Towards Greener ICUs: Redesigning the Use of Disposable Gloves

Lisanne van den Berg, Armağan Albayrak, Nicole Hunfeld, and Jan Carel Diehl

Abstract This research and design project is part of the Green ICU initiative and focused on reducing the environmental impact of gloves at the Intensive Care Unit (ICU) of the Erasmus Medical Center (EMC). At the ICU of the EMC around 108 gloves are used per patient per day; to protect the user (healthcare staff) from infections. The high frequency of use and the resource-intensive production define disposable nitrile gloves as one of the 'hotspots' contributing to the environmental impact created by the ICU. This research and design project addressed the problem from three different perspectives: user-centred, product-centred and supply-centred. The extensive research resulted in three design directions on how to reduce the environmental impact of gloves. Subsequently, all insights from the research were brought together into five design building blocks. These design building blocks provided guidance for the design phase of the project. The project resulted in a redesign of the current glove dispensers. The final design is named 'GloVe', a vertical dispense system. By incorporating the five building blocks, the design can provide benefits for multiple stakeholders within the healthcare system. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are dispensed at the cuff, which comes in little contact with the patient. The vertical movement is pleasant to the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. Also, nurses will see at a glance, which size gloves they are dispensing. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible.

Keywords Design for sustainability · Gloves · User-centred · Medisign · Infection prevention · Intensive care unit

L. van den Berg (✉) · A. Albayrak · J. C. Diehl
Delft University of Technology, Delft, The Netherlands

N. Hunfeld
Erasmus Medical Center, Rotterdam, The Netherlands

M. Melles et al. (eds.), *Convergence: Breaking Down Barriers Between Disciplines*, Springer Series in Design and Innovation 30,
https://doi.org/10.1007/978-3-031-32198-6_20

1 Background

The healthcare sector provides us access to high-quality care but is also responsible for a severe environmental impact. Currently, the healthcare sector is one of the most carbon-intensive sectors, contributing to 4.4% of global net greenhouse gas emissions and toxic air pollutants (Karliner et al. 2020). In the Netherlands, even 7% of the national footprint is associated with the healthcare sector (De Bruin et al. 2019). The complexity and intensity of care make the ICU one of the most resource-intensive departments of the hospital. Products such as syringes, liquid solutions, dressings, catheters, and personal protective equipment are used in fast quantities to treat patients and save lives (Browne-Wilkinson et al. 2021).

Disposable gloves are used as Personal Protective Equipment (PPE); to protect the user from contamination and radiation and are used for nonsterile activities. The high frequency of use, around 108 gloves per patient per day, and resource-intensive production identified disposable gloves as one of the five hotspots contributing to the negative environmental impact created by the ICU (Browne-Wilkinson et al. 2021). The aggregated weight makes up more than 12% of disposable medical devices' ICU weight. Furthermore, nitrile is highlighted as the material with the highest impact intensity, in the single-use medical devices category, in terms of carbon footprint (9.3 kg CO2-eq/kg nitrile) and water usage (0.5 m^3 water/kg nitrile) (Browne-Wilkinson et al. 2021). Therefore, the main question to be answered during this project was: *How could the environmental impact of gloves in the ICU be reduced, while remaining quality of care?*

2 Methodology

A design thinking process as visualized in Fig. 1 was followed to answer this question. The project has a non-linear approach and the steps contribute to each other.

Research is executed from three different perspectives: a user perspective, a product perspective and a supply chain perspective.

2.1 User-Centred Research

User observation. The observation aimed to understand and interpret the behaviour of the ICU staff during their work shift. The ICU context was entered without certain expectations. To execute the observation, the role of "participant as an observer" was taken on (Mulhall 2003).

Participant as observer. This role was taken on when following one of the ICU nurses for a complete work shift. The focus was on applying hand hygiene and using/

