



# Enhancing Bed Safety: An Innovative Interactive Bed Railing System

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## Motivation

Modern maternity wards allow for parents and newborns to interact more frequently rather than separating newborns in nurseries [1]. This change allows for greater parent-child bonding and breastfeeding which greatly benefits infant health [2]. This change does increase infant fall risk which are a major concern for both hospital staff and patients. Infant falls are classified as a newborn slipping or falling from a caregiver [3]. These can lead to serious injury and possibly death. Infant falls risk factors include cesarean birth, breastfeeding, and pain medication consumption [4]. Infant falls typically occur around the second or third postpartum night. Bassinets and Joey pouches have been implemented, but these devices and current bed rail height were not successful in mitigating infant falls. To prevent further infant falls, Parkview has requested a device to prevent infant falls and mitigate infant harm should an infant fall still occur.



Figure 1. Bassinet [5]



Figure 2. Joey Pouch [6]



Figure 3. Current Railing [7]

## Customer Expectations

Table 1. Customer Expectations and Requirements

Requirements / Constraints	Description	Significance
Safe-Sleep Guideline Compliance	Device must follow safe sleep guidelines set by Parkview to protect infants.	Essential
Does not interfere with workflow	Device must not interfere with activities performed by nurses or other Parkview staff.	Important
Able to be cleaned and sanitized	Device must be cleaned and sanitized to protect infants from pathogens	Important
Reusable	Device must be able to be reused multiple times so multiple infants can be protected	Essential
Optimizing space efficiency	Device must not impede workflow and must allow bed to function properly when installed	Critical
Creates alertness environment	Device will create an environment of alertness to prevent infant falls from occurring in the first place	Essential
Prevent infant falls	Device must be able to prevent infant falls and protect an infant should a fall still occur	Essential
Bilingual voice commands	Device must be able to communicate instructions to mothers in English and Spanish.	Desirable
Device must be affordable	Device must be under budget given by Parkview	Essential

## Validation

Mathematical model was created to calculate necessary forces and testing values. Device was further validated by performing two tests: tensile and drop testing. Tensile testing was performed on net material to determine if material met necessary device requirements. Tensile testing followed ASTM Standard D5034-21 [8]. Instron machine was calibrated, and 30 samples were tested in each direction to ensure statistical significance. Drop testing was performed to simulate an infant fall, which would ensure that device meets necessary safety requirements and fulfills project objectives made when project was assigned. This test was performed to validate the strength of the PLA rail and ensure that the strain gauge portion of the electrical system is functioning as intended.

## Design Components

### Railing System

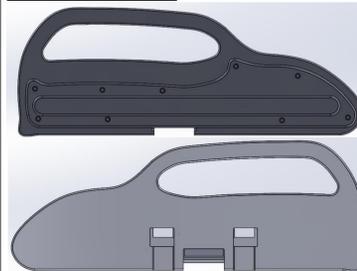


Figure 4. Railing System CAD

Length: 33.14 in.  
Width: 1.02 in.  
Height: 12.39 in.

Electrical system is housed within railing system and is covered by the railing lid. Railing and lid designs were inspired by current railing and lid system utilized at Parkview. Polylactic acid (PLA) was used to fabricate railing and lid via 3-D printing due to its high tensile and impact strength and high precision.

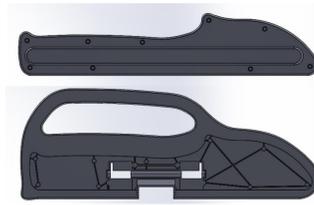


Figure 5. Railing and Lid CAD

Length: 32.08 in.  
Width: 0.45 in.  
Height: 6.64 in.

### Net System

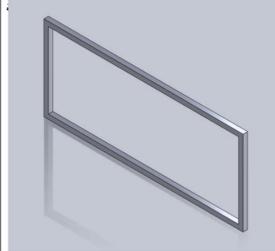


Figure 6. Net Frame CAD

Length: 33.00 in.  
Width: 0.75 in.  
Height: 14.00 in.  
Thickness: 0.12 in.

Net system was attached to railing system via net attachments and will rest on hinges attached to railing. Net frame would be set at an angle of 70° when opened. Square aluminum tubes were selected for the railing due to reduced parts and increased stability and were welded together. FEA analysis was performed on net frame to analyze displacement, stress, and strain when force is applied due to infant fall. Net frame had a maximum displacement of 1.155 mm, maximum stress of 1.544 \* 10<sup>7</sup> Pa, and had a maximum strain of 1.605 \* 10<sup>-4</sup>.

### Electrical System

Electrical system includes an Arduino command module, strain gauge sensor, and speech synthesis module. Strain gauge sensor detects whether an infant fall has occurred and sends out an audible alert. Speech synthesis module interacts with mothers to provide an environment of alertness and prevent infant falls from occurring. Electrical system is powered by USB cable to power supply.

