COVID-19 pandemic affects STEMI numbers and in-hospital mortality: results of a nationwide analysis in Germany

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Abstract
Background  The COVID-19 pandemic led to extensive restrictions in Germany in 2020, including the postponement of elective interventions. We examined the impact on ST-elevation myocardial infarction (STEMI) as an acute and non-postponable disease.

Methods  Using German national records, all STEMI between 2017 and 2020 were identified. Using the number of STEMI cases between 2017 and 2019, we created a forecast for 2020 and compared it with the observed number of STEMI in 2020.

Results  From 2017 to 2020, 248,062 patients were treated for STEMI in Germany. Mean age was 65.21 years and 28.36% were female. When comparing forecasted and observed STEMI in 2020, a correlation can be seen: noticeable fewer STEMI were treated in those weeks respectively months with an increasing COVID-19 hospitalization rate (monthly percentage decrease in STEMI: March −14.85%, April −13.39%, November −11.92%, December −22.95%). At the same time, the crude in-hospital mortality after STEMI increased significantly at the peaks of the first and second waves (relative risk/RR of monthly in-hospital mortality: April RR = 1.11 [95% CI 1.02; 1.21], November RR = 1.13 [1.04; 1.24], December RR = 1.16 [1.06; 1.27]).

Conclusion  The COVID-19 pandemic led to a noticeable decrease in the number of STEMI interventions in Germany at the peaks of the first and second waves in 2020, corresponding to an increase in COVID-19 hospitalizations. At the same time, in-hospital mortality after STEMI increased significantly in these phases.
Graphical abstract
Impact of the COVID-19 pandemic on STEMI numbers and in-hospital mortality in Germany. Relative difference between forecasted and observed STEMI numbers (above figure), the relative risk of in-hospital mortality (middle figure) as well as number of new hospital admissions for COVID-19 per million inhabitants according to Roser et al.27 (bottom figure).

Keywords COVID-19 pandemic · STEMI · Myocardial infarction · In-hospital mortality · National electronic health records

Introduction
In Germany, the first lockdown restrictions due to the upcoming COVID-19 pandemic were announced on March 16, 2020. This also had a strong impact on the German healthcare system. In order to maintain hospital resources for
COVID-19 patients, the postponement of elective patients was recommended [1]. However, although emergencies continued to be treated, it is discussed in the international literature that even patients with actually life-threatening diseases might have refrained from hospitalization for fear of a potential SARS-CoV-2 infection. This is also applied in particular to cardiovascular diseases such as acute coronary syndrome or myocardial infarction [2–4].

Concerning ST-elevation myocardial infarction (STEMI), several studies in Germany [5–7] as well as internationally [2, 8, 9] have already confirmed the influence of the COVID-19 pandemic in the form of declining numbers of STEMI interventions, but their results regarding in-hospital mortality after STEMI since the beginning of the COVID-19 pandemic are still unclear. In addition, nationwide analyzes are still lacking.

Therefore, this study examines the impact of the COVID-19 pandemic on the number of catheterizations due to STEMI, using nationwide healthcare data. We compare forecasted and observed numbers of STEMI in 2020 as well as in-hospital mortality throughout the first and second waves of the COVID-19 pandemic. Finally, recommendations are to be made for future handling of the pandemic with regard to emergency interventions such as STEMI.

Material and methods

The German Federal Statistical Office has been providing data on all hospital stays in Germany via its Research Data Center since 2005. The basis of these data is inpatient hospital billing under the German Diagnosis Related Groups (DRG) system, which is based on fixed charge groups—formed on the basis of diagnoses (coded according to ICD-10) and measures performed (coded according to the German Operation and Procedure Classification/OPS). Upon prespecified request, the Research Data Center may provide analysis of their data in the form of fully anonymous, aggregated results that are released by the Research Data Center. If necessary, partial results are censored. Our study did not involve direct access by the investigators to data on individual patients but only access to summary results provided by the Research Data Center. Therefore, approval by an ethics committee and informed consent were determined not to be required, in accordance with German law. All summary results were anonymized by Research Data Center. If necessary, partial results are censored. Our study did not involve direct access by the investigators to data on individual patients but only access to summary results provided by the Research Data Center. Therefore, approval by an ethics committee and informed consent were determined not to be required, in accordance with German law.

