Respiration

Clinical Investigations

Respiration
DOI: 10.1159/000541083

Received: March 14, 2024
Accepted: August 15, 2024
Published online: September 5, 2024

Impact of the COVID-19 Pandemic on Home Mechanical Ventilation in Germany: A Descriptive Observational Study

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Keywords
Home mechanical ventilation · Quality of life · Non-invasive ventilation · Prolonged weaning · Respiratory failure · Weaning failure

Abstract
Introduction: Over the last decade, the number of patients receiving home mechanical ventilation (HMV) has increased significantly, which has led to a limited availability of specialist centres, not least due to the scarcity of healthcare professionals. This situation was exacerbated by the COVID-19 pandemic. It is therefore assumed that the repurposing of resources has led to an aggravated change in the healthcare structure in HMV. ***Methods:*** This descriptive observational study analysed the Operation and Procedure Classification Codes for patients receiving HMV from 2008 to 2022. The data were provided by the Federal Statistical Office of Germany. Data were additionally analysed with respect to geographical distribution and ventilation status. ***Results:*** A total of 737,770 datasets were analysed (mean age in 2020: 66.5 years). There was a steady increase in HMV initiations (+6%) and controls (+9%) per year before the pandemic (2008–2019). Patient admissions during the pandemic revealed a 28% decrease, with the largest decrease in invasive ventilation (IV) follow-up visits (2019: 3,053; 2020: 2,199; −39%), while the number of IV initiations remained stable. There was a 19% decrease in the number of non-IV initiations in 2020 (16,919 vs. 14,227) and a 32% decrease in the number of follow-ups (45,812 vs. 34,813) in comparison with 2019. ***Conclusion:*** The pandemic has led to a significant decline of inpatient admissions for patients receiving HMV. This decline was most pronounced in the first year of the pandemic. Control visits in particular did not reach the pre-pandemic level. This is an indication of the ongoing change in the healthcare landscape as a result of the pandemic.

Introduction

Home mechanical ventilation (HMV) is now widely used as a treatment option for chronic hypercapnic respiratory failure, either invasively via tracheostoma or non-invasively via face masks [1]. Over the last decade, the number of patients receiving HMV increased

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significantly, resulting in high economic burden and reduced hospital capacity, as both induction and follow-up visits of HMV are regularly performed in the hospital [2–4]. As a result, new healthcare strategies have been implemented in order to maintain patient care. It has been shown that outpatient initiation of non-invasive ventilation (NIV) is possible for both COPD patients and patients with neuromuscular diseases and is associated with significant cost reduction [5–7]. There is also increasing evidence to support that follow-up visits, for both IV and NIV, can be carried out on an outpatient basis [8, 9].

The transition to a more outpatient care structure should counteract the reduced capacities of inpatient centres and optimize the available capacities. In addition, hospitalizations that are not absolutely necessary should be avoided in order to reduce the patient's burden of illness. This situation was exacerbated by the COVID-19 pandemic, as weaning wards were increasingly used for COVID-19 patients with acute respiratory failure and, thus, were not available for elective initiations and follow-ups of HMV [10]. It can therefore be assumed that the reallocation of resources has led to a more pronounced change in the structure of healthcare provision for these patients. These developments have already been scientifically proven for other chronic diseases. Here, it has been shown that the COVID-19 pandemic had significant effects on the inpatient treatment of cancer and cardiovascular diseases in Germany, with inpatient care capacities being restructured as part of pandemic-related adjustments [11, 12]. In cardiology, invasive examinations and procedures such as cardiac catheterization and stent implantations were partially delayed, and even heart surgeries significantly decreased. Since the risk of a deterioration in healthcare is associated with the lack of preventive follow-ups, these effects of healthcare alterations need to be scientifically assessed.

The impact of the COVID-19 pandemic on HMV has yet not been scientifically evaluated. This analysis aims to investigate how the shift in treatment capacity has affected the healthcare of HMV patients.

