changed.

We can compare pathogens associated with infectious respiratory illnesses in children between eras; it is well known that other viruses such as influenza, rhinovirus, adenovirus, or the recently discovered human metapneumovirus have emerged. RSV and influenza account for most of the cold-weather infections today,[1] but not all lower respiratory pathogens are associated with cold weather. Recent studies have demonstrated that parainfluenza virus, human metapneumovirus, rhinovirus, and adenovirus can present almost all year long. Thanks to polymerase chain reaction viral tests, rapid antigen tests, and serologies, among others, the causative agents of respiratory infections are much easier and faster to diagnose. However, the daily practice of pediatricians is dependent on the epidemiologic knowledge learned through the years.

A few months have passed since the start of the coronavirus disease 2019 (COVID-19) pandemic, and the world is learning about the epidemiology of this virus. We do not know if this disease will have a seasonal prevalence, if it will recur annually, or how it will affect the clinical differential diagnosis. What will we be writing 50 years from now about this and the other many respiratory pathogens that have challenged us over the last 5 decades?

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