Baseline characteristics and unadjusted endpoints

From 2017 to 2020, 248,062 patients were treated for a STEMI in Germany (Table 1). While 62,352–62,492 patients were treated per year from 2017 to 2019, in 2020 there were only 60,730 patients. Mean age was 65.21 years and 28.36% were female, which was comparable in all years observed. Other baseline characteristics such as logistic EuroSCORE and the extent of the coronary artery disease, i.e. 1-, 2- or 3-vessel disease, were also comparable in all years.

In-hospital mortality at 11.09% in 2020 was only slightly higher than the average at 10.94%. Regarding stent implantations, a continuous increase from 2017 to 2020 from 86.85 to 88.48% can be observed. The rate of mechanical ventilation > 48 h was comparable in all years.

Comparison of forecasted and observed STEMI in 2020

When comparing forecasted and observed STEMI numbers in 2020, a correlation can be seen (Fig. 1): noticeable fewer
STEMI were treated in those weeks respectively months with an increasing COVID-19 hospitalization rate (monthly percentage decrease in STEMI: March − 14.85%, April − 13.39%, November − 11.92%, December − 22.95%).

However, the observed number of STEMI interventions in those months with only small COVID-19 hospitalization rates following the first wave reached the forecasted value but did not exceed it in response to the previous lower ones. This resulted in an overall reduction of STEMI interventions in 2020 compared to 2017–2019.

When considering the forecasted and observed monthly in-hospital mortality in case of STEMI (Fig. 2), crude in-hospital mortality after STEMI increased significantly at the peaks of the first and second waves in 2020 (monthly in-hospital mortality: April RR = 1.11 [95% CI 1.02; 1.21], November RR = 1.13 [1.04; 1.24], December RR = 1.16 [1.06; 1.27]).
Discussion

Our results show that the COVID-19 pandemic resulted in a noticeable decrease in the number of STEMI interventions in Germany at the peaks of the first and second waves in 2020, corresponding to an increasing rate of COVID-19 hospitalizations. Meanwhile, in-hospital mortality after STEMI increased significantly during these phases. Decreases in the number of STEMI procedures during the lockdown were also reported by Mesnier et al. [10] in a registry study in France. Furthermore, the authors noted that there was no catch-up phenomenon in the 4 weeks following the lockdown. However, we observed a whole year. Our study confirmed those results for the entire year 2020: No catch-up effect could be observed in those months with only small COVID-19 hospitalization rates following the first wave. This resulted in an overall reduction of STEMI in Germany in 2020. There are several possible explanations for the lower number of STEMI: The population may have moved less during the lockdown, so STEMI occurred less frequently due to a reduction of excessive physical activity. The same applies to a possible decrease of professional stress, e.g. by reducing travel times or working in a familiar environment at home [2, 10]. However, these effects are speculative since physical activity is generally also considered to be a protective factor for cardiovascular disease and all-cause mortality [11, 12]. Furthermore, previous studies suggest that the rate of depression and mental stress during the COVID-19 pandemic may even have increased [13]. In addition, less pollution may have contributed to the reduced STEMI numbers. Alternatively, patients with STEMI may not have contacted medical emergency services due to fear of a SARS-CoV-2 infection [2, 10, 14]. In the last case, a catch-up effect is not to be expected.

Similar results with declining patient numbers during the COVID-19 pandemic but higher in-hospital mortality have also been observed in other disciplines such as acute stroke care [15] or in patients undergoing cholecystectomy [16].

Furthermore, Rattka et al. [2] analyzed the topic in a meta-analysis of ten international studies with 50,123 STEMI patients. In contrast to our results, the authors found no increase in in-hospital mortality. They argue that information campaigns may have been quickly implemented and pre- as well as in-hospital procedures may have been rapidly optimized by the medical teams and cardiology professionals. However, they also point out that the observed period may have been too short to discover significant differences in mortality.

On the other hand, and in line with our results, Glückman et al. [17] indicated an increasing in-hospital mortality after STEMI during the lockdown. They discussed a possible delay by patients, medical services or cardiac catheterization laboratories. Furthermore, Wienbergen et al. [18] showed a significantly higher rate of patients presenting with cardiogenic shock and out-of-hospital cardiac arrest. That may be associated with a delayed presentation in the case of STEMI and may also have contributed to the increased in-hospital mortality demonstrated in our study. Therefore, early hospital admission in the case of STEMI seems particularly important.