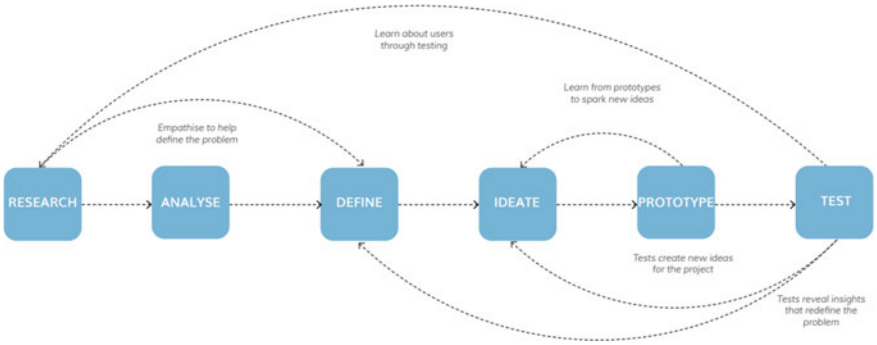

Fig. 1 Adapted model of the design thinking approach (*Source* Interaction Design Foundation Baeck and Gremett 2012)

changing and disposing of the gloves. The ICU nurse was asked to think out loud during her activities.

Product centred research. The goal of this observation was to follow the product through the Intensive Care Unit. For this observation another role was taken on;

Complete observer. This role was mainly adopted when sitting in the ward of the ICU on the fourth floor. It was observed how the different stakeholders distributed, used and disposed of the gloves and glove boxes. The routes were drawn on a floor plan. When an action or role was not clear it was asked after their activity.

Product analysis. The product was analyzed on variables. The dimensions of the box and opening were measured. To test the functionality of the product, gloves were taken out one by one.

2.2 Supply Centred Research

Expert interview. An experienced employee of the procurement team of the Erasmus MC was interviewed. A structured interview was used to answer questions about quantities and the market of gloves.

PICU waste observation. The previously obtained quantities from the Material Flow Analysis from Metabolic by Browne-Wilkinson, et al. (2021) at the ICU did not mention anything about the extent to which these gloves were used. The Paediatric Intensive Care UNIT (PICU) waste observation was done to map the waste created by this department. It was also used to define the ratio between used and unused products in the waste disposal.

3 Results

Product Analysis. The product analysis resulted in a photo series where the gloves were dispensed step by step (see Fig. 2) The gloves are packed so tightly and intertwined that it is almost impossible to remove one glove at a time.

Material Flow model. The Material Flow indicates how many gloves are used in the ICU compared to the bigger context, see Fig. 3. The number of gloves used in the ICU is relatively small compared to the worldwide production and distribution. Despite this, it can be seen that some of the gloves in the ICU are disposed unused. During the PICU waste observation, the number of unused gloves was determined to be 6% of the total used gloves. However, it was not possible to tell whether the gloves had been used properly, whether they had been used unnecessarily or whether they were overused.

3.1 Hospital Flow Model

The Hospital Flow model zooms in on two ICU rooms, see Fig. 4. The care assistant distributes the gloves in the ICU. The nurses and other medical staff use gloves. The care assistant will dispose of the gloves and waste workers collect the waste. The following problem situations do occur:

- The glove dispenser at the back corner is difficult to reach (position of dispenser).
- During care, a lot of unexpected materials are needed. The nurse should have bare hands when picking something from the storage on the counter. So, it is needed to take off the gloves (use protocols).
- The order of the sizes is not clear for every care assistant. Furthermore, it is difficult to read the size of the gloves on the box (not clear which size is in which box).