Methods

Study Design and Setting

The study was conducted as a retrospective, national, descriptive observational study. The report was prepared according to "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) recommendations [13]. The corresponding checklist can be obtained from the online data supplement. The data presented here are based on the datasets of the Federal Statistical Office, which were prepared in collaboration with the data managers. Due to the Hospital Remuneration Act, partial and full inpatient facilities in healthcare are required to report their performance data based on the International Classification of Diseases (ICD) and the procedures performed based on the Operation and Procedure Classification System (OPS) [14, 15]. The OPS codes for HMV were evaluated using the data from the Federal Statistical Office for the period from 2008 to 2022 (N = 737,770). The analysis of the main procedure 8-716 captures HMV via mask or tracheostoma and is divided into the procedure codes 8-716.0 (initial setting of non-invasive or invasive HMV) and 8-716.1 (control or optimization of a previously initiated non-invasive or invasive HMV). Since 2017, the categorization of the procedure code 8-716.0 further allows the differentiation of the ventilation access with invasive ventilation (IV) (8-716.01 after unsuccessful weaning attempt and 8-716.02 elective or without weaning attempt) and NIV forming two different groups for a more detailed analysis. The discontinuation of ventilation is categorized by the procedure codes 8-716.20 (NIV) and 8-716.21 (IV) since 2019.

Setting of HMV in Germany

In Germany, HMV must be performed under inpatient conditions irrespective of the ventilatory approach. This applies to both the initiation and follow-up of HMV. This is also reflected in the national scientific guidelines, which emphasize the complexity of the disease [16–18].

Definition of Periods Regarding the Pandemic

The pandemic period was defined as the years in which the COVID-19 pandemic had a major impact on the healthcare system in Germany. This included the years 2020–2022.

Statistical Analysis

The datasets provided by the Federal Statistical Office for the years 2008 to 2022 were used for the final analysis. The statistical analysis was carried out in the sense of a descriptive data evaluation. Microsoft® Excel 2016 (Microsoft Corporation, Redmond, USA) was used for the preparation, analysis, and graphical representation of the data. The variables time, state, age, ventilation access (invasive or non-invasive), and the setting of the contact (initiation or control of ventilation) were included in the analysis. The age data are available from the Federal Statistical Office in the form of 5-year intervals based on health insurance data. In order to calculate the age, the mean value was therefore used as a reference point. In the

