Delft University of Technology

Document Version
Final published version

Licence
CC BY

Citation (APA)
Pigmans, R. R. W. P., Klein-Blommert, R., Huysmans, T., Dijkman, C. D., & Bem, R. A. (2026). A Personalized, 3-Dimensionally Printed, Oronasal Noninvasive Ventilation Mask for an Infant with Acute Respiratory Failure: Noninvasive ventilation (NIV) is a first-line treatment for acute respiratory failure in the intensive care unit (ICU), but interface selection poses a major challenge.1 Commercial masks are not well adapted to the wide variety of facial dimensions of young children, resulting frequently in large, unintended air leakage, skin-pressure injuries, patient-ventilator asynchrony, and discomfort.1 As such, mask fit is a potentially modifiable factor to increase NIV treatment success in pediatric acute respiratory failure, underscoring the need for personalized strategies. *Journal of Pediatrics*, *293*, Article 115059. https://doi.org/10.1016/j.jpeds.2026.115059

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
In case the licence states “Dutch Copyright Act (Article 25fa)”, this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

Sharing and reuse
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.

A Personalized, 3-Dimensionally Printed, Oronasal Noninvasive Ventilation Mask for an Infant with Acute Respiratory Failure

Noninvasive ventilation (NIV) is a first-line treatment for acute respiratory failure in the intensive care unit (ICU), but interface selection poses a major challenge.[1] Commercial masks are not well adapted to the wide variety of facial dimensions of young children, resulting frequently in large, unintended air leakage, skin-pressure injuries, patient-ventilator asynchrony, and discomfort.[1] As such, mask fit is a potentially modifiable factor to increase NIV treatment success in pediatric acute respiratory failure, underscoring the need for personalized strategies.

We report a 3-week-old infant (3400 g) who experienced acute respiratory failure after extubation in our ICU. The patient had been treated with invasive mechanical ventilation for respiratory syncytial virus bronchiolitis complicated by methicillin-resistant *Staphylococcus aureus* septic shock and pneumothorax. This disease episode occurred 1 day before scheduled immunization with anti-respiratory syncytial virus monoclonal antibodies (nirsevimab). After extubation, complete right lung atelectasis (**Figure**, A) necessitated NIV to prevent reintubation. However, commercial oronasal NIV masks in various sizes, including a simple anesthetic mask placed in a holder as previously developed and described,[2] were found to be grossly inappropriate for this small infant. The only available total face mask by which NIV could be delivered was associated with major skin pressure injuries (**Figure**, B), requiring rotation with an alternative interface.

To optimize patient-mask fitting during NIV, we have established an in-house process for the development of personalized masks with a fully 3-dimensional (3D) printable, modular design, shown in **Figure**, C and D. This mask exists of a size-based frame, in which a personalized, soft cushion is placed and secured with a frame ring, as described previously during bench and simulation testing.[3] Given intended use in an acute clinical setting as the ICU, we developed a semiautomated workflow incorporating rapid (<30 seconds) handheld 3D scanning, a 3D modeling software plugin for generating patient-specific cushions, and a 3D printing station for production of all materials used (approved by the local medical device regulation committee for in-house production and all mask materials comply with ISO-10993 and ISO-18562). Using this novel workflow, we 3D-printed a personalized oronasal NIV mask for this infant within 6 hours after scanning. The patient was supported by NIV with a Hamilton C5 ventilator set on mode NIV spontaneous/timed, with positive end-expiratory pressure of 8 cm H_2O and peak inspiratory pressure of 20 cm H_2O. Mean air leak was 25% (0.5 L/min) using the personalized mask and 43% (2.1 L/min) using the total face. The patient was successfully weaned from NIV in the subsequent days, alternating both masks per local protocol. We want to share this original use of a fully 3D-printed oronasal NIV mask for personalized support in an acute pediatric critical care setting. ■

CRediT authorship contribution statement

Rosemijne R.W.P. Pigmans: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Rozalinde Klein-Blommert:** Data curation, Writing – review & editing. **Toon Huysmans:** Conceptualization, Writing – review & editing. **Coen D. Dijkman:** Conceptualization, Writing – review & editing. **Reinout A. Bem:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The research for the development of the personalized mask is funded by the Innovation Award Amsterdam UMC, the Emma Children's Hospital Foundation, the Cornelia Foundation, Vermas Foundation, and NWO (Grant ID https://doi.org/10.61686/XFSHL93482). The authors have nothing to declare.

We thank Robert Clemons and Hendric Drobinoha from Loctite 3D printing for their help to achieve a safe and biocompatible production process. We also thank Frank Schoenmaker from nSize for his help in the plugin development and ongoing will to improve our masks. Lastly, we thank the parents for their consent for data collection and publication.

