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Short communication

Impact of COVID-19 immunisation on COVID-19 incidence, hospitalisations, and deaths by age group in Germany from December 2020 to October 2021

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ABSTRACT

Background: Utilising national surveillance data, we investigated the impact of the COVID-19 immunisation campaign on COVID-19 morbidity and mortality between December/2020 and October/2021 in Germany.
Methods: We compared patterns in immunisation coverage, incidence, hospitalisations, and deaths among 12–17, 18–59, and 60+ year-olds and examined these patterns within the context of anti-pandemic measures.
Results: COVID-19 incidence increased in all age groups following the end of lockdown restrictions in March/2021, but as Germany experienced successive peaks in incidence, age groups with higher immunisation coverage experienced successively smaller peaks. Notwithstanding corresponding increases during periods of higher incidence, among those aged 60+ years, COVID-19 related hospitalisations and deaths declined considerably as immunisation coverage increased, despite circulation of virus variants known to cause more severe illness.
Conclusion: Although ecological in nature, this study allows us to demonstrate clear patterns of decline in COVID-19 morbidity and mortality in Germany during the course of the immunisation campaign.

1. Introduction

Germany began its national immunisation campaign against Coronavirus Disease 2019 (COVID-19), on December 27th, 2020 [1], immunising its population in order of age and risk prioritisation, with older age groups and those at higher risk of severe disease or exposure being vaccinated first [2,3]. All COVID-19 vaccinations are notified to the Robert Koch Institute (RKI), which maintains the national COVID-19 Electronic Vaccination Coverage Monitoring database (*Digitales Impfquotenmonitoring, DIM*) [4].

With this study, we investigated the population level impact of the COVID-19 immunisation campaign on COVID-19 incidence, hospitalisations, and deaths between December 2020 and October 2021 in Germany. We considered key anti-pandemic measures such as lockdowns and border controls, as well as spread of Variants of Concern (VoC) in our analysis. To our knowledge, only one state-level study on the effect/impact of immunisation at population level has been conducted to date in Germany [5]. With this analysis, we aim to rectify this knowledge gap and provide a first national overview of the impact of the immunisation campaign on the course of the COVID-19 pandemic.

2. Methods

Vaccination data (date of last vaccine dose, full vaccination status, and age group) were extracted from the DIM database. We included vaccinations administered between January 4th, 2021 (Calendar Week (CW) 01/2021) and September 26th, 2021 (CW38/2021). Individuals were considered fully vaccinated if they had received two doses of the BioNTech/Pfizer, Moderna, or Oxford/AstraZeneca vaccines in any combination or one dose of the Johnson & Johnson vaccine, and ≥14 days had elapsed since the last dose. Booster vaccinations were excluded from this analysis.

Abbreviations: RKI, Robert Koch Institute; DIM, *Digitales Impfquotenmonitoring* [Electronic Vaccination Coverage Monitoring]; VoC, Variant of Concern; CW, Calendar Week; NPI, Non-pharmaceutical intervention.

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As DIM is an anonymised immunisation registry that does not contain COVID-19 case data, data on COVID-19 incidence, hospitalisations, and deaths were extracted from RKI's national infectious disease notification database (SurvNet 3.0). The study period began on December 7th, 2020 (CW50/2020) to identify trends in COVID-19 morbidity and mortality in the weeks before the immunisation campaign and ended on October 17th, 2021 (CW41/2021). Case and vaccination data were extracted three weeks later on November 8, 2021 to account for notification lag. All laboratory-confirmed cases of COVID-19 who had a valid entry for age were included (99.96% of all notified cases). Cases who were notified as having been hospitalised with COVID-19 (any cause) or as having died due to COVID-19 were included in the hospitalisation and mortality analyses, respectively. Information on hospitalisation status was available for 79% and information on death status was available for 97% of all notified cases. Notification date was utilised for the incidence and hospitalisations analyses, whereas date of death was used for the mortality analysis.

We examined the vaccination coverage and case data by age group (12–17, 18–59, and 60+ years) and for the entire German population. We calculated, by age group, vaccination coverage, average incidence and average number of hospitalisations and deaths by calendar week, per 100,000 population (2020 German population [6]). The weekly values were then plotted in four separate plots. On the vaccination coverage plot, we denoted the availability and recommendations for vaccine products in Germany, as well as prioritisation rules. On the incidence, hospitalisations, and death rate plots, we denoted anti-pandemic measures and VoCs that potentially influenced the spread of the virus.

Ethical approval and informed consent were deemed not necessary as all data were collected via routine surveillance and anonymised at collection. Data analysis was conducted in R (version 3.6.1) and figures were created in Microsoft Excel 2019.