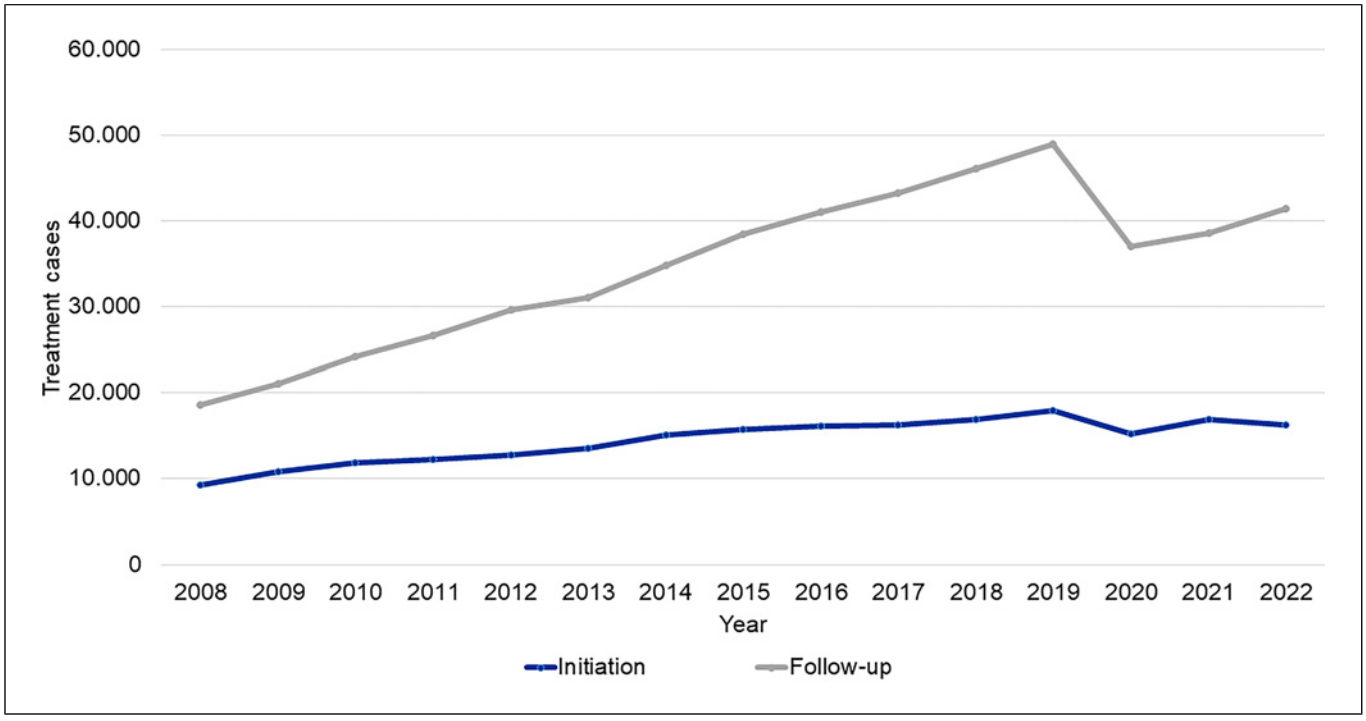

Fig. 1. Development of the number of all ventilated patients (IV and NIV) in relation to initiations and controls of HMV between 2008 and 2022.

case of official data from the Federal Statistical Office, which is based on health insurance data, it cannot be ruled out that this may also lead to incorrect coding and thus a bias in relation to the data.

Results

A total of 737,770 records were analysed in relation to the datasets over the period from 2008 to 2022. We are not affected by any missing data in official data from the Federal Statistical Office, as the entire data records were included. Figure 1 illustrates the overall development of HMV in Germany over the observation period covering 2008 to 2022. Annual percentage changes were also analysed for all HMV patients (Table 1). The mean age in 2020 was 66.5 years. Age at initiation of HMV in 2008 compared to 2020 is shown in Figure 2. The development of HMV showed a 28% decrease in HMV patients in the years in which the pandemic had a strong impact on the healthcare system in Germany (2020–2022) compared to 2019, the year in which no COVID-19 patients were treated in Germany. The most significant decrease was observed in the number of patients with IV follow-ups (3,053 cases treated in 2019 vs. 2,199 cases treated in 2020; −39%), while the number of IV initiations increased by 1% (1,039 cases treated in 2019 vs. 1,052 cases treated in 2020) (Fig. 3). The number of treatment cases for initiation and follow-up visits of NIV also decreased compared with the pre-pandemic period. By 2022, the number of cases treated had failed to return to pre-pandemic levels. The most significant difference is observed in the follow-up visits of invasively ventilated patients, which remain at a reduced level compared to 2019 (2020: −39%, 2021: −51%, 2022: −40%).

Treatment withdrawals similarly declined at the beginning of the pandemic, but increased above the pre-pandemic level in 2022 despite the reduced number of ventilation follow-up visits (Fig. 4). The great heterogeneity of the impact of the COVID-19 pandemic should be emphasized with regard to the individual federal states, which are illustrated graphically in Figure 5a, b.

