Recent Trends in Infant Car Seat Tolerance Screening Failure Within a Large Health Care System, 2014–2018

Skyler McLaurin-Jiang, MD,⁎ Emily A. Hannon, MD, IBCLC,⁎ Carl Seashore, MD,⁎ Colin J. Orr, MD, MPH,⁎ Victor Ritter, MsC,⁎ Kori B. Flower, MD, MS, MPH⁎

OBJECTIVES: To describe temporal trends in car seat tolerance screening (CSTS) failure within a large hospital system (2014–2018).

METHODS: We conducted a retrospective cohort study using electronic medical record data for infants who underwent a CSTS. Our primary outcome measure was the CSTS failure rate. Covariates included year, CSTS location (well nursery or NICU), gestational age (GA), race, sex, birth weight, CSTS date, and age at CSTS. Associations of covariates with CSTS failure were examined by using χ² tests, t tests, analysis of variance, and Wilcoxon rank tests. Multivariable logistic regression was used to determine the adjusted odds of CSTS failure.

RESULTS: Of 4849 infants tested, the failure rate was 8.1% (n = 394). Most CSTS occurred in the well nursery (79.5%) and involved late preterm (55.2%) or term infants (23.7%). In bivariate analyses, year, unit location, higher birth weight, younger chronological age at testing, and higher GA were positively associated with CSTS failure (P < .05). After stratification by CSTS location, the CSTS failure rate rose in the well nursery but remained stable in the NICU, and use of screening rose among term infants. In the adjusted model, year, GA, and corrected gestational age at CSTS were associated with failure. Each subsequent year was associated with a 19% increase in odds of CSTS failure (P < .001).

CONCLUSIONS: We found a higher rate of CSTS failure in the well nursery compared with the NICU, and the difference in failure rates increased over time. Improved understanding of infants at the highest risk of CSTS failure could impact routine screening guidelines.
The American Academy of Pediatrics recommends that preterm newborns undergo monitoring in a car seat (the car seat tolerance screening [CSTS]) before discharge. Published CSTS failure rates range from 4% to 83%, although the population of infants undergoing screening and the criteria for failure vary across sites. Higher failure rates among infants in the nursery compared with the NICU have been reported. Other infant characteristics, such as gestational age (GA), race, low birth weight (BW), and sex, have been inconsistently associated with failure.

Although authors of a recent large study described the epidemiology of CSTS across multiple NICUs, to our knowledge no authors of previous large studies have described CSTS failure in both well-newborn and NICU settings or have described trends in failure over time.

Our primary aim for this study was to determine the rate and trends of CSTS failure within a large hospital system. Our secondary aim was to examine infant characteristics that predicted CSTS failure in NICU and nursery populations.

**METHODS**

**Study Population**

We conducted a retrospective review of electronic medical record (EMR) data at 2 large hospitals in a major health care system. Both hospitals (1 academic, 1 community) used the same EMR (Epic) to log CSTS results. Inclusion criteria were infants who underwent a CSTS from April 5, 2014 (when Epic was initiated), to December 31, 2018, within well-newborn nurseries (nursery) and level II or higher nurseries (NICU). No infants were excluded. Approval was granted by the institutional review board.

**CSTS Procedures**

Infants <35 weeks’ gestation were admitted to the NICU. Otherwise well infants ≥35 weeks’ gestation were admitted to the nursery. Both units screened infants born <37 weeks’ GA or <2.27 kg. Additional infants were screened at physician discretion. CSTSs were conducted by using Philips IntelliVue MP50 monitors (10-second averaging times). Infants underwent 90 minutes of cardiorespiratory monitoring under observation by a trained registered nurse. Failure criteria were bradycardia (heart rate <80 beats per minute) sustained for ≥10 seconds, apnea (>20 seconds), or desaturation <92% sustained for ≥10 seconds (University of North Carolina at Chapel Hill Nursing Policy Committee, unpublished). A certified car seat technician was available for questions regarding proper infant positioning. Infants who failed underwent repeat testing no sooner than 12 hours after previous screen and underwent additional workup per physician recommendations. Criteria remained the same during the study period.

