



**The Who, What, When, Where, Why and How of the Car Seat Tolerance Test**

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**Disclosures**


- I have no financial relationships to disclose or Conflicts of Interest to resolve
- This presentation will not involve discussion of unapproved or off-label, experimental or investigational use
- I am an expert consultant for the Maryland Institute for Emergency Medical Services Systems (MIEMSS), Child Passenger Safety and Occupant Protection (CPS & OP)

**Objectives**


- Review the history and origin of the Car Seat Tolerance Screen (CSTS)
- Review current recommendations for testing including inclusion criteria and failure guidelines
- Review the available data on what a failed or passed CSTS means for the health of neonates
- Discuss recommendations for management of the infant who fails a CSTS

**Outline**

- **Why** do this test? History of the “Car Seat Test”
- Current recommendations on **Who** should be tested
- **What** failure guidelines should be used?
- What to do **When** a baby fails?
- **Where** is future research focusing?
- **How** should we counsel families when it comes to Car Seat Tolerance Testing



**What’s in a name?**



- Car Seat Test (CST)
- Car Seat Challenge (CSC)
- Infant Car Seat Challenge (ICSC)
- Car Seat Safety Test (CSST)
- Car Seat Screen (CSS)
- Car Seat Tolerance Screen (CSTS)



**Why?**

Why do this test? (History of the CST)

## Car Seat Tolerance Testing

- 1970s – AAP recommends infants travel in a car safety seat
- 1980s – Evidence that preterm infants at increased risk of desaturations while in the semi-upright car seat position
  - Lung immaturity? Breathing immaturity? Low tone?
  - Too small for the standard seat?
- 1990s – AAP recommends “a period of observation for apnea, bradycardia and desaturations” in the car seat prior to discharge for preterm infants → Car Seat Tolerance Test
- 2000s – Evidence that longer time in car seat increases risk of desaturations
- 2009 – Current AAP recommendations:
  - All infants born <37 weeks
  - 90-120 minutes, or length of car ride home, whichever is longer
  - No guidelines for “failure” criteria

Bull MJ, et al. *Pediatrics*. 2009; Willett. *Pediatrics*. 1986 and 1989; Salhab. *J Pediatr*. 2007

## CST: What’s Missing?

- No guidelines for what constitutes a “failure”
- Consensus on other groups to test
  - Low birth weight <2.5kg (5.5 lbs)?
  - Congenital Heart Disease?
  - Low Tone?
  - Oxygen requirement?
- What to do if an infant fails?
- What does a “failed” CST really mean for the health and safety of that baby?

## Safe Transportation of Preterm and Low Birth Weight Infants at Hospital Discharge

Bull et al, *Pediatrics*, 2009; reaffirmed 2013

- The increased frequency of oxygen desaturation and episodes of apnea or bradycardia while sitting in car safety seats suggests that **preterm** infants should have a period of observation in a car safety seat, preferably their own, before hospital discharge.
- A period of observation for a minimum of 90 to 120 minutes or the duration of travel, whichever is longer, is suggested.
- Hospitals should develop protocols to include car safety seat observation before discharge for infants born <37 weeks gestation
- Some hospital protocols include car safety seat observations for infants at risk of obstructive apnea, bradycardia, or oxygen desaturation other than those born at less than 37 weeks' gestation. Examples include infants with:
  - Hypotonia (eg, Down syndrome, congenital neuromuscular disorders)
  - Micrognathia (Pierre Robin sequence), and
  - Who have undergone congenital heart surgery

## Local Statistics

- Premature: born <37 weeks gestation
- USA: 9.6% of babies are born prematurely
  - 500,000 born prematurely in the US annually
- Pennsylvania
  - 9.4% born preterm (1 in 11 neonates)
    - Black infants 12.8%
  - 2016 Survey (PA AAP)
    - Of 95 birth centers, 69 participated in survey on CSTs
      - 87% (n=60) perform a CST on preterm/low birth weight
      - 6% (n=4) do NOT perform a CST
      - 7% (n=5) did not answer the question

March of Dimes, <https://www.marchofdimes.org/PeriStats/ViewTopic.aspx?reg=42&top=3&lev=0&slev=4>



## What?

What failure guidelines should be used?