Discussion

The present study illustrates the effects of the COVID-19 pandemic on the inpatient care of HMV patients. The analysis of treatment rates in Germany revealed a notable decline in the number of inpatient treatments for patients

Table 1. Annual change of patients receiving IV and NIV categorized by initiation or follow-up

Year	Initiation, *n*	Change compared to previous year, %	Follow-up, *n*	Change compared to previous year, %
Pre-pandemic				
2008	9.312		18.571	
2009	10.795	+16	21.032	+13
2010	11.916	+10	24.128	+15
2011	12.191	+2	26.614	+10
2012	12.774	+5	29.683	+12
2013	13.532	+6	30.994	+4
2014	15.146	+12	34.859	+12
2015	15.769	+4	38.429	+10
2016	16.132	+2	40.992	+7
2017	16.268	+1	43.239	+5
2018	16.942	+4	46.073	+7
2019	17.958	+6	48.865	+6
Mean annual change		+6		+9
Pandemic				
2020	15.279	−15	37.012	−24
2021	16.974	+11	38.608	+4
2022	16.314	−4	41.369	+7

Presentation of the mean percentage change in relation to the pre-pandemic period (2008–2019).

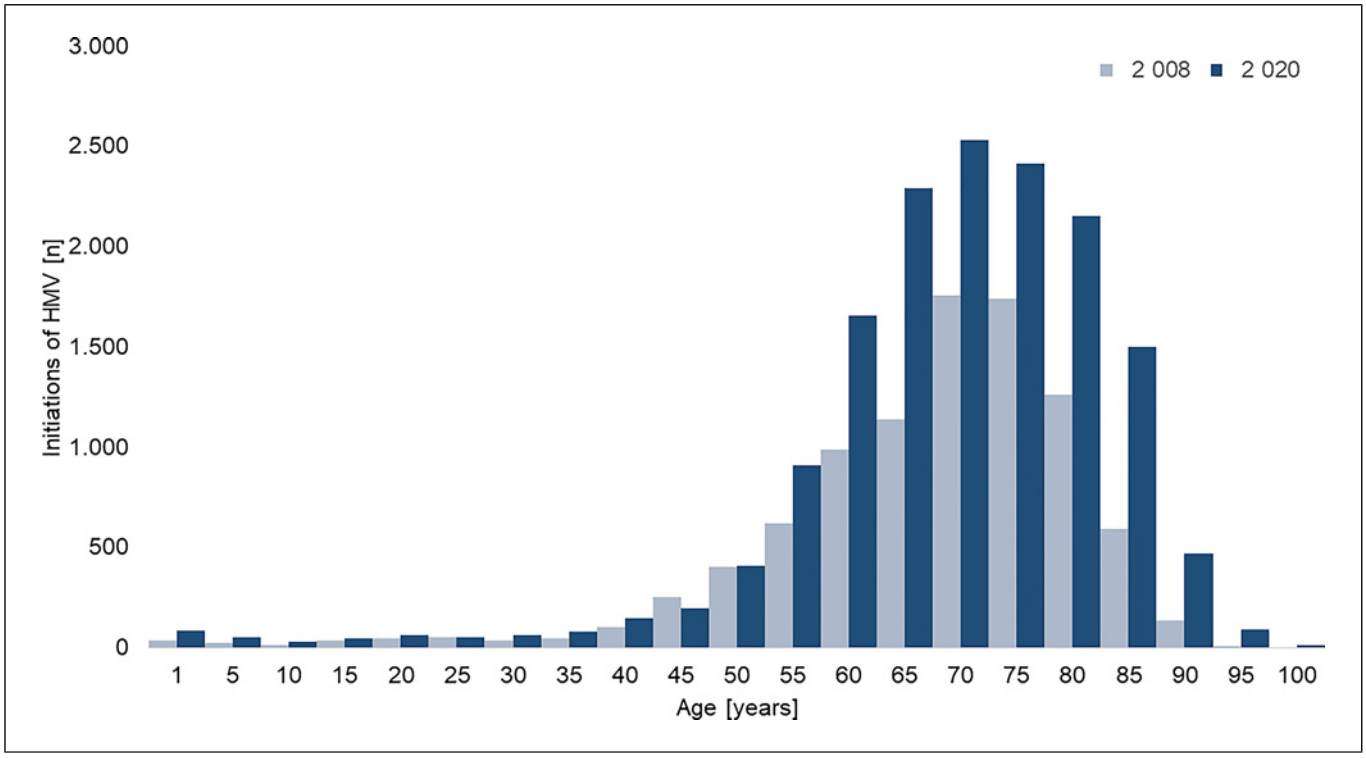

Fig. 2. Age at initiation of HMV in 2008 compared to 2020 (IV and NIV). HMV, home mechanical ventilation.