**Outcome**

The primary outcome was the rate of initial CSTS failure each study year. CSTS results were dichotomized (pass or fail).

**Statistical Methods**

Descriptive statistics were used to examine cohort characteristics. We compared infant characteristics by CSTS result (pass or fail).

**Covariables**

Covariables included study year, sex, race and/or ethnicity (white, African American, Asian American, or other or unknown), GA, GA category (early preterm [EPT] [<34 weeks’ gestation], late preterm [LPT] [≥34 and <37 weeks’ gestation], and term [≥37 weeks’ gestation]), BW, corrected gestational age (CGA), length of stay (LOS), hospital site, and location of admission (NICU or nursery). Dates of birth and CSTS results were extracted.

### TABLE 1: Demographic and Clinical Factors Associated With Initial CSTS Result

<table>
<thead>
<tr>
<th>Hospital site, n (%)</th>
<th>Passed</th>
<th>Failed</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>1984 (92.1)</td>
<td>172 (7.9)</td>
<td>.673</td>
</tr>
<tr>
<td>Academic</td>
<td>2461 (91.7)</td>
<td>222 (8.3)</td>
<td>.001</td>
</tr>
<tr>
<td>Location in hospital, n (%)</td>
<td></td>
<td></td>
<td>.012</td>
</tr>
<tr>
<td>Well newborn nursery</td>
<td>3519 (91.2)</td>
<td>338 (8.8)</td>
<td></td>
</tr>
<tr>
<td>NICU or SCN</td>
<td>936 (94.4)</td>
<td>56 (5.7)</td>
<td></td>
</tr>
<tr>
<td>Study year, n (%)</td>
<td></td>
<td></td>
<td>.095</td>
</tr>
<tr>
<td>2014</td>
<td>552 (93.1)</td>
<td>41 (6.9)</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>962 (93.5)</td>
<td>67 (6.5)</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>949 (92.5)</td>
<td>77 (7.5)</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>1001 (91.3)</td>
<td>95 (8.7)</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>981 (89.7)</td>
<td>114 (10.3)</td>
<td></td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td>.675</td>
</tr>
<tr>
<td>Female</td>
<td>2088 (91.7)</td>
<td>189 (8.3)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2357 (92.0)</td>
<td>205 (8.0)</td>
<td></td>
</tr>
<tr>
<td>Race or ethnicity, n (%)</td>
<td></td>
<td></td>
<td>.027</td>
</tr>
<tr>
<td>White</td>
<td>2417 (91.4)</td>
<td>227 (8.6)</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>988 (93.7)</td>
<td>66 (6.3)</td>
<td></td>
</tr>
<tr>
<td>Asian American</td>
<td>203 (91.0)</td>
<td>20 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Other or unknown</td>
<td>846 (91.3)</td>
<td>81 (8.7)</td>
<td></td>
</tr>
<tr>
<td>GA category, n (%)</td>
<td></td>
<td></td>
<td>.049</td>
</tr>
<tr>
<td>EPT</td>
<td>963 (93.9)</td>
<td>63 (6.1)</td>
<td></td>
</tr>
<tr>
<td>LPT</td>
<td>2439 (91.2)</td>
<td>236 (8.8)</td>
<td></td>
</tr>
<tr>
<td>Term</td>
<td>1053 (91.7)</td>
<td>95 (8.3)</td>
<td></td>
</tr>
<tr>
<td>GA, wk, mean ± SD</td>
<td>34.8 ± 3.2</td>
<td>35.1 ± 2.9</td>
<td></td>
</tr>
<tr>
<td>CGA, wk, mean ± SD</td>
<td>37.2 ± 3.3</td>
<td>36.9 ± 4.6</td>
<td></td>
</tr>
<tr>
<td>BW, kg, mean ± SD</td>
<td>2.4 ± 0.7</td>
<td>2.5 ± 0.7</td>
<td></td>
</tr>
<tr>
<td>LOS, d, median (IQR)</td>
<td>5.7 (3.0–18.3)</td>
<td>4.3 (3.1–11.7)</td>
<td>.043</td>
</tr>
</tbody>
</table>

EPST is categorized as <34 wk GA, LPT is categorized as <37 wk GA, and term is categorized as ≥37 wk GA. IQR, interquartile range; SCN, special care nursery.

