In-hospital mortality, comorbidities, and costs of one million mechanically ventilated patients in Germany: a nationwide observational study before, during, and after the COVID-19 pandemic

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Summary

Background Even more than hospital care in general, intensive care and mechanical ventilation capacities and its utilization in terms of rates, indications, ventilation types and outcomes vary largely among countries. We analyzed complete and nationwide data for Germany, a country with a large intensive care sector, before, during and after the COVID-19 pandemic.

Methods Analysis of administrative claims data, provided by the German health insurance, from all hospitals for all individual patients who were mechanically ventilated between 2019 and 2022. The data included age, sex, diagnoses, length of stay, procedures (e.g., form and duration of mechanical ventilation), outcome (dead vs. alive) and costs. We included all patients who were at least 18 years old at the time of discharge from January 1st, 2019 to December 31st, 2022. Patients were grouped according to year, age group and the form of mechanical ventilation. We further analyzed subgroups of patients being resuscitated and those being COVID-19 positive (vs. negative).

Findings During the four years, 1,003,882 patients were mechanically ventilated in 1395 hospitals. Rates per 100,000 inhabitants varied across age groups from 110 to 123 (18–59 years) to 1101–1275 (>80 years). The top main diagnoses were other forms of heart diseases, pneumonia, chronic obstructive pulmonary disease (COPD), ischemic heart diseases and cerebrovascular diseases. 43.3% (437,031/1,003,882) of all mechanically ventilated patients died in hospital with a remarkable increase in mortality with age and from 2019 to 2022 by almost 5%-points. The in-hospital mortality of ventilated COVID-19 patients was 53.7% (46,553/86,729), while it was 42.6% (390,478/917,153) in non-COVID patients. In-hospital mortality varied from 27.0% in non-invasive mechanical ventilation (NIV) only to 53.4% in invasive mechanical ventilation only cases, 59.4% with early NIV failure, 68.6% with late NIV failure, to 74.0% in patients receiving VV-ECMO and 80.0% in VA-ECMO. 17.5% of mechanically ventilated patients had been resuscitated before, of whom 78.2% (153,762/196,750) died. Total expenditure was around 6 billion Euros per year, i.e. 0.17% of the German GDP.

Interpretation Mechanical ventilation was widely used, before, during and after the COVID-19 pandemic in Germany, reaching more than 1000 patients per 100,000 inhabitants per year in the age over 80 years. In-hospital mortality rates in this nationwide and complete cohort exceeded most of the data known by far.

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Keywords: ARDS; NIV; Mechncial ventilation; Mortality; COVID

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Research in context

Evidence before this study

Mechanical ventilation (MV) of critically ill patients has gained considerable attention during the COVID-19 pandemic, especially in patients with respiratory failure (acute respiratory distress syndrome). Although internationally substantial amelioration in patient outcome has been achieved over the past two decades, mortality still ranges between 20 and up to 50% in mechanically ventilated patients with cardiogenic shock or most severe forms of ARDS. We searched PubMED for peer reviewed papers published until 17/05/2024 using the terms mechanical and ventilation and nationwide and ICU. We found no study with complete nationwide data comparing outcome and comorbidity of mechanically ventilated patients before, during and after the COVID-19 pandemic. However, we found complete nationwide data before the pandemic from 5 high-income and one low-income country and several studies focusing exclusively on nationwide COVID-19 outcome data in different subgroups. Additionally epidemiological data from a very limited number of countries show ventilation rates between 100 and more than 1000 per 100,000 inhabitants depending on age and country.

Added value of this study

This study analyses for the first time complete and unbiased in-hospital mortality rates of patients with different diagnoses receiving different types of MV before, during and after the COVID-19 pandemic. Both utilization and in-hospital mortality rates in this unselected cohort in Germany exceed most of the data known by far. They can serve as benchmarks for international comparisons of utilization, mortality, and costs.

Implications of all the available evidence

This high in-hospital mortality rates and high numbers of patients being mechanically ventilated raise the question of indication and futility of patients on MV in a health care system with very high capacities and a reimbursement system being completely dependent on utilization almost without limits.

Introduction

Mechanical ventilation (MV) of critically ill patients has gained considerable attention during the COVID-19 pandemic, especially in patients with respiratory failure (acute respiratory distress syndrome (ARDS)).[1–5] Although substantial amelioration in patient outcome has been achieved over the past two decades, mortality still ranges between 20 and up to 50% in mechanically ventilated patients with cardiogenic shock or most severe forms of ARDS.[2,4] In-hospital mortality of mechanically ventilated patients across a wide range of 38 countries declined over the past two decades from 40 to 36% with some country-related variability,[6] reflecting the scientific and clinical progress. Beside mechanical ventilation, extracorporeal heart and/or lung-support have gained special attention since the H1N1 pandemic[7–13] which have experienced a significant increase in their utilization since 2010. The substantial mortality rates in Germany in patients treated by extracorporeal membrane oxygenation (ECMO),[2,9] raise questions about the therapeutic indication, quality of care and quality of life after discharge, as well as the cost effectiveness of treatment.