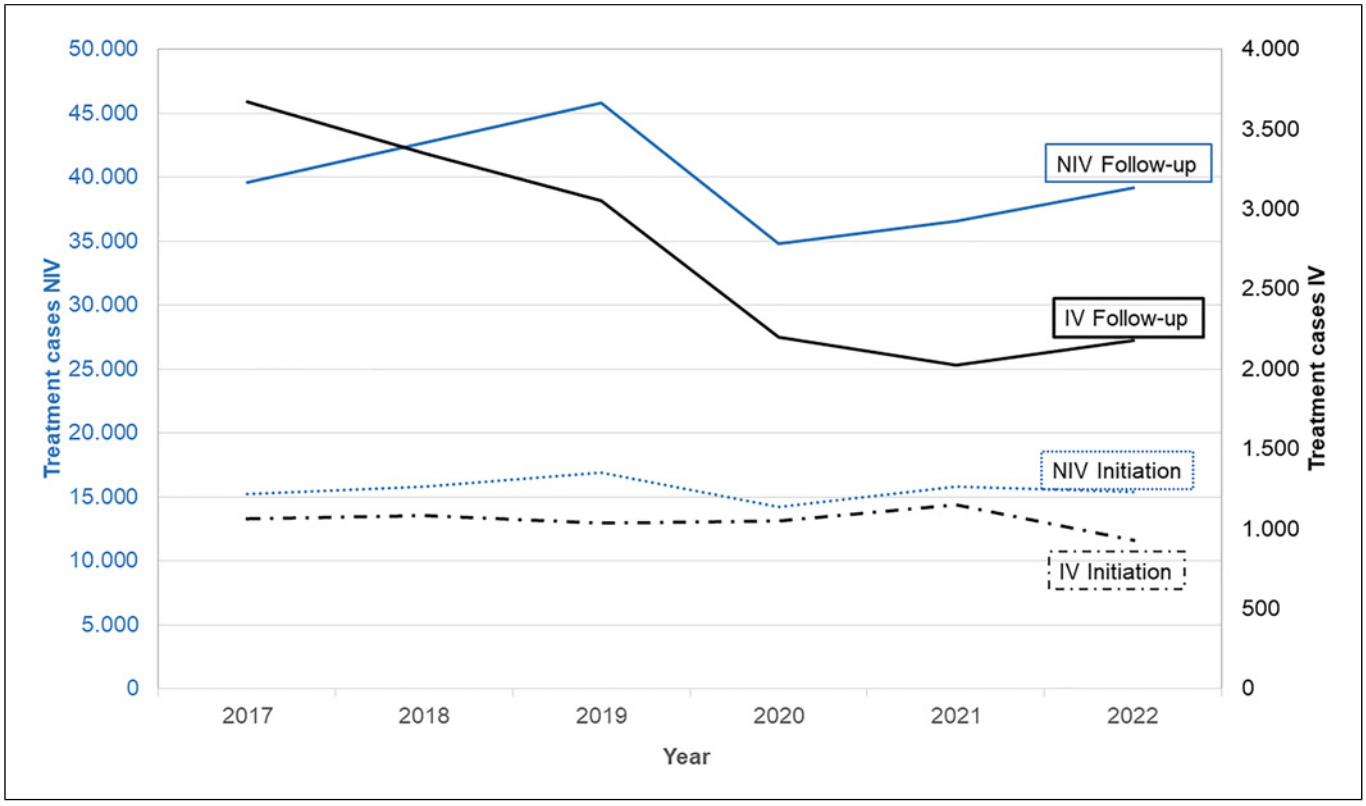

Fig. 3. Development of the treatment rates of initiations and follow-ups in the years 2017–2022 depending on the type of ventilation (invasive or non-invasive). NIV, non-invasive ventilation; IV, invasive ventilation.