EPT is categorized as <34 wk GA, LPT is categorized as <37 wk GA, and term is categorized as ≥37 wk GA.

### Covariables

- Study year
- Sex
- Race and/or ethnicity
- GA category (EPT, LPT, term)
- BW
- CGA
- LOS
- Hospital site
- Location of admission

**TABLE 2: Demographic and Clinical Factors Associated With Initial CSTS Result**

### Study Population

We conducted a retrospective review of electronic medical record (EMR) data at 2 large hospitals in a major health care system. Both hospitals (1 academic, 1 community) used the same EMR (Epic) to log CSTS results. Inclusion criteria were infants who underwent a CSTS from April 5, 2014 (when Epic was initiated), to December 31, 2018, within well-newborn nurseries (nursery) and level II or higher nurseries (NICU). No infants were excluded. Approval was granted by the institutional review board.

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**Outcome**

The primary outcome was the rate of initial CSTS failure each study year. CSTS results were dichotomized (pass or fail).

**Statistical Methods**

Descriptive statistics were used to examine cohort characteristics. We compared infant characteristics by CSTS result (pass or fail).
using \( \chi^2 \) tests, Fisher’s exact tests, \( t \) tests, and Wilcoxon rank tests as appropriate for categorical, continuous, and nonparametric variables. We used analysis of variance with Bonferroni correction (parametric) and Kruskal-Wallis tests (nonparametric) to examine differences in continuous outcomes between multiple groups. Logistic regression models were used to determine clinical characteristics associated with CSTS failure. Characteristics were chosen a priori, and models were reduced by using backward elimination. \( P < .05 \) was considered significant. StataIC version 15 (Stata Corp, College Station, TX) was used for analysis.

**RESULTS**

**Demographics**

Of 4849 infants, 8.1% failed an initial CSTS (\( n = 394 \); Table 1). Overall, 55.2% of infants were LPT, whereas 23.7% were term. Boys made up 53% of the cohort, and the mean BW was 2.41 ± 0.72 kg. The majority of infants were admitted to the nursery (79.5%). Infants were white (54.5%), African American (21.8%), and Asian American (4.6%).

**Failure Trends**

CSTS failure increased from 6.9% to 10.3% during the study (\( P < .05 \); Table 1). After stratifying by CSTS location, 5.7% of infants in the NICU failed, compared with 8.8% in the nursery (\( P < .001 \)). The increasing failure rate only occurred in the nursery (Table 2). The absolute number of CSTSs performed on term and LPT infants increased in the nursery, where they made up 24.3% to 28.1% and 52.1% to 53.6% of those tested from 2014 to 2018, respectively (\( P < .001 \)). There was a reciprocal decrease in the percentage of those screened who were EPT infants; however, the absolute number of tests among EPT infants remained stable.

**Characteristics Associated With Failure**

More LPT and term infants than EPT infants failed (8.8%, 8.3%, and 6.1%, respectively; \( P = .027 \); Table 1). The failure rate was lower among African American (6.3%) infants compared with white (8.6%) and Asian American (9.0%) infants, but it was not statistically significant (\( P = .095 \)). Higher GA and BW, but lower CGA (36.9 vs 37.2 weeks), were associated with failure (\( P < .05 \)). On the subgroup analysis, the association between higher GA and failure was only present among LPT infants (35.4 vs 35.3 weeks; \( P < .01 \)). The mean CGA of infants who failed was higher in the NICU compared with the nursery (39.2 vs 36.5 weeks; \( P < .001 \)).