With 29 intensive care unit (ICU) beds per 100,000 inhabitants, Germany has one of the highest rates among the countries of the Organisation for Economic Co-operation and Development (OECD), about 6-times that of Sweden and 4.5-times that of the Netherlands.[14] There are 40% more ICU per capita in Germany than in the US.[14] However, not all these German ICU beds are being used to treat mechanically ventilated patients. We hypothesize here that the indication for the use of MV is more generous in Germany, making it a good test case to analyze the incidence and outcome of MV. Therefore, countrywide real-world data before, during and after the COVID-19 pandemic provided here is essential for an evidence-based discussion on the indication for MV, the quality of care, and the limitations of this treatment option. The aim of the current study was, therefore, to determine complete and nationwide case characteristics and in-hospital mortality of mechanically ventilated patients for different diseases and according to the type of ventilation addressing a time period of four years: before, during and after the COVID-19 pandemic. Findings are also put in a societal context as we compare the rate of ventilated patients to the total population, patients who died on ventilation to all deceased, and expenditure for MV to gross domestic product (GDP).

Methods

We use anonymized nationwide administrative claims data from the German health insurance funds, thus including nearly all patients that were mechanically ventilated in Germany from 2019 to 2022. The German DRG-Systems (G-DRG) requires hospitals to supply relevant diagnoses, and procedures to be reported to the health insurance for the purpose of reimbursement. The data provided here includes age, gender, length of

hospital stay, diagnoses, procedure codes and discharge type (survival status) as well as the cost of the hospital stay (DRG relative weight). Diagnoses were coded according to the 10th revision of the International Classification of Diseases (ICD-10-GM) and procedures according to the German version of the International Classification of Procedures in Medicine, the "Operationen-und Prozedurenschlüssel" (OPS).

We included all patients who were at least 18 years old at the time of discharge from January 1st, 2019 to December 31st, 2022. Only patients ventilated with a driving pressure of more than 6 cmH_2O either non-invasively (NIV), invasively (IMV) or alternating with both types of MV were considered mechanically ventilated. Patients who were transferred between hospitals were excluded from this study, but in-hospital mortality rates between transferred and non-transferred patients were compared. However, the difference in in-hospital mortality was found to be below 1.5%.

Patients were grouped according to year, age group and the form of MV. For ventilated patients, six subgroups were formed: (a) patients with NIV, (b) patients with early NIV failure, (c) patients with late NIV failure (>24 h), (d) with NIV post extubation, (e) with IMV, and (f) with any kind of respiratory support and additional veno-arterial-(VA) or veno-venous-(VV)-ECMO therapy. The current data is a complete record of all inpatients. In the German DRG system, a patient having been transferred between two hospitals generates two separate cases for remuneration, but accurate retrospective merging of these two and more cases was not possible. Therefore, transferred patients have been excluded from the analysis. We further analyzed subgroups of patients being resuscitated and those being COVID-19 positive. Furthermore, we calculated incidences of utilization of mechanical ventilation per age decade. Population data were derived from publicly available data from the Federal Statistical Office of Germany.

The prevalence of COVID-19 in the study was monitored using the emergency codes U07.1 activated by the WHO. The Charlson comorbidity index (CCI)[15] was used to report comorbidities in an aggregated form. We report means and standard deviation (SD) for *continuous variables,* and frequencies as well as percentage values for *categorical variables*.

Hospital costs are the sum of the valuation (relative weight multiplied by base rate (Bundesbasisfallwert) in Euro) of the DRGs in the respective case groups. The DRGs are calculated annually by a central institute (InEK GmbH Siegburg) using all reported costs from a large, standardized, representative sample of the German hospitals. Hospitals are required by law to provide accurate data and to participate in the calculation process. The German DRG system provides detailed data in conjunction with OPS codes on MV. Invasive mechanical ventilation and non-invasive ventilation can be separated by different codes. Furthermore, hours on MV are counted and externally controlled by the Medical Review Board ("Medizinischer Dienst"). According to the German coding rules, an episode of MV more than 8 h a day is counted as 24 h, independent of the type of MV used as long as driving pressure is above 6 cm H_2O.

The study was approved by the Ethics Committee of the Witten/Herdecke University (research ethics board number 2020/256).

Results

This study includes 1,003,882 mechanically ventilated patients, who were treated in 1395 German hospitals (Table 1). 21.2% of all patients were in the age between 18 and 59 years, 23.6% between 60 and 69 years, 27.8% between 70 and 79 years, and 27.4% over 80 years old (Table 1).