Consequently, people and especially patients with already known heart disease such as coronary artery disease must be made aware that they should report to medical emergency services in the event of acute symptoms, pointing out the high risk of mortality and morbidity in these cases.

Table 1  Baseline characteristics and unadjusted endpoints of all STEMI procedures in Germany in 2017–2020

|                | 2017   | 2018   | 2019   | 2020   | Total  |
|----------------|--------|--------|--------|--------|--------|
| N              | 62,488 | 62,352 | 62,492 | 60,730 | 248,062|
| Logistic EuroSCORE, mean/SD | 7.25   | 7.23   | 7.31   | 7.33   | 7.33   |
| Age in years, mean/SD | 65.04  | 65.21  | 65.26  | 65.26  | 65.26  |
| Female, %       | 28.89% | 28.07% | 28.32% | 28.14% | 28.36% |
| 1-vessel CAD, % | 29.64% | 29.33% | 29.53% | 29.08% | 29.40% |
| 2-vessel CAD, % | 28.49% | 28.28% | 28.32% | 28.65% | 28.43% |
| 3-vessel CAD, % | 36.63% | 37.30% | 37.24% | 37.47% | 37.16% |
| Left main stenosis, % | 6.10% | 6.43% | 6.18% | 6.14% | 6.21% |
| Mortality, %    | 10.83% | 10.96% | 10.87% | 11.09% | 10.94% |
| Stent implantation, % | 86.85% | 87.63% | 88.01% | 88.48% | 87.73% |
| Ventilation >48 h, % | 8.49% | 8.32% | 8.13% | 8.42% | 8.34% |

CAD coronary artery disease, EuroSCORE European System for Cardiac Operative Risk Evaluation, N number of procedures, SD standard deviation
The study has certain strengths and limitations, in accordance with previous analyzes [19–24]. A major strength is the use of a very large, complete national data set of all STEMI based on electronic health records, allowing us to draw conclusions with high applicability. There are also limitations beyond those typical of retrospective studies. The analysis relies on administrative data, so coding errors are almost unavoidable. Usually, however, 20% of DRG are reviewed by independent physician teams from health insurances, so overall reliability should be good. Furthermore, data is limited to the actual hospital stay as well as to the coded data that are transmitted by the hospitals. Therefore, statements about parameters before or after the stay, or a differentiation within the stay are not possible. This refers e.g. to parameters like rate of cardiogenic shocks or resuscitations before admission, time delays to hospitalization, or the door-to-balloon time. For the same reason, rates of out-of-hospital deaths or unsuccessful resuscitations before hospital admission due to STEMI could not be captured and thus the overall mortality may be even higher than the observed in-hospital mortality suggests. In addition, the use of risk scores recommended in the ESC Guidelines [25, 26], e.g. the GRACE risk score, was not suitable because it can hardly be calculated using the data sent to DESTATIS by the hospitals (e.g. no transmission of precise heart rate or blood pressure). The logistic EuroSCORE used in this study is therefore one way of at least roughly estimating the risk. Finally, no long-term follow-up is possible because the data source used does not allow a connection between different hospital stays of the same patient. Our study thus solely provides data on in-hospital outcomes, although for a very large, complete national yearly cohort of procedures.
Conclusions

In summary, the COVID-19 pandemic led to a noticeable decrease in the number of STEMI interventions in Germany at the peaks of the first and second waves in 2020. At the same time, in-hospital mortality after STEMI increased significantly in these phases.

Supplementary Information  The online version contains supplementary material available at https://doi.org/10.1007/s00392-022-02102-2.

Author contributions VO: conception and design as well as analysis and interpretation of the data primarily from the medical perspective, first draft, substantive revision. PS: interpretation of data, substantive revision. IH: interpretation of data, substantive revision. AH: interpretation of data, substantive revision. CM: conception and design as well as analysis and interpretation of the data particularly from the statistical-methodological perspective, first draft, substantive revision. DW: interpretation of data, substantive revision. KK: interpretation of data, substantive revision. MZ: interpretation of data, substantive revision. IH: interpretation of data, substantive revision. PS: interpretation of data, substantive revision.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval and informed consent Our study did not involve direct access by the investigators to data on individual patients but only access to summary results provided by the Research Data Center of the Federal Bureau of Statistics. Therefore, approval by an ethics committee and informed consent were determined not to be required, in accordance with German law.