**Multivariable Models**

We created separate multivariable models for infants in the nursery and NICU (Table 3). Multivariable logistic regression models included study year, sex, race, GA, BW, and CGA. In the fully adjusted model, within the nursery, study year, GA, and CGA at time of CSTS were associated with CSTS failure (Table 3). Every additional study year was associated with a 19% increase in odds of

### Table 2: Characteristics of Infants by CSTS Result and Location of Test Within Hospital

<table>
<thead>
<tr>
<th></th>
<th>Well-Newborn Nursery (( n = 3957 ))</th>
<th>NICU (( n = 892 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n = 3519 ) (91.2%)</td>
<td></td>
<td>( n = 936 ) (94.4%)</td>
</tr>
<tr>
<td>Failed</td>
<td></td>
<td>( n = 338 ) (8.8%)</td>
</tr>
<tr>
<td>Passed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n = 56 ) (5.7%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( P \) values reflect the statistical significance of the differences between the two groups. IQR, interquartile range.
which CSTS is currently recommended other
specific conditions or weight cutoffs for
infants who fail the CSTS are of substantial
undergoing screening each study year. Term
proportion of both term and LPT infants
infants undergoing CSTS, such as a
changes in screening guidelines, equipment,
protocols during this period revealed no
likely multifactorial. A review of CSTS
which CSTS failures are examined over time.

DISCUSSION
To our knowledge, this is the first study in
which CSTS failures are examined over time.
The rise in CSTS failures in the nursery was
likely multifactorial. A review of CSTS
protocols during this period revealed no
changes in screening guidelines, equipment,
or criteria for failure. However, we identified
differences over time in characteristics of
infants undergoing CSTS, such as a
significantly higher absolute number and
proportion of both term and LPT infants
undergoing screening each study year. Term
infants who fail the CSTS are of substantial
clinical importance given that there are no
specific conditions or weight cutoffs for
which CSTS is currently recommended other
than prematurity. As providers become
more familiar with the CSTS, they may
screen at-risk infants with conditions such
as low BW, Down syndrome, neuromuscular
disorders, craniofacial abnormalities, and
genital heart disease (as referenced in the
American Academy of Pediatrics
guidelines) more often, which are important
areas for future research.2

Similar to previous studies, CSTS failure
was more common in the nursery than the
NICU.4,11,12 Possible explanations for higher
failure rates in the nursery include the
following: (1) infants in the NICU undergo
more cardiorespiratory evaluation,
potentially leading to identification of apnea
and bradycardia before CSTS and (2) well-
nursery discharges often occur between
48 and 96 hours, so providers may perform
the CSTS at an earlier CGA, when infants are
less mature. Supporting this explanation,
our data reveal that compared with infants
in the nursery, infants in NICU had a higher
cGA at the CSTS and more frequently passed
the screen. A greater postnatal age,
perhaps as a result of a longer interval
for postnatal maturation, is associated
with passing the CSTS.4,15 Somewhat
counterintuitively, infants with an older GA
and higher BW were more likely to fail in the
nursery. Authors of some previous studies
reported this association, whereas others
found no association.1,4,14–16

For infants screened in the NICU, it is
possible that characteristics not examined
in this study may better predict CSTS failure.
Factors shown to be associated with CSTS
failure among infants screened in the NICU
(eg, caffeine, requiring continuous positive
airway pressure, maternal cesarean
delivery, surfactant use, or antacid use)11
were not examined in this study.

Despite widespread CSTS implementation,
its benefits remain unclear. One study
revealed that infants who failed the CSTS had
lower adjusted odds of readmission by
30 days.11 Although CSTS is routine in many
US hospitals, the Canadian Pediatric Society
does not recommend routine screening,
citing lack of evidence to support improved
outcomes and concern for potential risk.17–19
One potential risk is increased cost given
that each test requires a minimum of
90 minutes of direct staff and/or nursing
observation.2,19 Other potential risks include
maternal-infant separation, caregiver stress,
and false reassurance among caregivers.17

Limitations of this study include the inability
to examine all factors associated with CSTS
results, such as underlying medical
conditions or indication(s) for which
providers chose to screen infants. Also, we
did not examine reasons for failure or
transfers between the NICU and nursery and
their association with failure, which are
important areas for future study. Although
2 major sites were included, the data
represent only 1 health care system, and
only partial EMR data were available for
2014 because of EMR implementation that
year. Lack of CSTS outcome data limits our
ability to assess the risk/benefit ratio.