Ventilation rates per 100,000 population

Ventilation rates per 100,000 inhabitants varied across age groups by a factor of 10, from 110 to 123 in the age group of 18–59 years up to 1101–1275 in the group of patients over 80 years, with rates decreasing from 2019 to 2022 (Table 1, Fig. 1A).

Ventilated patients: type of ventilation, main diagnosis and comorbidities

The frequency in type of MV was as follows: (a) NIV only: 31.6%, (b) patients with early NIV failure: 0.1%, (c) patients with late NIV failure (>24 h) 3.4%, (d) with NIV post extubating 2.5%, (e) with invasive mechanical ventilation only (IMV) 37.6%, and (f) with any kind of respiratory support and additional VA or VV-ECMO therapy 1.5%. 18.5% of all cases could not be classified accurately. COVID-19 was diagnosed in 10.6% of all cases from 2019 to 2022 being treated with NIV only, in 15.4% in those with early NIV failure, in 31.8% with late NIV failure, in 6.8% with NIV post extubation, and in 6.4% of all IMV only cases. Fig. 1B depicts all cases being mechanically ventilated on a daily bases including patients with COVID-19. However, the two main groups of patients on NIV and IMV only consisted of 10% or less COVID patients per group. The number of influenza patients requiring MV was low with 6408 cases in the 4-year period observed (0.6% of all cases).

The top 5 main diagnoses concerning the complete cohort, as depicted in Fig. 2A, were dominated by other forms of heart diseases (150,234 cases), viral and bacterial pneumonia (112,968 cases), bronchitis, chronic obstructive pulmonary disease (COPD) and asthma (83,258 cases), ischemic heart diseases (74,046 cases) and cerebrovascular diseases (52,095 cases). Of note, the Top 3 diagnoses for patients with NIV treatment below 24 h were 1. heart failure, 2. COPD and asthma and 3. acute myocardial infarction, whereas the Top 3 diagnoses for patients with NIV for more than 24 h were:

	18–59 y		60–69 y		70–79 y		>80 y		Total	
A. Number of ventilated patients over 18 years										
2019	56,153		61,096		75,901		72,423		265,573	
2020	52,289		57,133		68,723		67,483		245,628	
2021	54,936		60,205		68,704		67,291		251,136	
2022	49,722		58,184		65,870		67,769		241,545	
2019–2022	213,100		236,618		279,198		274,966		1,003,882	
B. Number of ventilated patients per 100,000 population over 18 years										
2019	123		581		1005		1275			
2020	115		533		924		1137			
2021	122		549		934		1101			
2022	110		516		968		1109			
C. Mortality of ventilated patients over 18 years (number and percentage)										
2019	14,476	25.8%	20,174	33.0%	32,317	42.6%	40,443	55.8%	107,410	40.4%
2020	14,284	27.3%	20,670	36.2%	31,446	45.8%	39,719	58.9%	106,119	43.2%
2021	15,764	28.7%	23,772	39.5%	34,327	50.0%	41,290	61.4%	115,153	45.9%
2022	14,348	28.9%	22,164	38.1%	31,153	47.3%	40,684	60.0%	108,349	44.9%
2019–2022	58,872	27.6%	86,780	36.7%	129,243	46.3%	162,136	59.0%	437,031	43.5%
D. Percentage of all deceased in population over 18years										
2019	17.4%		17.6%		15.9%		7.6%			
2020	17.1%		17.4%		15.6%		6.9%			
2021	18.3%		18.8%		16.8%		6.9%			
2022	17.2%		17.2%		15.1%		6.3%			
2019–2022	17.5%		17.8%		15.8%		6.9%			

Only non-transferred cases are shown. Of note, mortality does not differ between transferred and non-transferred cases. For further details see methods and discussion.

Table 1: **Number of included patients and selected results for age groups and total population by year.**

1. asthma and COPD, 2. heart failure and 3. viral pneumonia (Supplemental Table S1).

Comorbidities were present in many patients, especially above the age of 60 years. Fig. 2B shows a Charlson-Comorbidity Index of 0 or 1 in 50.6% of cases for men aged 60 years or less (women 50.2%), whereas the percentage decreases to 31.0%, respectively 33.5% between 60 and 69 years, to 25.3%, resp. 28.7% for those aged 70–79 years and to 25.5%, resp. 28.2% above 80 years. The median duration of MV varied remarkably between the different types of MV as shown in Fig. 2C. The median in NIV patients being treated with NIV only was lowest ranging between 13 and 18 h, whereas the highest duration was reached in those with late NIV failure (193–264 h).