## Car Seat Safety for Preterm Neonates: ICSC Implementation and Testing Parameters

Survey 100 Level II/III NICUs in New England/ New York and categorized CST policies based on:

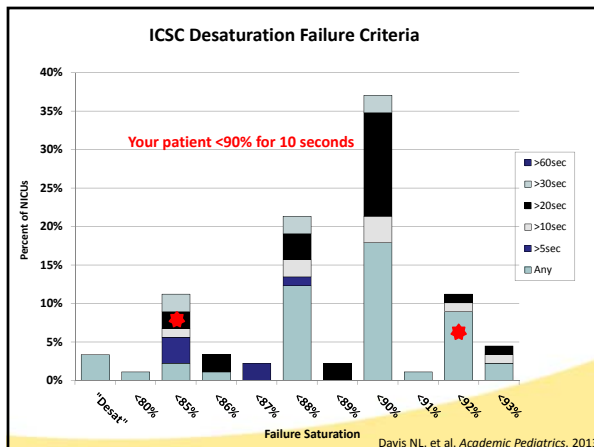
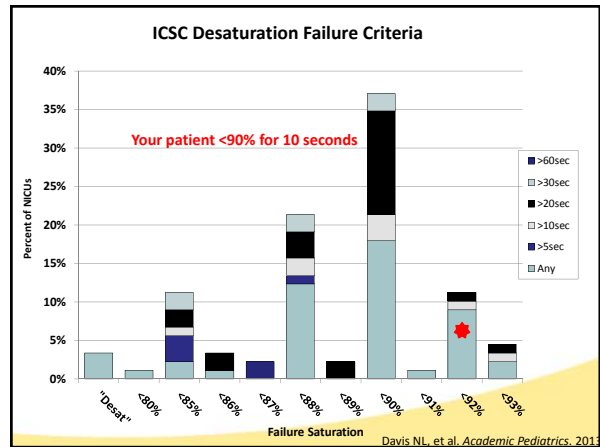
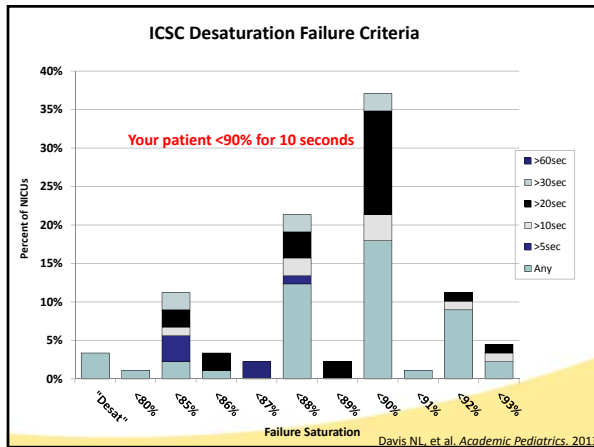
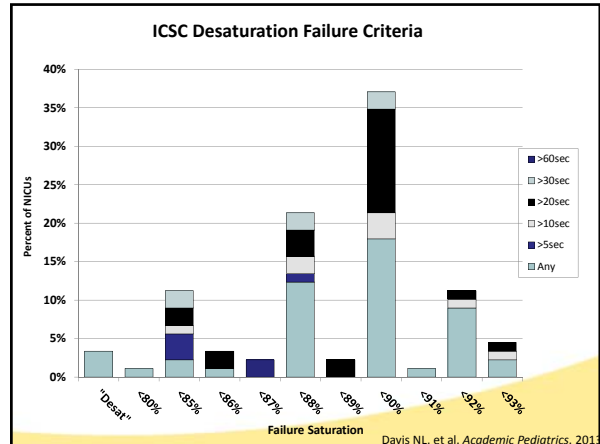
- Inclusion criteria for testing
  - Gestational age **\*\* (AAP recommendation <37 wks)**
  - Weight
- Duration of the test **\*\* (AAP recommendation 90-120min or car ride home)**
- Failure criteria/definitions
  - Oxygen desaturations
  - Bradycardia

Davis NL, et al. *Academic Pediatrics*. 2013

### Car Seat Safety for Preterm Neonates: ICSC Implementation and Testing Parameters

- Following AAP Guidelines (n=100)
  - 11% did not perform CST
  - 17% did not test all infants born <37 weeks GA
  - 45% tested for <90 minutes
- Additional Criteria
  - 45% included “Low Birth Weight” as a testing criterion, testing all babies born <2.5kg
  - No consensus on failure criteria for bradycardia or desaturations

Davis NL, et al. *Academic Pediatrics*. 2013



### Suggested Failure Criteria

- Apnea (breathing pause) >20 seconds
- Heart Rate <80 beats per minute for >10 seconds
- Saturation <90% for >10 seconds
- Respiratory distress not improved with proper positioning
- Canadian Paediatric Society:
  - Two episodes <88% for >10 seconds
  - 2016 – no longer recommends routine CSTs

Van Schaik C; Canadian Paediatric Society, Injury Prevention Committee, *Paediatr Child Health* 2008

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### Who?