Rosemijne R.W.P. Pigmans, MSc
Pediatric Intensive Care Unit, Emma Children's Hospital, Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands
Amsterdam Reproduction and Development Research Institute, Amsterdam, The Netherlands

Rozalinde Klein-Blommert, MSc
Pediatric Intensive Care Unit, Emma Children's Hospital, Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands

J Pediatr 2026;293:115059.
0022-3476/© 2026 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
https://doi.org/10.1016/j.jpeds.2026.115059

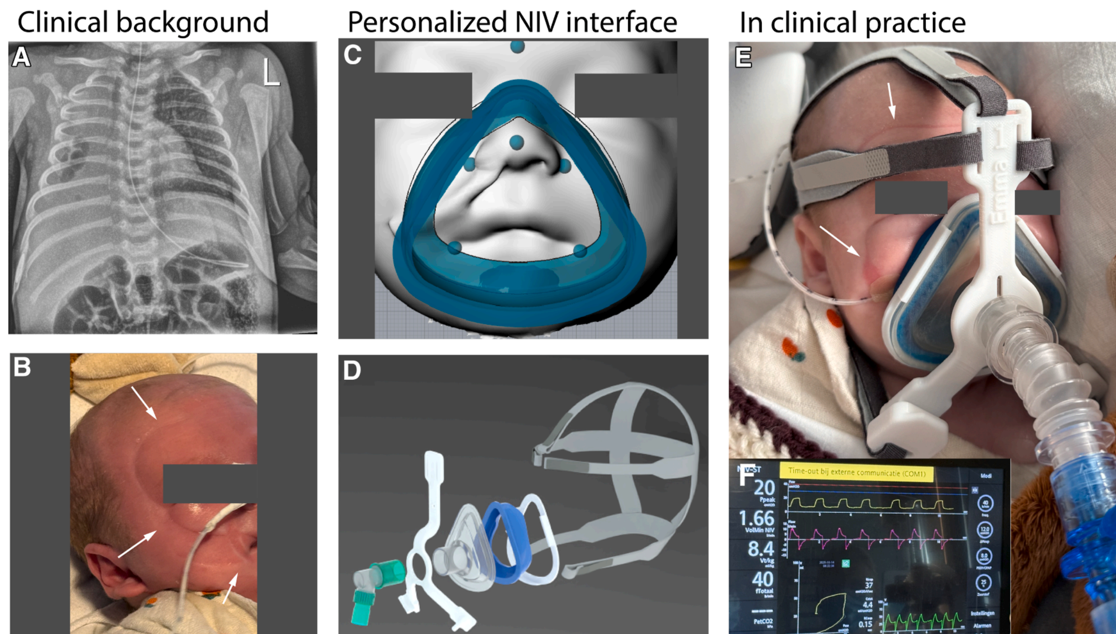

Figure. **A,** Radiograph of the chest showing complete right lung atelectasis and pneumatocele 1 day after extubation after a complicated course of invasive mechanical ventilation. **B,** Example of skin-pressure injuries (*arrows*) resulting from tightening a commercial total face mask to minimize air leaks during NIV. **C,** 3D-modeling of a personalized cushion for an oronasal NIV mask using semiautomated software (Rhinoceros plugin; nSize). **D,** A rendering of the fully 3D printed personalized oronasal NIV mask, which consists of a size-based mask with a frame (material: MED 9851; Henkel), frame ring, and holder (material: PC-ISO; Stratasys). The mask holder is attached to commercial headgear (Respireo SOFT from Air Liquide Healthcare) and placed around the mask to secure the mask to the face. In this size-based mask, a personalized, soft cushion is placed (material: MED 414; Henkel). **E,** A photograph, obtained with permission, of NIV treatment using the personalized oronasal NIV mask in the infant with postextubation acute respiratory failure. *Arrows* depict the skin-pressure injuries from the commercial total face mask that are still visible from its previous use. **F,** The ventilator mode was set on NIV Spontaneous/Timed, with positive end-expiratory pressure of 8 cmH_2O and peak inspiratory pressure of 20 cmH_2O.

Toon Huysmans, PhD
Faculty of Industrial Design Engineering, Delft University of Technology, Delft, The Netherlands

Coen D. Dijkman, MSc
Department MedTech Prototyping and Development, Amsterdam UMC, Amsterdam, The Netherlands

Reinout A. Bem, MD, PhD
Pediatric Intensive Care Unit, Emma Children's Hospital, Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands
Amsterdam Reproduction and Development Research Institute, Amsterdam, The Netherlands

References

1. Mortamet G, Amaddeo A, Essouri S, Renolleau S, Emeriaud G, Fauroux B. Interfaces for noninvasive ventilation in the acute setting in children. Paediatr Respir Rev 2017;23:84-8. https://doi.org/10.1016/j.prrv.2016.09.004
2. Muller GJ, Hovenier R, Spijker J, Van Gestel M, Klein-Blommert R, Markhorst D, et al. Non-invasive ventilation for pediatric hypoxic acute respiratory failure using a simple anesthetic mask with 3D printed adaptor: a case report. Front Pediatr 2021;9:710829. https://doi.org/10.3389/fped.2021.710829
3. Pigmans RRWP, Klein-Blommert R, Van Gestel MC, Markhorst DG, Hammond P, Boomsma P, et al. Development of personalized non-invasive ventilation masks for critically ill children: a bench study. Intensive Care Med Exp 2024;12:12. https://doi.org/10.1186/s40635-024-00607-w