In-hospital mortality

43.3% mechanically ventilated patients died in hospital (minimum 27.6% in the age of 18–59 years, maximum 59.0% in the age over 80 years). We observed a remarkable increase in mortality with increasing age (Fig. 3 and Table 1). In-hospital mortality increased from 2019 to 2022 by almost 5%-points, with the number of deaths remaining stable in spite of a smaller number of patients being ventilated. Mortality varied substantially between patients being treated with different modes of MV: from 27.0% in NIV only, 31.2% in those with NIV post extubation, 53.4% in IMV only cases, 59.4% in those with early NIV failure, 68.6% with late NIV failure, to 76.5% in patients being treated with VV- or VA-ECMO. Regarding the top five main diagnoses, the highest in-hospital mortality was observed in patients with other forms of heart diseases and viral/bacterial pneumonia, while bronchitis, COPD and asthma had the relatively lowest in-hospital mortality (Table 2). 17.5% of all patients mechanically ventilated had been resuscitated before. 78% of these resuscitation patients subsequently died.

Non-surviving ventilated patients compared to all deceased in population

From 2019 to 2022, approximately 1 million people (min 939,520 in 2019 to max 1,066,341 in 2022 according to the German Federal Statistical Office (Statistisches Bundesamt) died in Germany per year. The data provided here suggests that close to 11% of these deaths occurred while being mechanically ventilated. This proportion varied between 17.5% in the age of 18–59 years and 7% in the age over 80 years (Table 1).

Costs

The average costs per adult patient on MV accounted for almost 22,000 Euro in 2019 and more than 25,500 Euros in 2022. In more detail, the median costs per case per year (IQR) were in 2019: 12,826 Euros [IQR 5512; 26,170], in 2020: 14,274 Euros [IQR 6633; 29,091], in

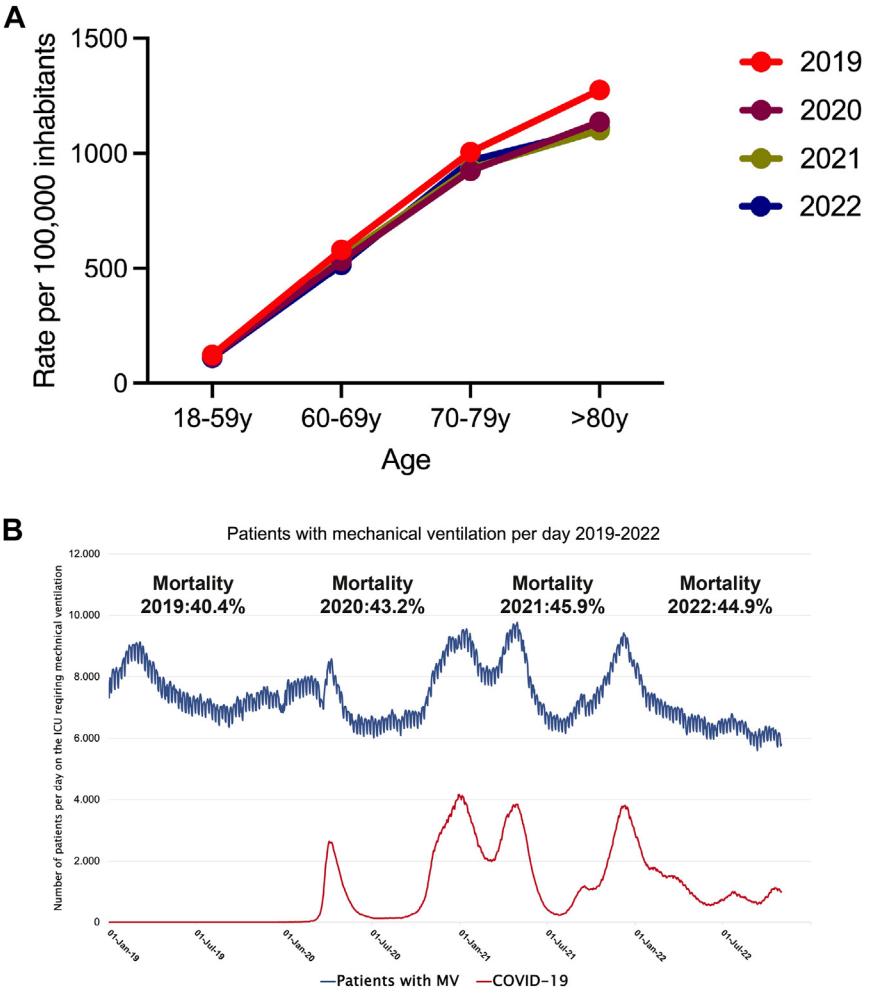

Fig. 1: **A**. Number of ventilated patients per 100,000 inhabitants in the corresponding age group. Data from US, Canada, and UK from 2018 show remarkable differences.[16] For comparison, in the group of patients over 80 years in England approx. 200 patients are ventilated per 100,000 inhabitants, in Canada 700 per 100,000 and in the US 1800 per 100,000. **B**. Patients on mechanical ventilation (all) and with COVID-19 (red) on a daily base from 2019 to 2022. Only non-transferred cases are shown. Of note, mortality between transferred and non-transferred cases does not differ significantly. For further details see methods and discussion.