Who should be tested?

### Who should we test? What's the data?

- Premature birth (<37 weeks)
- Low Birth Weight
- Cardiac patients
- Low tone (hypotonia)
- Airway anomalies (PRS)
- Oxygen requirement



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### Epidemiology and Predictors of Failure of the Infant Car Seat Challenge

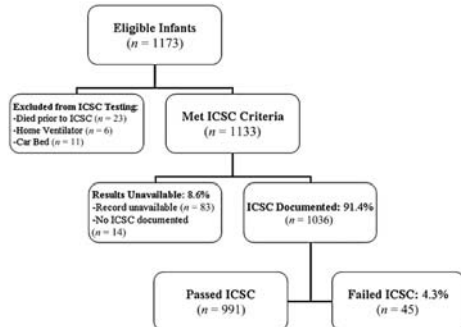


FIGURE 1 Flow diagram of study population.

Davis NL, et al. *Pediatrics*. 2013



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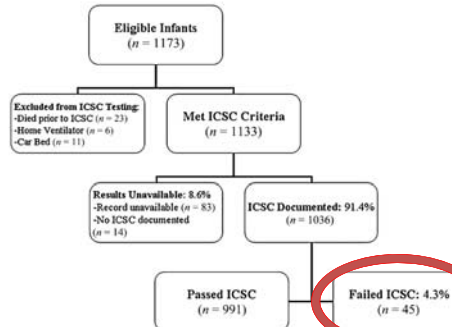


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TABLE 1 Age and Weight Predictors of ICSC Failure

	ICSC Pass, n = 991, Estimate (error)	ICSC Fail, n = 45, Estimate (error)	P
Birth gestational age, wk <sup>a</sup>	34 <sup>4/7</sup> (3.6)	36 <sup>0/7</sup> (2.3)	.0008
Birth weight, g <sup>b</sup>	2169 (694)	2467 (653)	.0045
Chronologic age at test, d <sup>a</sup>	16 (33)	4 (16)	.0002
CGA at test, wk <sup>a</sup>	36 <sup>6/7</sup> (1.6)	36 <sup>3/7</sup> (0.6)	.08
Weight at test, g <sup>a</sup>	2565 (615)	2565 (577)	.71

<sup>a</sup> Denotes effect estimate reported in median with SE reported via interquartile range.  
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Passed  
\*More immature  
\*Lower BW  
\*Chronologically older

Davis NL, et al. *Pediatrics*. 2013

## Risk Factors for Failure in Preterms

- **Passed**
  - Smaller birth weights
  - Younger birth GA/more premature
  - Older chronologic ages at the time of testing
  - More evidence of critical illness
    - Required caffeine for apnea of prematurity
    - Required some form of respiratory support during their hospitalization
- **Failed**
  - Larger birth weights
  - Older birth GA/less premature
  - Younger chronologic ages at the time of testing

## Incidence of CSTS Failure

- Overall failure rate of 4.3%
  - 2.4% in infants born early preterm <34 weeks GA
  - 5.6% in late preterm born 34<sup>+0/7</sup> – 36<sup>+6/7</sup> weeks GA
- Although only 60% of our study population were late preterm, this group accounted for 78% of failures ( $p=0.019$ )
- 62% of failures came from Newborn Nursery
  - 35% required admission to NICU (mean 7 days)

## Higher Failure Rate in “Healthy” Late Preterm Infants

- **Chronologic age and level of maturity at the time of testing**
  - Intermittent hypoxic events a function of maturation
  - Decreasing events with increasing chronologic age
- **Timing and duration of cardiopulmonary monitoring**
  - Early preterm infants admitted to NICU and monitored
  - Late preterm infants admitted to NBN and not monitored
    - Identified based solely on the requirement for a screening CST, not due to noted respiratory distress

