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Reducing waste and improving provider safety: a retrospective analysis with lessons from the COVID-19 Pandemic

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SUMMARY

Background: Reducing waste is an important component in comprehensive efforts to create greener intensive care units (ICU). Personal protective equipment (PPE) constitutes a significant share of the waste produced during ICU care. During the COVID-19 pandemic, the availability and supply of PPE posed substantial challenges globally. We aimed to investigate the lessons learned from the use of PPE during the pandemic (regarding the reduction of PPE consumption) and impact on hospital-acquired infections in healthcare workers.

Methods: Conducting a retrospective analysis, we examined all newly issued standard operating procedures for the ICU related to the pandemic. We observed for a potential effect on the use of PPE and scrutinized PPE consumption and patient day data focusing on potential differences between 2020 and the following years until 2023. The primary objective was to evaluate the impact of the protocols and measures on PPE consumption.

Results: Our analysis revealed that the implementation of four key infection control measures (cohorting, limitation of visits, institutional protocols for PPE use, staff training) lead to a substantial reduction in the use of masks and isolation gowns during the initial stages of the COVID-19 pandemic with no recorded hospital-acquired infections among healthcare workers.

Conclusion: It is possible to reduce PPE consumption without compromising the safety of our healthcare professionals. Our observations may guide future policies to reduce PPE consumption with the intent of reducing the environmental impact.

Introduction

Personal protective equipment (PPE) is a significant contributor to the waste produced in intensive care units (ICUs) [1]. Items such as non-sterile gloves, surgical gowns, surgical masks and respirators are frequently used and often discarded after a single use, leading to substantial amounts of plastic waste. During the initial months of the COVID-19 pandemic, we observed a scarcity of PPE, leading to the implementation of new policies to improve provider safety and reduce PPE consumption. Our

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objective was to assess whether lessons can be drawn from this observation on how to conserve PPE without endangering medical staff. To this end, we analyzed PPE consumption per patient-day from 2020 to 2023 and retrospectively reviewed all procedural guidelines for PPE usage. In addition, we gathered data regarding hospital acquired healthcare worker infections during the initial year of the pandemic.

PPE, which includes gloves, gowns, masks, aprons, caps and face protection, represents the most used type of consumable in healthcare, significantly contributing to the total plastic waste [2]. Frequently used by ICU staff, PPE is designed to reduce the risk of the wearer acquiring infections and limit infection spread [3]. Typical PPEs are made of over 50% plastics, which can take up to 500 years to degrade [4]. When single-use PPE is discarded in the environment, it is fragmented by physical (wind, UV radiation, sea currents) and biochemical processes (enzymatic activity), resulting in microscopic particles such as microfibers and microplastics [5,6]. As microplastic and microfibers are nonbiodegradable in nature, they will exist in aquatic and terrestrial environments for an extended duration and will affect different biota, compartments, and biological systems [7]. The COVID-19 pandemic not only raised discussions about resource importance but also highlighted the environmental impact of PPE. While municipal solid waste (MSW) decreased due to lockdowns, medical hazardous waste surged [8]. The extensive use of predominantly non-degradable plastics in PPE has led to their accumulation in landfills, with potential consequences for marine environments through the formation of microplastic [9].

During the COVID-19 pandemic, the World Health Organization (WHO) recommended that healthcare workers wear PPE when treating patients, especially during aerosol-generating procedures (AGP) on patients suspected of having COVID-19. For regular patient interactions with COVID-19 patients, the use of a medical mask, gown, gloves, and eye protection was advised. For AGP, the WHO specified that healthcare workers should wear a mask meeting N95 or FFP2 standards, or equivalent [10]. PPE has proven to be the most reliable and visible means of preventing COVID-19 transmission [11]. Research indicates that ensuring healthcare worker safety when utilizing PPE involves comprehensive training in the proper use of such equipment [12,13]. Respirators such as N95, FFP2 or equivalents have been used extensively during previous public health emergencies involving acute respiratory illnesses like H1N1 influenza, especially when PPE supplies were low [14]. Practices included wearing the same respirator while caring for multiple patients with the same diagnosis without removing it, as evidence shows that respirators maintain their protective efficacy even over extended use [15]. Overall, studies indicate that reuse and prolonged use can be done safely with carefully implemented disinfection methodologies [16,17].

To tackle supply challenges and reduce environmental impact, it is essential to adopt sustainable practices for PPE use. These practices should help manage supplies effectively while ensuring the safety of patients and healthcare workers. At the same time, they should also protect the environment. The COVID-19 pandemic has highlighted significant lessons regarding not only the shortage of PPE but also the environmental impact of PPE. The crisis underscored the need for sustainable practices in healthcare settings to balance safety and environmental considerations [17,18]. Intensive care medicine has, in particular, been one of the highest carbon footprint areas in healthcare due to its continuous staff activity, higher resource use and energy demands compared to other hospital wards [1,19,20]. In our study, we aim to identify potential pathways to make our ICUs more environmentally friendly by reducing PPE consumption without compromising the safety of healthcare workers.