2021: 15,237 Euros [IQR 7194; 30,589] and in 2022: 14,803 Euros [IQR 6504; 30,525]. The total expenditure volume was 5,770,299,478 Euro in 2019 (265,573 cases), 5,944,307,403 Euro in 2020 (245,628 cases), 6,334,007,086 Euro in 2021 (251,136 cases) and 6,168,285,574 Euro in 2022 (241,545 cases), respectively. These expenditures amounted to approximately 0.17% of the Gross Domestic Product (GDP) in 2019–2021, and 0.16% in 2022.

Discussion

The current study describes the characteristics and outcome of all patients being mechanically ventilated, either non-invasively or invasively between 2019 and 2022 in Germany. We noticed a remarkably high in-hospital mortality rate of 43.6% in this complete cohort of 1,003,822 patients discharged from 1395 hospitals, over a 4-year-period. Our main findings are: Germany has a high rate of patients being mechanically ventilated per capita even compared to most other countries with similar developed health care systems.[16] This high rate of MV increases beyond the age of 80 years to >1% (1000/100,000) per year. These patients suffer a very high in-hospital mortality rate between 50 and 70% for patients on IMV. The highest mortality rates were observed in patients with late NIV failure. There is a steep increase in mortality with age, especially in patients of 60 years and older. Furthermore, a substantial part of the German population dies while being