### Factors associated with car seat test failure in late preterm infants: A retrospective chart review

- >300 late preterm infants (34 – 36+6/7 weeks)
  - Failure = 2 desaturations <88% for >10 sec
  - 26% (n=80) failed
    - 15% failure in NICU patients
    - 28% failure in well baby nursery patients
      - Over 50% admitted to the NICU
- Those who passed had older postnatal ages (chronologically older)

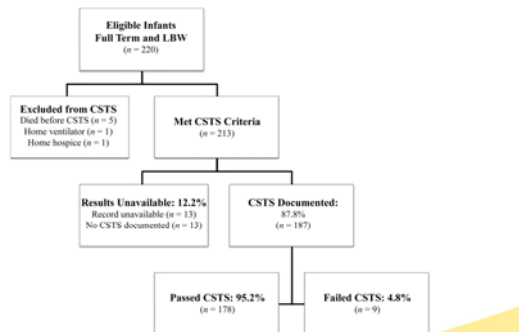
Smith et al. Paediatr Child Health. 2016

### Who should we test? What's the data?

- Premature birth (<37 weeks)
- **Low Birth Weight**
- Cardiac patients
- Low tone (hypotonia)
- Airway anomalies (PRS)
- Oxygen requirement



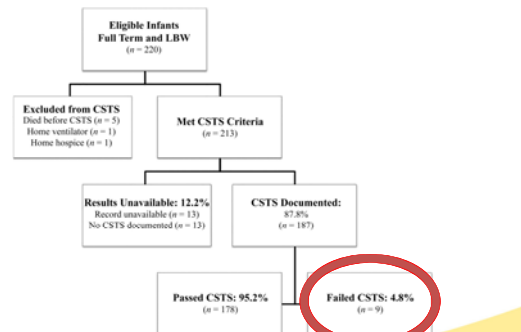
### Car Seat Screening for Low Birth Weight Term Neonates



Davis NL. Pediatrics 2015;136:89-96  
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PEDIATRICS

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### Car Seat Screening for Low Birth Weight Term Neonates

- 78% (n=7) failed due to desaturations
  - 1 diagnosed with Prader Willi Syndrome
- 22% (n=2) failed due to bradycardia
  - 1 diagnosed with Long QT Syndrome, follow up outpatient with Cardiology
- Notation of passing after blanket rolls added for stability and strap adjustments

Davis NL, Pediatrics, 2015

### Car Seat Screening for Low Birth Weight Term Neonates

- The only factor found to be statistically significant was maternal toxicology results for opiates.
  - Of those who failed, 22.2% (n = 2 of 9) had mothers who tested positive for opiates
  - Compared with 5.6% (n = 10 of 178) of those who passed (p=0.047)
- Does this mean we add opiate exposed infants to the testing criteria?

Davis NL, Pediatrics, 2015

**Who should we test? What's the data?**

- Premature birth (<37 weeks)
- Low Birth Weight
- **Cardiac patients**
- Low tone (hypotonia)
- Airway anomalies (PRS)
- Oxygen requirement



**Prehospital Discharge Car Safety Seat Testing of Infants After Congenital Heart Surgery**

- 66 post-operative babies with variety of cardiac diagnoses
  - 2 born <37 weeks – neither failed
  - 4 failed Car Seat Test (6%)
    - No relationship between type of surgery, duration of mechanical ventilation, age at discharge between those who did and did not fail.
    - No specific neurologic issue in any of the 4 who failed.

Simsic et al. *Pediatr Cardiology* 2008.

**Who should we test? What's the data?**

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**Who should we test? What's the data?**

- Premature birth (<37 weeks)
- Low Birth Weight
- Cardiac patients
- **Low tone (hypotonia)**
- **Airway anomalies (PRS)**
- **Oxygen requirement**
- No data!!!



**When?**

What to do when a baby fails?