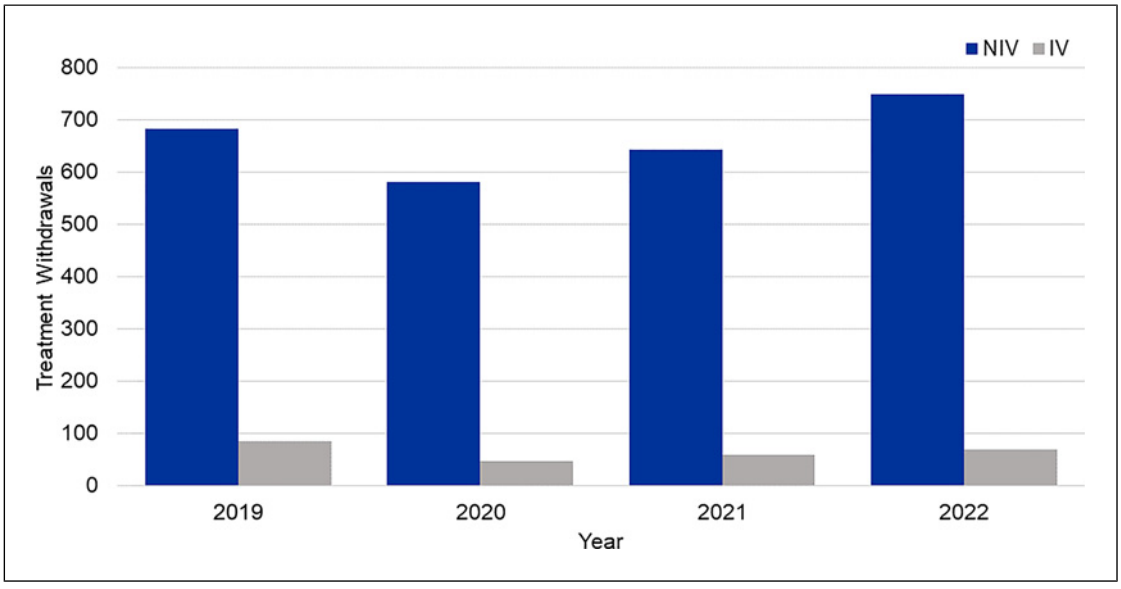

Fig. 4. Development of treatment withdrawals in the years 2019–2022 depending on the type of ventilation (invasive or non-invasive). NIV, non-invasive ventilation; IV, invasive ventilation.