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References

1. Kapsner LA, Kampf MO, Seuchter SA, Gruendler J, Gulden C, Mate S, Maraz JM, Schuttler C, Deppenwies W, Krause L, Zoller D, Balig J, Fuchs T, Fischer P, Haverkamp C, Holderried M, Mayer G, Stenzhorn H, Stolnicu A, Storck M, Storf H, Zohner J, Koblischker O, Strzelczyk A, Schuttler J, Acker T, Boeker M, Kaisers UX, Kestler HA, Prokosch HU (2020) Reduced Rate of Inpatient Hospital Admissions in 18 German University Hospitals during the COVID-19 lockdown. Front Public Health 8:594117

2. Rattka M, Dreyhaupt J, Winsauer C, Stuhler L, Baumbard M, Thiessen K, Rottbauer W, Imhof A (2021) Effect of the COVID-19 pandemic on mortality of patients with STEMI: a systematic review and meta-analysis. Heart 107:482–487

3. Toscano O, Cosentino N, Campodonico J, Bartorelli AL, Marenzi G (2021) Acute myocardial infarction during the COVID-19 pandemic: an update on clinical characteristics and outcomes. Front Cardiovasc Med 8:648290

4. Malham MM, Spata E, Goldacre R, Gair D, Curnow P, Bray M, Hollings S, Roebuck C, Gale CP, Mamas MA, Deanfield JE, de Belder MA, Luescher TF, Denwood T, Landray MJ, Emberson JR, Collins R, Morris EJF, Casadei B, Baigent C (2020) COVID-19 pandemic and admission rates for and management of acute coronary syndromes in England. Lancet 396:381–389

5. Scholz KH, Lengenfelder B, Thilo C, Jeron A, Stefanov S, Jansens U, Bauersachs J, Schulze PC, Winter KD, Schroder J, Vom Dahl J, von Beckerath N, Seidl K, Friede T, Meyer T (2020) Impact of COVID-19 outbreak on regional STEMI care in Germany. Clin Res Cardiol 109:1511–1521

6. Seiffert M, Brunfer FJ, Remmel M, Thomalla G, Marschall U, L’Hoest H, Acaar L, Debus ES, Blankenberg S, Gerloff C, Behrendt M (2021) Acute myocardial infarction during the COVID-19 pandemic: a review and meta-analysis. Heart 107:482–487

7. Eckner D, Hofmann EM, Ademaj F, Marinovic K, Vogt F, Becher PM, Schrage B, Westermann D, Pauschinger M (2021) Differences in the treatment of acute coronary syndrome in the pre-COVID and COVID Era: an analysis from two German High-Volume Centers. J Cardiovasc Dev Dis 8:145

8. De Luca G, Verdoia M, Cerneck M, Jensen LO, Vlakvuijs M, Calmac L, Johnson T, Ferrer GR, Ganyukov V, Wojakowski W (2020) Impact of COVID-19 pandemic on mechanical reperfusion for patients with STEMI. J Am Coll Cardiol 76:2321–2330

9. Rodríguez-Leor O, Cid-Álvarez B, de Prado AP, Rossello X, Ojeda S, Serrador A, López-Palop R, Martín-Moreiras J, Rourrés OJ, Cequier À (2020) Impact of COVID-19 on ST-segment elevation myocardial infarction care. The Spanish experience. Revista Española de Cardiología (English Edition) 73:994–1002

10. Mesnér J, Cottin Y, Coste P, Ferrari E, Schiele F, Lemesle G, Thuillier C, Angoulvant D, Cayler G, Bouleti C (2020) Hospital admissions for acute myocardial infarction before and after lockdown according to regional prevalence of COVID-19 and patient profile in France: a registry study. Lancet Public Health 5:e536–e542

11. Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, Collet J-P, Corrado D, Drezner JA, Halle M (2021) 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease: the Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). Eur Heart J 42:17–96