**Why do they fail?**

- Likely multifactorial
  - Lung immaturity/inflammation
    - Low reserve, small lung capacity
  - Low tone and strength
    - Floppy, easily malpositioned, unable to correct neck flexion
    - Straps compress the chest
  - Small size
    - Poor fit in car seat - neck flexed/occlude airway
    - Straps hit incorrectly
  - Neurologic immaturity and increased risk of apnea
    - Poor response to low oxygen saturations



## Why do they fail?

- Willett, 1989
  - More frequent and severe desaturations, but...
  - IMPROVED pulmonary function, improved compliance, decreased resistance, stable tidal volume,
    - No PFT correlates with vital sign changes
- Carlo, 1989
  - Former preemies at 8-10 months of age had decreased pulmonary resistance, increased lung compliance and no change in minute ventilation in the semiupright position compared with supine.
  - Neck flexion significantly increased pulmonary resistance and decreased minute ventilation.
- Tonkin, 2003
  - Car Seat Inserts – neck in neutral position
  - Reduction in frequency of desaturation events
- McIntosh, 2013
  - Inserts reduced obstructive events and severe (<85%) desaturations
  - Did not affect overall rate of moderate desaturations

## Why do they fail?

- Hertz, 1994:
  - Polysomnography (PSG) on preterms while in car seat
  - Presence of  $\geq 1$  abnormal event (apnea, desaturation, bradycardia, periodic breathing) more frequent in car seat vs. prone
  - MORE periodic breathing noted in car seat
  - Periodic breathing related to sleep-state, more common during active sleep regardless of position.
- Arya, 2016
  - Is the Infant Car Seat Challenge Useful? A Pilot Study in a Simulated Moving Vehicle
  - Compared to baseline, # of desaturations increased in car seat
  - During motion, HR and RR increased and saturation decreased, which were not identified in standard car seat challenge
  - More adverse cardiorespiratory events in simulated motion than were identified in a static challenge → questions whether CST is useful?

## What does CST failure mean?

- ?????
- Failed CST
  - No studies on long term outcomes in infants that fail CST
  - Marker of immaturity? Need for closer monitoring?
    - Increased incidence SIDS in upright position? Related?
- What does a “Pass” mean for that matter?

## Test-Retest Reliability of CST

- Most NICUs/nurseries perform one CST on their preterm neonates (within 24-48 hours of anticipated discharge)
  - **Fail - the next step in evaluation varies between units**
    - Prolonged admission and retesting in car seat
    - NICU admission for a period of monitored observation
    - Retest in car bed
  - **Pass - discharged in an approved car safety seat**
- Unclear what an isolated failure or passage of the CST means for the safety of the neonate
  - Does a passed CST mean safety?

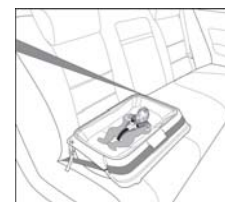
## Test-Retest Reliability of CST

- DeGrazia M, 2007
  - Performed 2 CSTs on each subject
  - 8% of subjects passed a 1<sup>st</sup> CST and failed their 2<sup>nd</sup>
- Davis NL, 2014
  - Performed 3 CSTs on each subject 24-48hrs apart
  - 11% passed an initial CST and failed one subsequent test
- Similar findings:
  - ~90% of those who pass one test will go on to pass future CSTs, but...
  - ~10% will pass a CST but go on to fail!

DeGrazia M. J Obstet Gynecol Neonatal Nurs. 2007  
Davis NL, Gregory ML, Rhein L. J Perinatal. 2014

## Failed Car Seat Tolerance Test

- Retest in car seat after a period of observation
  - 1 hour
  - 6 hours
  - 12 hours
  - 24 hours
- Test in car bed and d/c in car bed
- Admit for further work up

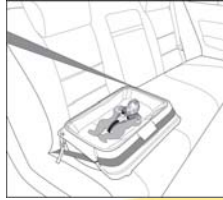


[http://injuryresearch.chop.edu/sites/default/files/car\\_bed.jpg](http://injuryresearch.chop.edu/sites/default/files/car_bed.jpg)



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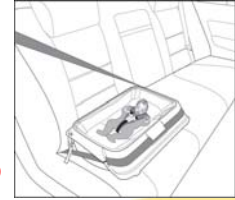
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## Clinical Outcomes Associated with Failed Infant Car Seat Challenge

- Prentice Women's Hospital, Northwestern U, Chicago
- Infants from Newborn Nursery who failed CSTS are routinely admitted to NICU for 24-48hrs of continuous monitoring
  - <=85% for >10 seconds
  - Apnea >20 seconds
  - Bradycardia with HR<80 for >10 seconds
- 2009-2015, n=148 failed
  - Desaturation (59%)
  - Bradycardia (37%)
  - Tachpnea (4%)