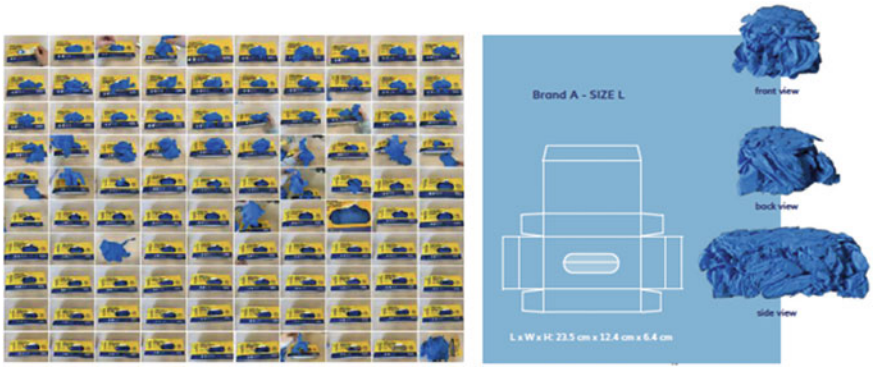

Fig. 2 Results of the glove box product analysis

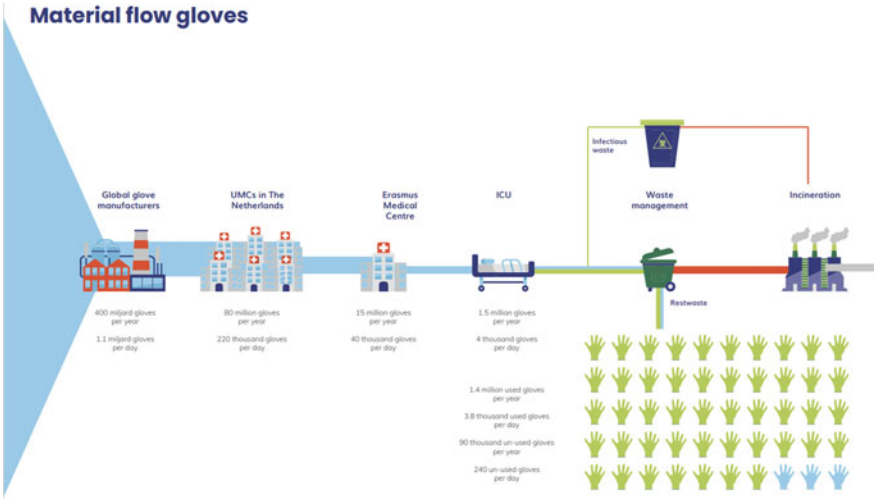

Fig. 3 Material flow model gloves

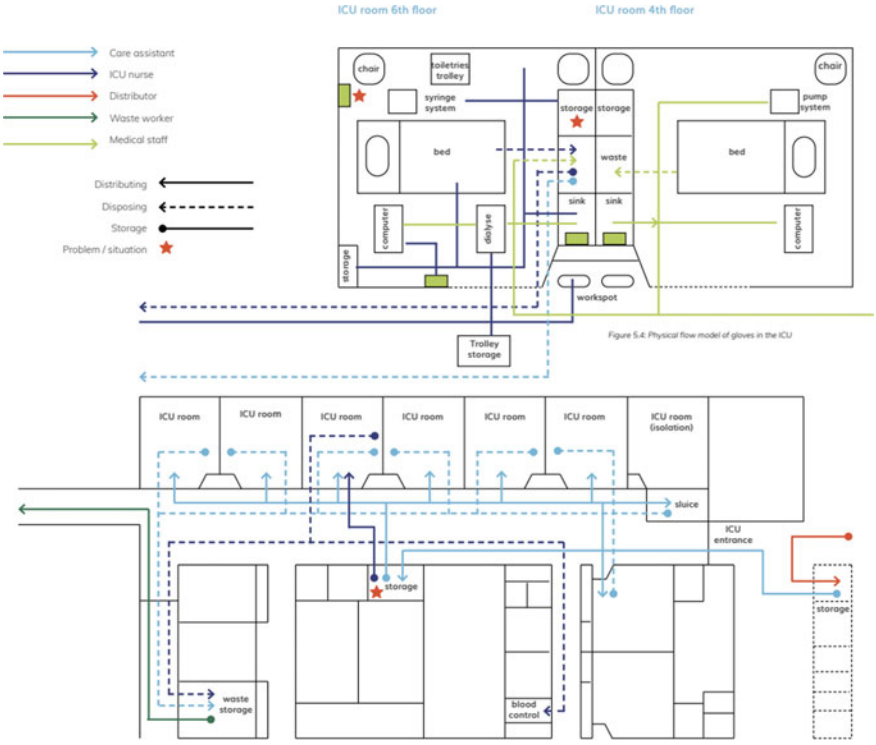

Fig. 4 Hospital Flow model gloves

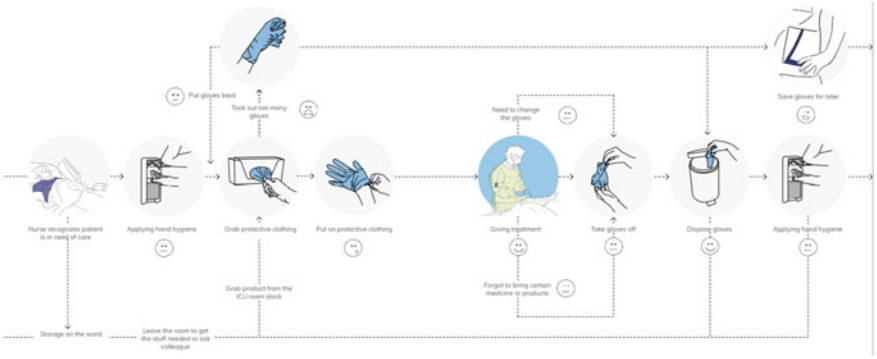

Fig. 5 User journey of ICU nurse using gloves

3.2 User Journey

The user journey illustrates the activities and tasks performed while interacting with the product, see Fig. 5.