CONCLUSIONS
The CSTS failure rates differed in nursery
and NICU settings, and failures increased in

TABLE 3  Unadjusted and Adjusted Odds Ratios of Factors Associated With CSTS Failure

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted OR (95% CI)</th>
<th>P</th>
<th>Adjusted OR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well-newborn nursery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study year</td>
<td>1.17 (1.07–1.27)</td>
<td>&lt;.001</td>
<td>1.19 (1.09–1.30)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.11 (0.88–1.38)</td>
<td>.379</td>
<td>1.14 (0.90–1.43)</td>
<td>.269</td>
</tr>
<tr>
<td>Race or ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>Reference</td>
<td>—</td>
<td>Reference</td>
<td>—</td>
</tr>
<tr>
<td>African American</td>
<td>0.72 (0.53–0.98)</td>
<td>.040</td>
<td>0.76 (0.55–1.04)</td>
<td>.086</td>
</tr>
<tr>
<td>Asian American</td>
<td>1.12 (0.89–1.82)</td>
<td>.651</td>
<td>1.11 (0.86–1.81)</td>
<td>.681</td>
</tr>
<tr>
<td>Other or unknown</td>
<td>1.18 (0.89–1.58)</td>
<td>.247</td>
<td>1.13 (0.84–1.52)</td>
<td>.401</td>
</tr>
<tr>
<td>GA, wk</td>
<td>1.08 (1.03–1.13)</td>
<td>.003</td>
<td>1.08 (1.00–1.18)</td>
<td>.049</td>
</tr>
<tr>
<td>BW, kg</td>
<td>1.17 (1.14–1.64)</td>
<td>.001</td>
<td>1.21 (0.95–1.54)</td>
<td>.123</td>
</tr>
<tr>
<td>CGA, wk</td>
<td>0.95 (0.90–1.01)</td>
<td>.111</td>
<td>0.89 (0.82–0.97)</td>
<td>.008</td>
</tr>
<tr>
<td><strong>NICU</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study year</td>
<td>0.98 (0.80–1.19)</td>
<td>.217</td>
<td>1.01 (0.82–1.23)</td>
<td>.950</td>
</tr>
<tr>
<td>Female sex</td>
<td>0.72 (0.41–1.25)</td>
<td>.237</td>
<td>0.72 (0.41–1.28)</td>
<td>.267</td>
</tr>
<tr>
<td>Race or ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>Reference</td>
<td>—</td>
<td>Reference</td>
<td>—</td>
</tr>
<tr>
<td>African American</td>
<td>0.71 (0.36–1.39)</td>
<td>—</td>
<td>0.70 (0.35–1.41)</td>
<td>.320</td>
</tr>
<tr>
<td>Asian American*</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Other or unknown</td>
<td>0.56 (0.05–0.11)</td>
<td>.121</td>
<td>0.63 (0.30–1.30)</td>
<td>.210</td>
</tr>
<tr>
<td>GA, wk</td>
<td>0.96 (0.90–1.01)</td>
<td>.120</td>
<td>0.88 (0.77–1.00)</td>
<td>.051</td>
</tr>
<tr>
<td>BW, kg</td>
<td>0.84 (0.72–1.24)</td>
<td>.696</td>
<td>1.53 (0.85–2.76)</td>
<td>.158</td>
</tr>
<tr>
<td>CGA, wk</td>
<td>1.00 (0.95–1.05)</td>
<td>.904</td>
<td>1.00 (0.95–1.08)</td>
<td>.880</td>
</tr>
</tbody>
</table>

CI, confidence interval; OR, odds ratio; —, not applicable.
* Asian American infants were not included in the NICU model because no Asian American infants failed the CSTS.
the well nursery. Authors of future studies should examine if these trends in CSTS failure exist across other hospitals, should further elucidate predictors of failure, and should examine longer-term outcomes. Improved identification of infants at highest risk of CSTS failure may impact routine screening guidelines.

Acknowledgments
We thank Ashley Wallace, PNP; Alison Sweeney, MD; John Stephens, MD; Johanna Hales, MD; and Michael O’Shea, MD, MPH, for their contributions.

REFERENCES
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