Methods

We conducted a retrospective examination of all newly developed procedural guidelines published from 01/2022 to 12/2023 to identify measures that influenced PPE consumption in our institution.

Using data from the purchasing department, we monitored the quantity of masks and gowns delivered, and we analyzed COVID-19 patient data from the controlling department to assess the number of treatment days for patients with SARS-CoV-2 infections in our ICU. The data from the purchasing unit were the number of gowns and masks delivered and the delivery date. We counted the number of new admissions of COVID- 19 patients and the number of ICU beds that were occupied by COVID- 19 patients at midnight daily. A bed occupied with a COVID- 19 patient at midnight was counted as one treatment day. No other data was collected. To compare the differences in the consumption of masks and gowns per treatment day between 2020 and the subsequent years, we described the relative change of PPE consumption from the initial year to the subsequent years. In 2020, a ward-based self-reporting system for healthcare worker infections was used in our ICU to protect our team and our patients. In the following years, this simple system became obsolete due to more advanced systems involving mandatory testing, contact tracing, and apps. We used Microsoft Excel to process the data.

Our focus is on the medical ICU at Katharinen hospital, Klinikum, Stuttgart. Located in a tertiary care center, our medical ICU is equipped with nineteen beds and is one of the fifty-six maximal care centers in Germany. The regular staffing of our ICU operates a three-shift system. There are seven nurses on the morning and evening shifts and six on the night shift. There are three physicians on the morning shift, three on the evening shift, and two on the night shift. The supervision is done by one attending physician in the morning shift and one attending physician for evening and night shift. During the pandemic, PPE was also very scarce and valuable in our hospital. The hospital made significant efforts in training for the proper use of PPE and implemented internal protocols to manage the shortage.

Results

From 2020 to 2023, we treated a total of 279 COVID-19 positive patients in our ICU. During the initial year of the pandemic in 2020, we documented 35 COVID-19 patients. In 2020 our self- reporting system counted zero infections among healthcare workers. In the subsequent years, we recorded 102, 98 and 44 patients, respectively. Due to data protection reasons, we are unable to obtain information on healthcare worker infections for the years 2021—2023.

PPE consumption

In 2020, only 6.6 FFP2 masks were used per patient day in our ICU (Table I). In 2021 and 2022, there was a notable and

Table I
PPE consumption in relation to patient days

Year	FFP masks	Gowns	Patients	Patient days	Masks/Patient day (relative change from 2020)	Gown/Patient day (relative change from 2020)
2020	1820	16900	35	275	6.6	61.5
2021	25000	35300	102	1230	20.3 (3.08)	28.7 (0.47)
2022	28780	29820	98	992	29.0 (4.39)	30.1 (0.49)
2023	20500	22169	44	188	109.0 (16.52)	117.9 (1.92)

significant increase in usage—up to three to four times higher than in 2020. Additionally, in 2023, there was another significant rise in the utilization of masks per patient day compared to preceding years. Similarly, the quantity of gowns used per patient day exhibited a noteworthy rise from its lowest point in 2021 to higher figures in 2023.

The factors that contributed to the 2020 low in PPE consumption were identified as the limitation of visits, consistent cohorting, adaptation of hospital internal protocols on PPE in a state of emergency, and online and in-person training on the proper use of PPE.

Limitation on visits

Since respirators and gowns were provided for visitors, the limitation of visits had an impact on PPE consumption. Initially, no visitors were allowed due to stringent isolation rules aimed at preventing the further spread of the virus. Subsequently, a daily opportunity for farewell visits to dying patients was introduced. These strict limitations were gradually removed. Starting from May 2020 one visitor per day was permitted for patients with prolonged hospital stays. In May 2022 these strict rules were replaced by recommendations to limit visits. This differs from our standard visitation policy, which typically has no daily limitations but restricts routine visits to two people simultaneously per room to avoid overcrowding.

Consistent cohorting

We divided the ICU into two segments: one designated for COVID-19 isolation (with consolidated resources within this space) and the other designated as COVID-free. A makeshift provisional "airlock," including an existing fire door, served as a barrier in the corridor, effectively separating the ICU into its two fire sections. This practice aligns with the standard approach in Central Europe, utilizing existing fire sections for cohorting in ICUs. Rather than using individual PPE for each patient, we streamlined the process to save time and materials by changing into PPE once while attending to all patients in this area, provided no additional infections or colonization with multidrug-resistant organisms were documented. Cohorting was practiced during the entire time from 2020 until 2023.