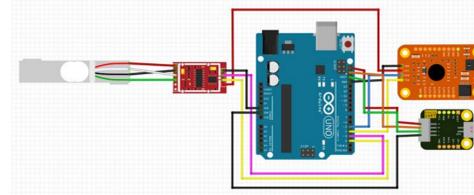


Figure 7. Electrical System Diagram

### Padding System

Padding was incorporated within device to protect infant from harm due to directly impacting net frame or railing. High resilience foam was utilized as it offered enhanced protection and comfort compared to polyurethane. Pleather fabric covers were used since fabric can be easily sterilized and is more aesthetically pleasing. Padding is incorporated on net frame segments, railing lid, and covers hinges.



Figure 8. Railing Padding CAD

Length: 31.55 in. Width: 1.00 in. Height: 6.64 in.



Figure 9. Hinge Padding CAD

Length: 28.49 in. Diameter: 1.00 in



Figure 10. Net Frame 33 in. Padding CAD

Length: 30.24 in. Diameter: 1.75 in.



Figure 11. Net Frame 14 in. Padding CAD

Length: 14.00 in. Diameter: 1.75 in.

## Testing



Figure 12. Tensile Testing Setup

### Net Material Testing

Standard gave required testing specifications for net fabric tensile testing. Statistical analysis was performed by employing a one-tailed two-sample z-test with a p-value of 1 \* 10<sup>-6</sup> and 95% confidence interval.

Table 2. Tensile Testing Results

	Horizontal (psi)	Vertical (psi)
Mean	138.6075	45.4118
Standard Deviation	5.1686	1.5141
n	30	30

### Drop Testing

To pass the drop test, the device had to catch the infant without sustaining any mechanical failures, and strain gauge sensor must successfully detect and emit an alarm when infant fall occurs. Device passed drop testing for all fifteen trials.



Figure 13. Drop Testing Setup

## Conclusion

Table 3. Completed Requirements

Requirements / Constraints	Completed
Safe-Sleep Guideline Compliance	✓
Does not interfere with workflow	✓
Able to be cleaned and sanitized	✓
Reusable	✓
Optimizing space efficiency	✓
Creates alertness environment	✓
Prevent infant falls	✓
Bilingual voice commands	✗
Device must be affordable	✓

## References

- [1] P. P. S. Authority, "Balancing Family Bonding with Newborn Safety | Advisory," Pennsylvania Patient Safety Authority, vol. 11, no. 3, 2014, Accessed Oct. 06, 2023. [Online]. Available: [http://patientsafety.pa.gov/ADVISORIES/Pages/201409\\_102.aspx](http://patientsafety.pa.gov/ADVISORIES/Pages/201409_102.aspx)
- [2] M. Allen and K. Bilger, "Balancing Newborn Safety in a Baby-Friendly Environment," Journal of Obstetric, Gynecologic & Neonatal Nursing, vol. 46, no. 3, Jun. 2017, doi: <https://doi.org/10.1016/j.jogn.2017.04.055>.
- [3] R. M. Ainsworth, S. Summerlin-Long, and C. Mog, "A Comprehensive Initiative to Prevent Falls Among Newborns," Nursing for Women's Health, vol. 20, no. 3, pp. 247-257, Jun. 2016, doi: <https://doi.org/10.1016/j.nwh.2016.04.025>.
- [4] "Preventing Newborn Falls and Drops," Joint Commission, Mar. 2018. [https://www.jointcommission.org/media/newsletters/quick\\_safety\\_issue\\_40\\_2018\\_newborn\\_falls\\_drop.pdf?webid=8A91597BE19908F84BD4EA5261F3B48B](https://www.jointcommission.org/media/newsletters/quick_safety_issue_40_2018_newborn_falls_drop.pdf?webid=8A91597BE19908F84BD4EA5261F3B48B)
- [5] Halosleep.com, 2022. <https://www.halosleep.com/bassinets-swivel-sleeper-3-0-4792>
- [6] "Buy Now Joey Wrap Online | Joey Wrap," Wanderling, [https://wanderling.us/products/joey-wrap?variant=32263282202102&v=USD&utm\\_medium=product\\_sync&utm\\_source=google&utm\\_content=sag\\_organic&utm\\_campaign=sag\\_organic&utm\\_id=2052715722&adg\\_id=4&ad=4&device=c&gclid=EA1BQACMBR00kIdEgMvqgBh6t5uAwkAKYAAdEgJh0D\\_BwE](https://wanderling.us/products/joey-wrap?variant=32263282202102&v=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&utm_id=2052715722&adg_id=4&ad=4&device=c&gclid=EA1BQACMBR00kIdEgMvqgBh6t5uAwkAKYAAdEgJh0D_BwE) (accessed Nov. 14, 2023).
- [7] 4MD Medical, "Versicare Hospital Bed Refurbished," 4MD Medical. [https://4mdmedical.com/products/versicare-hospital-bed-refurbished?\\_\\_store=default&variant=44506155385141](https://4mdmedical.com/products/versicare-hospital-bed-refurbished?__store=default&variant=44506155385141) (accessed Apr. 21, 2024).
- [8] Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test). ASTM, 2021. Available: <https://compass.astm.org/document/?contentCode=ASTM%7CD5034-21%7Cen-US&proxyCl=https%3A%2F%2Fsecure.astm.org&fromLogin=true>

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