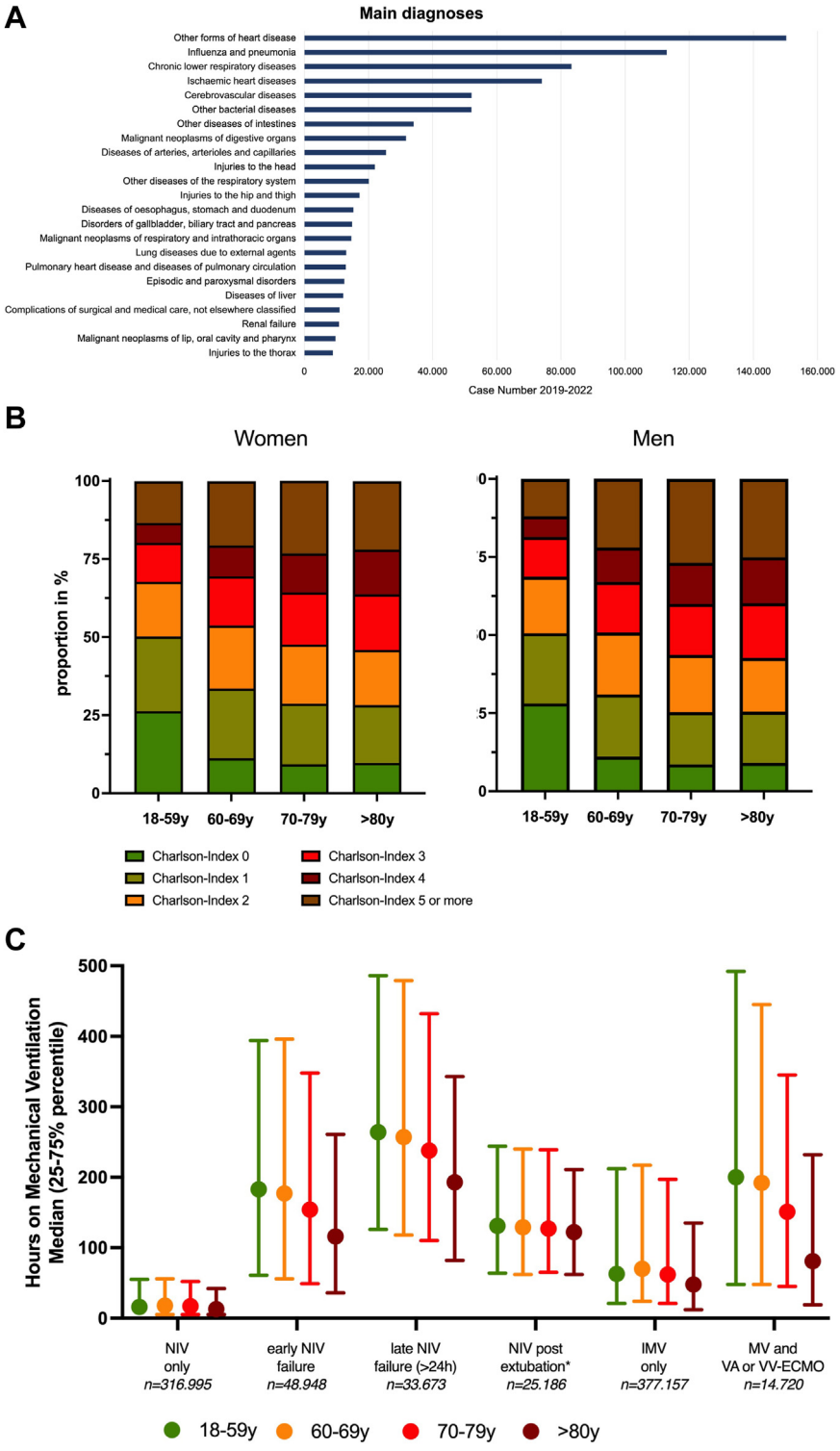

Fig. 2: **A.** Case numbers based on main diagnosis between 2019 and 2022 for patients having been mechanically ventilated, either invasively or non-invasively. **B.** Charlson Comorbidity Index in all patients with mechanical ventilation by age group and sex. **C.** Hours on ventilation (median and IQR) for different groups of MV patient Notes: Early NIV failure was defined by intubation <24 h, late NIV failure for those cases with NIV longer than 24 h. VA, veno-arterial; VV, veno-venous; ECMO, extracorporeal membrane oxygenation.

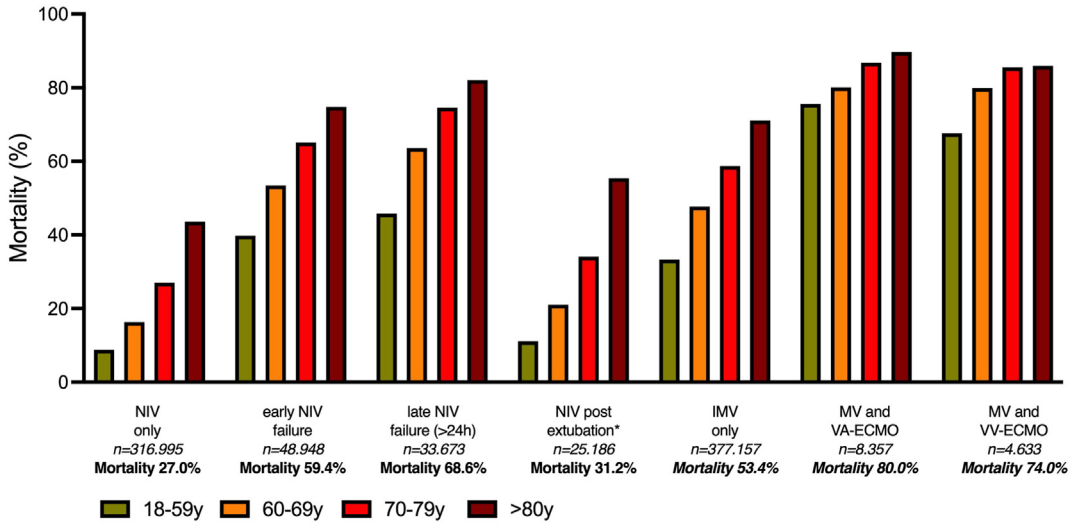

Fig. 3: In-hospital mortality rates by age and type of mechanical ventilation (for notes on types see Fig. 2C).

mechanically ventilated. Of note, the mortality even increased during the period from 2019 to 2022 by 5% points, which can be partly attributed to the COVID-19 pandemic with higher mortality rates and longer duration of MV compared to non-COVID patients (Supplemental Table S3). This accounts for patients being hospitalized and especially those on MV.[17–19]

International comparison revealed that the case count of patients being mechanically ventilated in Germany per capita is in the same range as the figures from the US and far higher compared to Canada or the UK.[16] Interestingly, only the US and Germany have the highest percentage of ventilated patients in the age group over 80. Both countries[20] similarly provide a high