Institutional protocols

Our hospital has formulated an emergency protocol regarding the use of PPE during emergencies and shortages (Table II). In specific circumstances, the extended use of FFP2 masks when attending to multiple patients was permitted, provided the mask remained uncontaminated. Additionally, in low-risk scenarios, the substitution of an FFP2 mask with a

Table II
Internal protocol regarding the use of personal protective equipment (PPE) during emergencies and shortages

PPE type	Context	Regular use	Emergency use
FFP2 respirator	SARS-CoV2 patients	Single use	If no contamination occurred personal reuse for up to 5 days is allowed. In case of contamination of the mask discard the mask immediately. Requirement for reuse of FFP2 masks - removing medical disposable gloves and hand disinfection before removing the mask - patient or and personnel-specific use, for cohort: cohort area and personnel specific use - protected storage and personnel-specific labeling (name on a plastic bag) - folding the mask so that the inner side faces inward - do not seal the plastic bag (with mask) airtight to prevent condensation - do not put the mask in the coat pocket - hand disinfection before and after removing the mask - dispose of the mask immediately if damaged or wet
Gown	Contact or droplet transmission	Single use	No gown for interaction without expected contamination (no direct contact with patient or patient surroundings)

surgical mask (MNS) was implemented as an alternative measure. The protocol regarding the use of PPE during emergencies and shortages was only used in the initial year of the pandemic and removed as soon as the necessary amount of PPE was available.

Training

Education and training significantly improved the correct usage of PPE through various instructional videos. Furthermore, in-person training in donning and doffing with a certified expert in hospital hygiene was conducted at our ICU. We used a buddy system for mutual monitoring and assistance during donning and doffing to increase safety and compliance with our procedures.

Discussion

We demonstrated that it was possible to achieve a significant reduction in the usage of masks and isolation gowns without any healthcare provider infections during the first year of the pandemic. This was followed by a gradual increase in PPE use, particularly masks, in the subsequent years. Healthcare worker hospital acquired infection data for subsequent years was not available for the study.

We identified limiting visits to our ICU as one of the key measures. While this conserved our hospital's PPE supplies, it had its drawbacks. It strained the emotional well-being of our medical staff, added to their already demanding workloads by requiring them to assist with remote goodbyes, and left patients and families feeling profoundly helpless and often without closure [21—23]. Overly restrictive visitor policies can contribute to feelings of isolation among patients, anxiety of family members, and moral distress among healthcare workers [24,25]. However, limiting visits is an effective and easy-to-implement method to reduce mask usage. With careful planning and rule implementation, the number of visits can be optimized if necessary. Future studies should investigate the amount of PPE used for visitors to assess the number of possible reductions.

The next pillar in our strategy was patient screening and cohorting. Rigorous and early screening of patients at first contact and effective isolation in cohorts prevented the spread of infections within healthcare facilities. Studies have indicated that in cohort settings, doctors spend slightly more time with patients compared to non-cohort settings. However, working in cohort areas presents challenges, leading to more interruptions for medical staff and an increased perceived workload [26]. In our experience, challenges include communicating outside the cohorting area and wearing full PPE for an entire shift. The impact on PPE usage becomes more significant as the size of the cohorted group increases.

Shortages of PPE during the initial stages of the pandemic led to the exploration of unvalidated techniques to extend the lifespan of single-use PPE. Some studies show that FFP masks can be reused as long as they are not visibly soiled or damaged and they remain effective barriers even after donning and doffing [27]. Even before the COVID-19 pandemic, a study from a hospital in Brazil showed that healthcare workers used N95 respirators for extended periods. The authors concluded that it's acceptable to use them for shifts lasting up to 12 hours and to reuse them for up to five days [15].

We observed, out of necessity, that reducing PPE usage during the pandemic through prolonged use or reuse of PPE was effective without any increase in healthcare provider infections. Following the global shortage of equipment for frontline healthcare workers during the COVID-19 pandemic, there's evidence supporting our observation of the prolonged use and potential reuse of masks, isolation gowns and other PPE in pandemic scenarios [17,28]. However, our intention is not to advocate for extended use of PPE, particularly masks, beyond industry guidelines.

Online and in-person training on the proper use of PPE, including donning and doffing, is important in keeping healthcare workers protected. While it requires both time and financial investment, when done correctly, the resources invested in training will lead to a reduction in the risk of infections among staff [29,30]. While the training does probably not reduce PPE consumption, it ensures that the available PPE is used correctly. This maximizes the effect of PPE on staff safety.

Our observations raise several important questions for future research.

Firstly, there is a need to investigate the safe duration for mask or isolation gown usage and the feasibility of their reuse without compromising safety. Understanding how long these items can be effectively used and under what conditions they can be safely reused is crucial for both conserving resources and ensuring the protection of healthcare workers.