12. Piercy KL, Troiano RP, Balfour RM, Carlson SA, Fulton JE, Galuska DA, George SM, Olson RD (2018) The physical activity guidelines for Americans. JAMA 320:2020–2028
13. Bäuerle A, Teufel M, Musche V, Weismüller B, Kohler H, Het-kamp M, Dörrie N, Schweda A, Skoda E-M (2020) Increased
generalized anxiety, depression and distress during the COVID-19
pandemic: a cross-sectional study in Germany. J Public Health
42:672–678
14. Hannan EL, Wu Y, Cozzens K, Friedrich M, Tamis-Holland J,
Jacobs AK, Ling FS, King SB III, Venditti FJ, Walford G (2021)
Percutaneous coronary intervention for ST-elevation myocardial
infarction before and during COVID in New York. Am J Cardiol
142:25–34
15. Richter D, Eyding J, Weber R, Bartig D, Grau A, Hacke W, Kro-
gias C (2021) Analysis of nationwide stroke patient care in times
of COVID-19 pandemic in Germany. Stroke 52:716–721
16. Koch F, Hohenstein S, Bollmann A, Meier-Hellmann A, Kuhlen
R, Ritz J-P (2022) Cholecystectomies in the COVID-19 pandemic
during and after the first lockdown in Germany: an analysis of
8561 patients. J Gastrointest Surg 26:408–413
17. Gluckman TJ, Wilson MA, Chiu ST, Penny BW, Chepuri
VB, Waggoner JW, Spinelli KJ (2020) Case rates, treatment
approaches, and outcomes in acute myocardial infarction dur-
ing the coronavirus disease 2019 pandemic. JAMA Cardiol
5:1419–1424
18. Wienbergen H, Retzlaff T, Schmucker J, Marin LAM, Rühle S,
Garstka D, Osteresch R, Fach A, Hambrecht R (2021) Impact of
COVID-19 pandemic on presentation and outcome of consecu-
tive patients admitted to hospital due to ST-elevation myocardial
infarction. Am J Cardiol 151:10–14
19. Oettinger V, Kaier K, Reinecke H, Schmoor C, Frankenstein
L, Vach W, Hehn P, von zur Mühlen C, Stachon P (2020) Out-
comes of transcatheter aortic valve implantations in high-volume
or low-volume centres in Germany. Heart 106:1604–1608
20. Kaier K, Oettinger V, Reinecke H, Schmoor C, Frankenstein
L, Vach W, Hehn P, von zur Mühlen C, Bode C, Zehender M,
ReinhöI J (2018) Volume–outcome relationship in transcatheter
aortic valve implantations in Germany 2008–2014: a secondary
data analysis of electronic health records. BMJ Open 8:e020204
21. Stachon P, Hehn P, Wolf D, Heidt T, Oettinger V, Zehender M,
Bode C, von zur Mühlen C, Kaier K (2021) In-hospital outcomes
of self-expanding and balloon-expandable transcatheter heart
valves in Germany. Clin Res Cardiol 110:1977–1982
22. Schrage B, Becher PM, Gößling A, Savarese G, Dabboura S, Yan
I, Beer B, Stöfker G, Seiffert M, Kluge S, Kirchhoff P, Blanken-
berg S, Westermann D (2021) Temporal trends in incidence,
causes, use of mechanical circulatory support and mortality in
cardiogenic shock. ESC Heart Failure 8:1295–1303
23. Neumann JT, Gößling A, Sörensen NA, Blankenberg S, Mag-
nussen C, Westermann D (2020) Temporal trends in incidence
and outcome of acute coronary syndrome. Clin Res Cardiol
109:1186–1192
24. Freisinger E, Fuerstenberg T, Malýar NM, Wellmann J, Keil U,
Breithardt G, Reinecke H (2014) German nationwide data on
current trends and management of acute myocardial infarction:
discrepancies between trials and real-life. Eur Heart J 35:979–988
25. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci
C, Bueno H, Caforio AL, Crea F, Goudevenos JA, Halvorsen S
(2018) 2017 ESC Guidelines for the management of acute myo-
cardial infarction in patients presenting with ST-segment eleva-
tion: the Task Force for the management of acute myocardial
infarction in patients presenting with ST-segment elevation of the
European Society of Cardiology (ESC). Eur Heart J 39:119–177
26. Collet J-P, Thiele H, Barbato E, Barthélémy O, Bauersachs J,
Bhatt DL, Dendale P, Dorobantu M, Edvardsen T, Folliguet T
(2021) 2020 ESC Guidelines for the management of acute cor-
onary syndromes in patients presenting without persistent ST-
segment elevation: the Task Force for the management of acute
 coronary syndromes in patients presenting without persistent ST-
segment elevation of the European Society of Cardiology (ESC).
Eur Heart J 42:1289–1367
27. Roser M, Ritchie H, Ortiz-Ospina E, Hasell J (2020) Coronavirus
Pandemic (COVID-19), Published Online at OurWorldInData.org.
https://ourworldindata.org/COVID-hospitalizations