Shah MD et al. *J Pediatrics*, 2016

## Clinical Outcomes Associated with Failed Infant Car Seat Challenge

- **39% of infants admitted were identified to have apnea**
  - 48% of preterms
  - 17% low birth weight terms
- 2% NG feeds
- 5% IV fluid support
- 7% temperature support
- 10% antibiotic treatment
- 12% hypoglycemia
- 19% phototherapy
- 25% no comorbid conditions

Shah MD et al. *J Pediatrics*, 2016

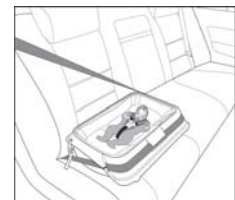
## Long Term Follow up of Failed CSTS

- Case-Control Study (2013)
  - 1 Failed initial CSTS: 2 Passed
- Matched
  - Birth Gestational Age (within 1 week)
  - Birth Weight (within 100g)
  - Sex
- 19 subjects failed: 37 controls
  - 3 subjects with sleep study documenting apnea and desaturations – home on monitor and oxygen (~16%)

Sharma P, Davis NL. Prelim Data 2017

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## Safety: Car Seat vs. Car Bed

- 150 VLBW babies born <37 weeks gestation
- Cross over study, each tested in car bed and car seat
- Randomly assigned to one, then retested in the other mode

Car Seat	Car Bed
15% had an event	19% had an event
One needed test stopped	One needed test stopped
Time to first event: 55 minutes	Time to first event: 54 minutes

**28% had an event in BOTH**  
**Same number had events after 60 minutes and 90 minutes**  
**Same number needed nursing intervention**

Salhab WA, et al. *J Peds* 2007



## How?

How should we counsel families?

## Best Practice for CST



- Discuss the test with the family and the reasons for performing it BEFORE testing
  - Performed on premature babies and babies with other issues that put them at risk of breathing problems
  - Goal is to make sure their breathing is safe in that position before they go home
  - How long is their car ride home?
- Bring in car seat well before anticipated discharge
  - NICU: 2-3 days before discharge
  - Full term nursery: bring in as soon as they can
  - Assess for safety of the seat, appropriate sizing

## Best Practice for CST



- Test can be done any time of night or day, but make sure parents are aware
  - Demonstrate proper positioning
- Perform a “realistic” CST – recreate what will be happening at home
  - Use family’s actual car seat
  - Perform within 30 minutes of a feed
  - Ok to use pacifier if the family will be using this at home

## Suggested Failure Criteria



- Apnea >20 seconds
- Heart Rate <80 beats per minute for >10 seconds
- Saturation <90% for >10 seconds
- Respiratory distress not improved with proper positioning

## Failed CST



- Assess for fit of infant in car seat, appropriateness of positioning
- Update family
- Perform repeat CST  $\geq$  12-24 hours from failed test
  - Time to recover
  - Additional day of respiratory maturity and improved tone
- Fail a 2<sup>nd</sup> CST:
  - Discuss with family
  - Consider subspecialty consult (NICU, pulmonology, cardiology)
  - Test in a car bed
    - PASS: discharge in car bed
      - Follow-up at 44 weeks corrected or one month of age
    - FAIL: recommend medical evaluation
      - Rule out respiratory, neurologic, cardiac etiology

## Failed CST – follow up

- Car beds
  - Attempt to avoid car beds
  - If they cannot safely be discharged in a car seat, you must perform Car Bed Tolerance Screen to assess respiratory status
- Follow up:
  - Does your hospital or local hospital offer repeat CSTS?
  - Does the PMD office offer repeat CSTS?
  - Consider pediatric pulmonary referral for advice on repeat testing
  - Ideally secure a location for retesting by 44 weeks CGA or 1mo of age, whichever is later.



## Counseling Families

- Minimize time in the car seat or semi-upright position
  - Left sleeping in car seat
  - Bouncy chairs
  - Slings
- Close observation while in the car seat
  - Try to take breaks during long periods of travel to allow infant to lay flat



## Where?

Where is future research headed?

## Future Directions

- Using recorded oximetry to identify whether respiratory immaturity can predict CST result
- Long term follow-up of infants with an initial failure of CST
- Identifying appropriate timing/location of follow-up CSTs for those discharged in car beds
- Brain perfusion in semi-upright position
- Moving vehicle simulation



## Thank you!

Questions?