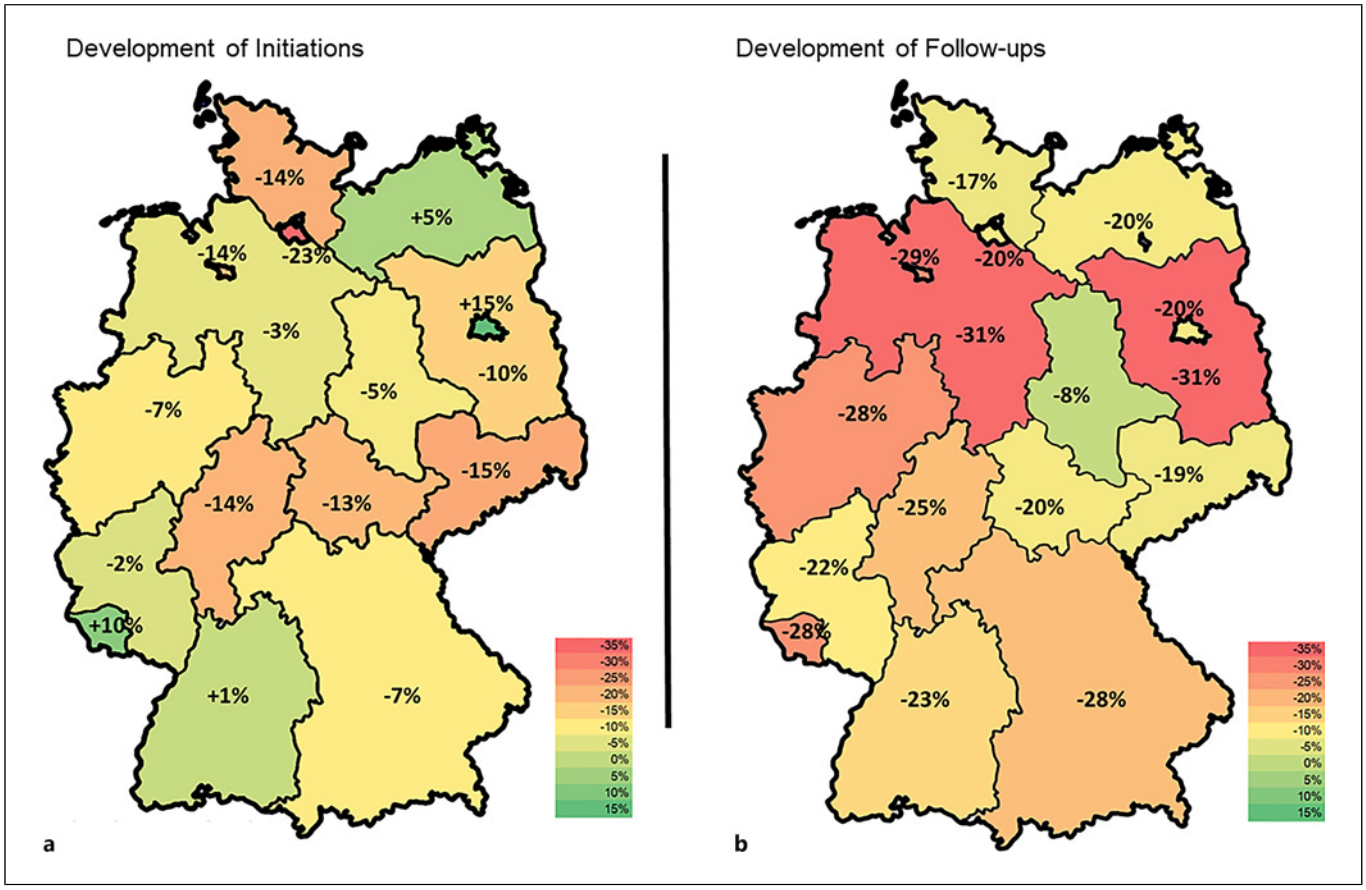

Fig. 5. a, **b** Graphical illustration of the heterogeneity of the effects of the COVID-19 pandemic on HMV with regard to the individual federal states in terms of 2019 (defined as pre-pandemic) to 2020. **a** shows the initiations of ventilation; **b** shows the follow-ups.