	NIV only	Early NIV failure	late NIV failure (>24 h)	NIV post extubation	IMV only	VA or VV-ECMO and MV
ALL PATIENTS	27.0%	59.4%	68.6%	31.2%	53.4%	76.5%
Other forms of heart diseases	23.9%	60.2%	72.6%	29.6%	55.1%	77.3%
Viral and bacterial pneumonia	34.8%	63.9%	74.6%	35.5%	64.0%	77.8%
Bronchitis, COPD and asthma	15.5%	39.5%	55.8%	26.5%	46.3%	37.5%
Ischemic heart diseases	17.7%	62.5%	70.5%	17.6%	55.5%	80.4%
Cerebrovascular diseases	42.4%	52.2%	58.0%	39.6%	56.6%	80.6%
Other bacterial infections	42.5%	69.0%	68.6%	37.5%	70.8%	78.8%
Intestinal diseases	30.6%	60.0%	59.7%	37.9%	56.0%	77.8%
Malignant neoplasms of the digestive organs	22.4%	55.5%	58.7%	28.1%	47.7%	80.8%
Diseases of the arteries, arterioles and capillaries	24.1%	56.5%	66.7%	22.7%	56.8%	81.9%
Head injury	37.4%	50.0%	55.4%	32.0%	48.7%	78.6%
Other respiratory diseases	25.4%	49.9%	59.7%	34.1%	51.6%	69.4%
Hip and thigh injuries	44.6%	69.2%	75.0%	49.8%	63.7%	81.3%
Diseases of the esophagus, stomach and duodenum	32.4%	57.6%	60.2%	37.7%	48.8%	84.6%
Diseases of the gallbladder, bile ducts and pancreas	20.8%	58.9%	61.9%	31.7%	51.9%	72.9%
Malignant neoplasms of the respiratory system and other intrathoracic organs	41.9%	69.0%	70.1%	41.2%	54.7%	64.3%
Lung diseases caused by exogenous substances	43.2%	52.9%	51.7%	41.9%	53.9%	63.2%
Pulmonary heart disease and diseases of the pulmonary circulation	25.8%	69.1%	76.6%	19.8%	79.2%	79.2%
Episodic and paroxysmal diseases of the nervous system	23.9%	39.9%	48.0%	28.2%	29.3%	78.9%
Diseases of the liver	60.2%	80.3%	80.7%	38.6%	67.1%	83.3%
Complications of surgical procedures and medical treatment	27.8%	62.8%	68.1%	31.3%	49.5%	69.3%
Renal failure	38.1%	67.2%	70.7%	41.7%	72.2%	75.9%
Malignant neoplasms of the lip, oral cavity and pharynx	44.5%	31.9%	53.1%	13.3%	9.9%	73.7%
Injuries to the thorax	17.3%	44.6%	53.2%	20.8%	42.2%	61.9%

Table 2: **Mortality according to main diagnosis (in descending order of frequency) and type of mechanical ventilation, sorted by frequency.**

number of ICU beds, suggesting that supply-induced demand may play a role. Most of the German hospitals provide ICU beds independent of their level (Supplemental Table S2), while 6 ICU beds is the basic prerequisite even for the lowest level. However, compared to Austria, which has nearly as many capacities per 100.000 inhabitants, mortality in Germany remains higher.[21,22] Lack of advanced care planning and different admission policies may play a pivotal role. The health care costs for MV exceed more than 6 billion Euro per year, thus reaching 0.17% of the total German GDP.

ICU medicine and in particular mechanical ventilation is one of the main pillars of hospital reimbursement in Germany, as ventilated patients are grouped, independent of their diagnosis, into specific "ventilation DRGs", based on the duration of MV. Of note, CPAP is not reimbursed in Germany, therefore NIV is the first treatment of choice, even for patients with congestive heart failure.

Regarding the different types of MV, remarkable differences can be observed. Patients being non-invasively ventilated for less than 24 h had the lowest overall in-hospital mortality independent of the underlying disease, whereas early and in particular late NIV failure had the highest mortality rates exceeding by far study data known by now.[4,20,23–25] The causes for this phenomen may well be multifactorial. This data can be interpreted in light of a pathophysiologic concept, which has recently been described by Brochard and colleagues called "patient self-inflicted lung-injury".[26,27] We show here that patients with late NIV failure spend the longest time on MV and also have highest mortality rates. Moreover patients on IMV had even higher mortality rates compared to patients with the most severe form of ARDS.[28] Viral and bacterial pneumonia as main diagnosis reached mortality rates of 64% including COVID-19, influenza and other common respiratory diseases, which is by far higher than in any clinical trial.[29] Compared to other OECD countries, mortality in Germany has remained high, while it has declined elsewhere.[30] Penuelas et al.[6] could show high inter-country variability over time in the mortality of mechanically ventilated patients, while mortality decreased from 40 to 36% in the last two decades. In comparison, our data demonstrate high in-hospital mortality rates in the upper ranges of countries in that sample-based comparison. However, the strength of our study is a complete recording of all cases between 2019 and 2022, since reimbursement is dependent on transmission of the data of all hospitals.