The field research including observations and interviews gave an understanding of different perspectives and system levels. The main insights can be listed and divided into three design directions. The design directions are substantiated by the drivers.

1. Rethink the (unnecessary) use
2. Reduce the number of unused gloves
3. Reduce the number of glove changes.

In consultation with the ICU staff, it was decided to reduce the number of unused gloves in the design part of the project.

3.3 Building Blocks for Design

The different steps of the research and design process resulted in a better understanding of the problem. The sustainability impact of disposable gloves is a difficult problem. Various properties and factors are intertwined. Also, the stakeholders have different interests in a new design. Altogether, 12 main insights were listed, divided into five building blocks that should be incorporated into the new design.

3.4 Ease of Use

- **Sizes should be visible:** Both the ICU nurse and care assistants would like to see at a glance which size of gloves a box contains. Having difficulties reading the

size or placing the box into the wrong holder can result in dispensing the gloves in the wrong size.
- **Fixed place:** The glove boxes should have a fixed place. The order of the sizes must always be the same.
- **Ready to use:** When a glove comes out of the package, it should be ready to use right away. It should not be necessary to unfold the glove first.

3.5 Infection Prevention

- **Touch only one glove at a time:** Contamination of gloves can be prevented if only the glove that will be used is touched. Also, only one glove should be opened to the environment.
- **Dispense by the cuff:** The fingers and the middle part of the glove are mostly in contact with the patient. Therefore, it is preferred to dispense the gloves, by touching the cuff. The cuff is less in contact with the patient.
- **Prevent undesirable behaviour:** It is unwanted that gloves are pushed back into a package. The opening in the current glove boxes is big enough to place gloves back. Contamination of gloves can be reduced when this undesirable behaviour is prevented.
- **Cleanable:** Hygiene is an important topic in the ICU. The patients in the ICU often have a malfunctioning immune system and infections can be life-threatening. That is why the design must be cleanable.

3.6 Zero Risk

- **Procurement:** Because the functioning of the hospital is of vital importance, a zero-risk approach is applied in the hospital. This also applies to buying gloves. In the current high-demand market, it is not beneficial to be dependent on one supplier. This should certainly be included in the solution.

3.7 Technology

- **Manufacturing in Malaysia:** Gloves are currently produced in Malaysia. The factories are producing at full capacity. Setting up and or changing a glove factory is a big investment. It would be beneficial if the solution could be made in with the technologies available in the current factories.

3.8 *Efficiency*

- **Time;** Many gloves are used every day in the ICU. The design should not require more time from the users.
- **Quality:** Quality over quantity. Presenting gloves of good quality is important for the user. Also from a sustainable perspective, good quality gloves can reduce the number of gloves used. Bad quality gloves need to be changed more often or are overused.
- **Space:** The ICU boxes have limited space for a lot of equipment and supplies. The product must deal well with the available space.

3.9 *Final Design*

The final design is GloVe, a vertical dispense system. By incorporating the five building blocks, the design can provide benefits for multiple stakeholders. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are dispensed at the cuff, which comes in little contact with the patient. The vertical movement is pleasant to the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. Also, nurses will see at a glance, which size gloves they are dispensing. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible (Fig. 6).

Fig. 6 Final design GloVe

4 Discussion

This project was focused on the research phase of the design process. There was not much information available in the literature on sustainability-related issues of disposable gloves. Furthermore, there were no resources that combined information. Research with a broad scope was applied to investigate the problem from multiple perspectives and system levels. The research and prototyping phase revealed the complex and intertwining factors on the functioning of the product. The extensive research resulted in less time in the design phase. Having more time in the design phase or being closer to the manufacturing phase could have resulted in an even more detailed understanding of the physical factors influencing the functioning of the product; resistance, material properties etc. Furthermore, the scope of this project was to apply a product or system in the ICU in the short term. Since manufacturers are bound to the general shape of the product, this general shape was used as a basis for the design. Applying a completely different shape to the box can't be applied in the short term. But, letting go of the general shape of the box could have led to more inventive designs.