requiring HMV. In particular, the number of follow-up visits performed to evaluate long-term NIV and IV in 2022 did not reach the pre-pandemic level of 2019. This indicates a significant structural transformation in healthcare provision. In this context, the reasons for the changed healthcare structure are presumably multifactorial. Patient-related causes for healthcare services not being accessed, e.g., due to fear of a possible nosocomial infection, must be differentiated from a supply-dependent shortage of inpatient care services due to pandemic-related reallocation of capacities. It can be assumed that the latter is particularly the case in the field of respiratory medicine, given the high level of expertise in the treatment of patients with COVID-19, especially in pulmonary departments. Consequently, a high number of patients with acute respiratory failure due to COVID-19 were treated in specialized pulmonary departments. It should be emphasized that the number of HMV follow-ups remained low, despite the almost equivalent number of NIV initiations. Potential reasons could be the termination of treatment initiated by patients, which would explain the increased number of treatment withdrawals, as well as an increase in outpatient healthcare services for patients. This approach to respiratory medicine, which involves monitoring patients in their own environment, has already demonstrated positive outcomes in some clinical trials [5, 6, 8, 19–22]. The decline in the number of IV follow-up visits also supports the hypothesis that reduced capacity and alternative care services, such as outpatient care, are increasing, as the number of IV follow-up visits started to decline pre-pandemic. However, the lack of scientific evidence is problematic, and it is essential that scientific support is provided for the changed healthcare landscape resulting from the pandemic in order to ensure long-term security of care. This lack of evidence currently results in the inability to provide unambiguous recommendations regarding the type of healthcare in evidence-based guidelines [1].

A comparison of the geographical distributions of the variation in number of treatments with the incidence statistics for COVID-19 in the corresponding areas shows no correlation. The north-south and east-west gradient in incidence rates that prevailed in the first year of the pandemic is not reflected in the reduction of hospitalized patients receiving mechanical ventilation [23]. A similar distribution pattern can only be observed with regard to the initiation of HMV, which could possibly indicate an increased initiation of HMV following a COVID-19 infection or a focus of the remaining capacities on therapy initiation.

In the event of a shortage of resources, care structures should be adapted to the requirements of a pandemic, but also to other fundamental problems such as a persistent shortage of healthcare professionals [24]. This may involve the implementation of telemedicine, the development of outpatient healthcare structures, or the implementation of cross-sectoral treatment programs to ensure patient safety [25, 26]. In addition, evidence-based treatment algorithms should be developed to aid decisions on which treatments should be prioritized for inpatient treatment in order to ensure optimal use of available resources.

It must be acknowledged that the current analysis of insurance data can only provide a limited reflection of the real-world patient population. Consequently, further clinical studies are required to ascertain the rationale and outcomes of the modified treatment strategies. This will ensure the long-term efficacy and reliability of HMV. In conclusion, this analysis reveals a lasting transformation of healthcare conditions with regional differences. The decreased number of follow-up visits while ventilation is constantly being initiated may indicate an increase in outpatient care for patients or even its neglection. In this respect, the pandemic can also serve as an impetus to adapt healthcare more rapidly for the benefit of patients. Further studies should investigate the effects of these changes and elucidate the impact on treatment efficiency.

Statement of Ethics

Ethical approval and consent were not required as this study was based on publicly available data. Patient consent was not required as this study was based on publicly available data.

Conflict of Interest Statement

The Cologne study group (S.B.S., M.W.S., D.S.M., D.K., M.Z., and W.W.) received open research grants from Löwenstein Medical/Germany and GCE group/UK and by the Innovation Fund for Health Services Research (01VSF1905) of the German Federal Joint Committee. S.B.S., M.W.S., and M.Z. received travel grants from companies dealing with mechanical ventilation products; D.S.M. received open research grant from Philips Respironics/USA MB. F.S. and J.H. have nothing to declare.

Funding Sources

The authors state that neither the study design, results, interpretation of the findings, nor any other subject discussed in the submitted manuscript was dependent on financial support.

Author Contributions

S.B.S., M.W.S., D.S.M., D.K., M.Z., and W.W. had full access to all data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis, especially including any adverse effects. S.B.S. and W.W. contributed substantially to the study design. S.B.S., M.W.S., D.S.M., D.K., M.Z., W.W., M.B., F.S., and J.H. contributed substantially to the data analysis and interpretation and the writing of the manuscript. All authors read and approved the final manuscript. All authors agreed to be accountable for all aspects of the work.

Data Availability Statement

The data that support the findings of this study are not publicly available due to information that could compromise the privacy of research participants but are available from the first author S.B.S.

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