These findings and in particular the high in-hospital mortality rate raises several questions. It may be explained in several ways: the decision for ventilation therapy may be taken too generously even in patients with a poor prognosis and/or treatment quality may be lacking. The data presented here suggests medically futile treatment choices (treatments or interventions such as resuscitation in end-stage patients, where the probability of successful outcome or patient survival is very low) in a cohort of critical ill patients, as well as a tendency towards widening the indication for MV. Futility has previously been recognized as a severe ethical problem in German Intensive Care Medicine.[29] Quality standards may not be sufficiently high compared to other countries with the same level of medical care, which show a remarkably lower mortality rate. Germany has no external quality assurance and no ICU registries as in the UK or Sweden, except for capacity monitoring. NIV, IMV and ECMO-treatment are offered in very small hospitals as well as in well-equipped centers in Germany (Supplemental Table S2).[31] The relatively low percentage of patients with post-extubation NIV compared to other countries and current recommendations is a reference to heterogenous implementation of guidelines and current recommendations. Furthermore, as shown in Supplemental Table S4, resuscitation especially in men is a main driver of mortality. Lastly, there are no data available about withholding and withdrawing life sustaining therapy, which might be a key explanation of the high in-hospital mortality rates in elderly patients.

The high reimbursement rate and the high number of intensive care beds seem to encourage futile treatment, clearly supply-dependent. However, the strongest predictor for death remains the high rate of older patients, who are treated on German ICUs. Compared to the UK, 5–10 times as many patients per 100,000 inhabitants are treated in intensive care, depending on the age group, and at least twice as many compared to Canada.[16] Very recent data show that many people over 80 are admitted to emergency rooms in Germany and obviously not a few are transferred to intensive care.[32] Regarding ECMO therapy, the pandemic increased the pre-existing mortality in heart or lung support further. Especially compared to the ELSO registry, these data give a clear hint towards treatment of ECMO patients in dedicated centers.[2,9,11,33,34]

The current data should generate a broader discussion about structural[35] and outcome quality of ICU care and futility treatment in general. A new reimbursement system which reduces cased based reimbursement and favors reimbursement on the basis of structural and personnel quality may be one key solution a future with better outcomes and is under current discussion in Germany.

The study has some limitations. In the German DRG system, a patient having been transferred between two hospitals generates two separate cases for remuneration, but accurate retrospective merging of these two and more cases was not possible. Therefore, transferred patients have been excluded from the analysis. Furthermore, it was almost impossible to accurately classify 20% of study patients in any MV group.

However, the overall in-hospital mortality of the presented cohort is 43.3% and, therefore, comparable to the cohort of 133,955 patients having been transferred with a treatment duration in the transferring hospital of longer than 24 h (42.9%). Furthermore, the in-hospital mortality of 34,736 patients having been transferred with a treatment duration in the transferring hospital of less than 24 h was 44.5%. Of note, that data on severity at admission were not available and therefore its potential on the influence of outcome cannot be estimated. Finally, previous studies indicate that a substantial number of patients successfully mechanically ventilated in hospital will eventually die in the subsequent year following hospital discharge. In this study, only in-hospital mortality is reported. The 1-year mortality rate of the patients described here is likely even higher.[36]

Conclusions

Mechanical ventilation was widely used, before, during and after the COVID-19 pandemic in Germany, reaching more than 1000 patients per 100,000 inhabitants per year in patients over 80 years. In-hospital mortality rates in this unbiased and unselected cohort in Germany exceed most of the data known by far.

Contributors

CK and RB conceived the study and its design, had full access to the data, and take responsibility for the integrity of the data and accuracy of the analysis. FK, CB and JW organised and entered data. All authors contributed to data analyses and to data interpretation. CK, TB, WW and RB wrote the main draft of the manuscript. All authors had full access to the data, contributed to the final drafting of the manuscript, read and approved the final manuscript.

Data sharing statement

The data used in this study cannot be made available in the manuscript, the supplemental files, or in a public repository due to German data protection laws (Bundesdatenschutzgesetz). Therefore, they are stored on a secure drive in the GKV-Spitzenverband to facilitate replication of the results. Generally, access to data of statutory health insurance funds for research purposes is possible only under the conditions defined in German Social Law (SGB V § 287). Requests for data access can be sent as a formal proposal specifying the recipient and purpose of the data transfer to the appropriate data protection agency. Access to the data used in this study can only be provided to external parties under the conditions of the cooperation contract of this research project and after written approval by the GKV-Spitzenverband.

Declaration of interests

C.K. received lecture fees from Maquet, Rastatt, Germany. C.K. received travel grants and fees for advisory board meetings from Xenios (Germany) and Bayer (Germany). C.K. is the speaker of the German register of ICUs and Member of the Government Commission on Modern and Needs-based Hospital Care; Member of the Expert Commission on "Resilience and Health".

F.K., C.B. and J.W. work for the National Association of Statutory Health Insurance Funds (GKV-Spitzenverband). T.B. reports no conflicts of interest.

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R.B. reports honoraria for presentations on the ongoing hospital reform in Germany. He is Member of the Government Commission on Modern and Needs-based Hospital Care; Member of the Expert Commission on "Resilience and Health"; and Chair of the Scientic Advisory Board, Federal Association of General Local Sickness Funds.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2024.100954.

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