5 Conclusions

The main question to be answered during this project was: *How could the environmental impact of gloves in the ICU be reduced, while remaining quality of care?*

To answer this question, remote research was executed, fieldwork with different focuses was done, and concepts were developed into prototypes. The prototypes were evaluated with the ICU team. As the final step of the project, the GloVe dispensing system was designed.

The research on the existing state of the art of disposable gloves revealed paint points. The market for disposable gloves is a difficult one; only a few manufacturers are producing at maximum capacity for the high demand worldwide. Disposable gloves are produced in worrisome circumstances. More transparency on the production circumstances could influence the choice between alternatives.

The gloves are packed so tightly and intertwined that it is almost impossible to remove one glove at a time. Technologies to stack the gloves without intertwining are available. But, manufacturers are less likely to change the production process, due to the high demand on the market and the high investment costs.

The field research resulted in three design directions to reduce the environmental impact of the use of disposable gloves. Two out of three design directions are focused on human behaviour and protocols. ICU nurses need to do a lot of activities around the patient, which include the use of a lot of glove changes. Potentially, the number of glove changes can be decreased by changing the protocols. Furthermore, the research demonstrated that gloves are not always used as intended. Revising the protocols

and having sustainable alternatives for certain activities can decrease the number of gloves. Also, the field research showed that the product itself can be improved. The product dispenser does not function as desired and does not dispense the gloves one by one.

Because of an Integrated Product Design background, it was decided to reduce the number of unused gloves in the short term and focus on the glove box. The design building blocks provided a foundation for the design process. The concepts showed it is not possible to judge ideas based on just drawings. For this reason, prototyping and testing at the ICU with healthcare staff were used to evaluate the ideas. The prototyping and testing revealed even more complex factors behind the functioning of the product.

The final design is GloVe, a vertical dispensing system. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are touched at the non-critical part, at the cuff. The vertical dispensing movement is pleasant for the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible.

All in all, there is not one way to answer the main question. The research with different perspectives on the product of a disposable glove box revealed overall intertwined complexity. Answering the question and creating a solution is challenging, since the different stages of the product, production, purchasing and use, are so far apart and do influence each other. The research showed the importance of including the user (and other stakeholders) in the design- and procurement process.

The design project was not a linear process, but with this project, the complex problem could be defined better. Resulting in a concept design and a lot of recommendations to transform towards a greener ICU.

The final report of this research (Berg 2022) can be found at https://repository.tudelft.nl/islandora/object/uuid%3A1732b9db-6795-4990-ae56-c02fb6d7c81a?collection=education.

Acknowledgements We would like to thank Alicia Ville and Margot Honkoop for collaborating during the research. We would also like to extend thanks to the employees of the ICU team of the Erasmus MC for enabling visiting their offices and observe their daily operations. We would like to thank all experts of different departments of the Erasmus MC for providing us with the information needed, in particular Maarten Timmermann.

References

Baeck A, Gremett P (2012) Design thinking: expanding UX methods beyond designers. In: Degen H, Yuan X (eds) UX Best practices: how to achieve more impact with user experience. Osborne, New York, pp 229–250

Van den Berg L (2022) Reducing the environmental impact of gloves used in the intensive care unit: towards greener ICUs. MSc, Delft University of Technology, Delft

Browne-Wilkinson S, van Exter P, Bouwens J, Souder J, Chatel É (2021) Circulaire Intensive Care Unit. Metabolic

De Bruin J, Houwert T, Merkus K (2019) Een stuur voor de transitie naar duurzame gezondheidszorg. https://gupta-strategists.nl/storage/files/1920_Studie_Duurzame_Gezondheidszorg_DIGITAL_DEF.pdf

Karliner J, Slotterback S, Boyd R, Ashby B, Steele K, Wang J (2020) Health care's climate footprint: the health sector contribution and opportunities for action. Eur J Public Health 30(Supplement_5). https://doi.org/10.1093/eurpub/ckaa165.843

Mulhall A (2003) In the field: notes on observation in qualitative research. J Adv Nurs 41(3):306–313. https://doi.org/10.1046/j.1365-2648.2003.02514.x