Secondly, evaluating the effectiveness of cohorting strategies in reducing PPE usage and their impact on communication and workflow in healthcare settings is essential. Cohorting patients with similar conditions can streamline the use of PPE, but it is important to assess how this practice affects the overall efficiency and communication within healthcare teams.

Limitations of our analysis include the fact that our data is limited to a single center and the numbers are small. The findings in our retrospective study may also be due to information bias, selection bias or confounding which was not adequately controlled for. Our method to count treatment time is imprecise for very short admissions to the ICU. It is possible that psychological factors, such as heightened caution due to fear of infection, influenced the behavior of staff, especially in the first year of the pandemic. Another possible bias may be detection bias for healthcare worker infections. Initially, testing was only performed for symptomatic individuals, so asymptomatic infections may have been unnoticed. Furthermore, healthcare worker COVID-19 infections may have been incorrectly designated as hospital acquired. Later, routine testing was made available for all staff. Our data does not indicate how large the effect of each of these interventions was. We are unable to access data on healthcare worker infections due to data protections regulations for the years 2021—2023. Since we observed zero infections in the first year when the number of FFP2 respirators used was minimal, we think that this data is sufficient to support our main hypothesis, that reduction of PPE consumption is possible without an increased risk to the providers. In the early months of the pandemic, the most important source of infection for healthcare workers was their workplace [31]. Later in the pandemic, with increasing community incidence, most infections were community acquired [32]. These facts support our hypothesis, that the rate of worker infections in the early months of the pandemic is particularly valuable to assess the specific risk at

the workplace for healthcare providers. Later in the pandemic, healthcare worker infections correlate with community incidence. Because of this, the value of data on healthcare provider infections later in the pandemic is limited regarding the assessment of the specific risk at the workplace. Information on healthcare provider infections in the subsequent years would be helpful to estimate the role of other factors, e.g. fear of infections.

There are few indications for the use of FFP2 masks except for SARS- CoV-2. The only other prevalent indications in our unit for FFP2 masks include influenza and active pulmonary tuberculosis. We therefore obtained the delivery dates for oseltamivir and isoniazid for the years 2020—2023. This data indicates that during this timeframe, 16 patients with influenza and 6 patients with active tuberculosis were treated in our unit. There were 76 treatment days for influenza patients (2020: 29 days, 2021: 0 days, 2022 17 days, 2023 30 days) and 16 treatment days for active tuberculosis. We therefore think that the magnitude of these infections on the changes in use of PPE between 2020 and 2023 is limited.

We think the main strength of our study is that it summarizes the experiences we had with limited access to PPE during a pandemic to make this information available for future pandemics.

Conclusion

Our study demonstrated that a reduction in mask and gown usage was possible with zero healthcare provider infections registered in the initial year of the COVID-19 pandemic. Rationalising the number of PPE products used is the most effective way to manage limited resources and reduce waste in the future.

As we strive to take better care of our environment, finding sustainable solutions for PPE waste becomes imperative. Balancing the immediate need for protection with long-term environmental considerations is crucial for developing a resilient and environmentally conscious healthcare system. Raising awareness among healthcare professionals about the environmental impact of PPE waste and emphasizing that the responsibility for change lies with us is a critical step towards sustainable management of consumables.

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Credit author statement

Johannes Heymer: project administration; conception and design of the study; validation; acquisition of data, analysis and interpretation of data; methodology; revising the article critically for important intellectual content, final approval of the version to be submitted.

Stefani Fruchi: conception and design of the study, acquisition of data, analysis and interpretation of data; drafting the article, final approval of the version to be submitted.

Anna Hein: conception and design of the study, acquisition of data, analysis and interpretation of data; revising the article critically for important intellectual content, final approval of the version to be submitted.

Matthias Ott: conception and design of the study, acquisition of data, analysis and interpretation of data; revising the article critically for important intellectual content, final approval of the version to be submitted.

Daniel Räpple: conception and design of the study, supervision, resources, acquisition of data, analysis and interpretation of data; revising the article critically for important intellectual content, final approval of the version to be submitted.

All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflict of interest statement

Johannes Heymer, Stefani Fruchi, Anna Hein and Matthias Ott have no conflict of interest to disclose. Daniel Räpple receives book royalties from Springer Verlag for a medical textbook.

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Ethics statement

According to local guidelines (Ethics Committee of the North Württemberg Medical Association), ethical approval is required if data used can be attributed to an individual person (§15 Professional Code: https://files.aerztekammer-bw.de/c73ea88bf1eb2331/fbaf22825106/Berufsordnung.pdf, https://www.aerztekammer-bw.de/ethikkommission#frei).

We exclusively used aggregated numerical data that cannot be attributed to any individual person. The data on ICU occupancy was publicly available (e.g., from the intensive care registry "intensive register", from the local health authorites or the non-profit organization Risklayer). Therefore, according to our regulations, no ethical approval was required.

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