3. Results

3.1. Vaccination coverage

From the start of the immunisation campaign, weekly vaccination coverage for complete immunisation against COVID-19 was highest among the 60+ years age group in comparison to the other age groups (Fig. 1). It increased rapidly between approximately CW19/2021 and CW28/2021 and slowed considerably thereafter. Rapid vaccination uptake was seen among the 18–59 year-olds between approximately CW20/2021 and CW32/2021 and among the 12–17 year-olds from approximately CW30/2021 onwards. By the end of CW38/2021, 84% of those aged 60+ years, 70% of 18–59 year-olds, and 33% of 12–17 year-olds were fully vaccinated, translating to 64% of the entire German population.

3.2. Incidence

Towards the beginning of the study period (CW51/2020), average weekly COVID-19 incidence was 206 cases per 100,000 among those aged 60+ years and 238, 170, and 210 per 100,000 among those aged 18–59 years, 12–17 years, and the entire population, respectively (Fig. 2). A nationwide lockdown was implemented in Germany in CW51/2020, followed by the start of the immunisation campaign in CW52/2020. COVID-19 incidence decreased rapidly in all age groups from CW01/2021. From CW08/2021 onwards, the 60 + years age group had the lowest incidence in comparison to all other age groups. Average incidence rose once again in all age groups and peaked in CW15-CW16/2021 (first incidence peak of 2021), following the easing of lockdown restrictions in CW09/2021 and in parallel with the dominantly circulating B.1.1.7. (Alpha) variant. However, the increase in the 60+ years age group was smaller (from 48 cases per 100,000 to 96 cases per 100,000) relative to the age groups 18–59 years (from 80 to 206 per 100,000) and 12–17 years (from 45 to 244 per 100,000). At the same time, vaccine coverage at CW13/2021 was 13%, 3%, and 0.2% among those aged 60+ years, 18–59 years, and 12–17 years, respectively. Incidence continued decreasing in the oldest age group between CW15/2021 and CW27/2021, to 2 per 100,000, and reached a maximum of 23 per 100,000 when Germany experienced its second incidence peak of 2021 at CW35/2021, driven by the dominant circulation of the B.1.617.2 (Delta) variant (CW33/2021 vaccine coverage: 82%).

Among the 18–59 year-olds, the incidence pattern over time followed a very similar trajectory to the oldest age group, with the magnitude of the peaks decreasing with each successive incidence peak, particularly from the first (CW16/2021: 207 cases per 100,000) to the second peak (CW35/2021: 100 per 100,000) of 2021 (CW33/2021 vaccine coverage: 63%). Due to the large population size of this age group, the decline in incidence also simultaneously led to a steep decrease in the national COVID-19 incidence for Germany.

Over the course of 2021, the youngest age group of 12–17 year-olds overtook the two older age groups to have the highest COVID-19 incidence. At the second peak of 2021 in CW35/2021, incidence in this age group was 221 cases per 100,000 population (CW33/2021 vaccine coverage: 18%).

3.3. Hospitalisations

At the start of the study period, those aged 60+ years had the highest average weekly COVID-19 hospitalisation rate by far at 40 hospitalisations per 100,000 population in CW51/2020; in comparison, hospitalisations were 6 and 2 per 100,000 among those aged 18–59 years and 12–17 years, respectively (Fig. 3). Hospitalisations followed a pattern over time similar to that of case incidence, with two peaks occurring in 2021 around the same time periods. As with case incidence, the hospitalisation rate decreased considerably in the oldest age group after CW51/2020; gradual decreases of smaller magnitude were also present in the younger age groups during this period. Following the easing of the lockdown restrictions in CW09/2021, hospitalisations once again showed an increasing trend for all age groups. However, the magnitude of the hospitalisation rate at the first peak of 2021 was much smaller among the 60+ years age group in comparison to the previous peak among this age group: hospitalization rate at CW51/2020 was 40 per 100,000, whereas it was 19 per 100,000 at CW15/2021. By the time of the second, Delta-driven peak in CW36/2021, the hospitalisation rate was 6 per 100,000 in the 60 + years age group. Among those aged 18–59 years, the relatively low hospitalisation rate declined further between the first 2021 peak (CW16/2021: 7 per 100,000) to the second (CW34/2021: 4 per 100,000). Hospitalisation rate remained constantly low at approximately 1–2 hospitalisations per 100,000 for those aged 12–17 years throughout the study period.

3.4. Deaths

Deaths due to COVID-19 among the 60+ years age group followed a very similar pattern over the study period as that observed for hospitalisations, with an offset of 1–2 weeks (Fig. 4). The death rate for the entire German population was driven by the relatively high rate of death among those aged 60+ years in comparison to the younger age groups. In CW52/2020, those aged 60+ years died at a rate of 33 per 100,000 population, while the rate was 0.5 deaths per 100,000 for those aged 18–59 years and no deaths were notified among the 12–17 year-olds. Deaths among the 60+ years

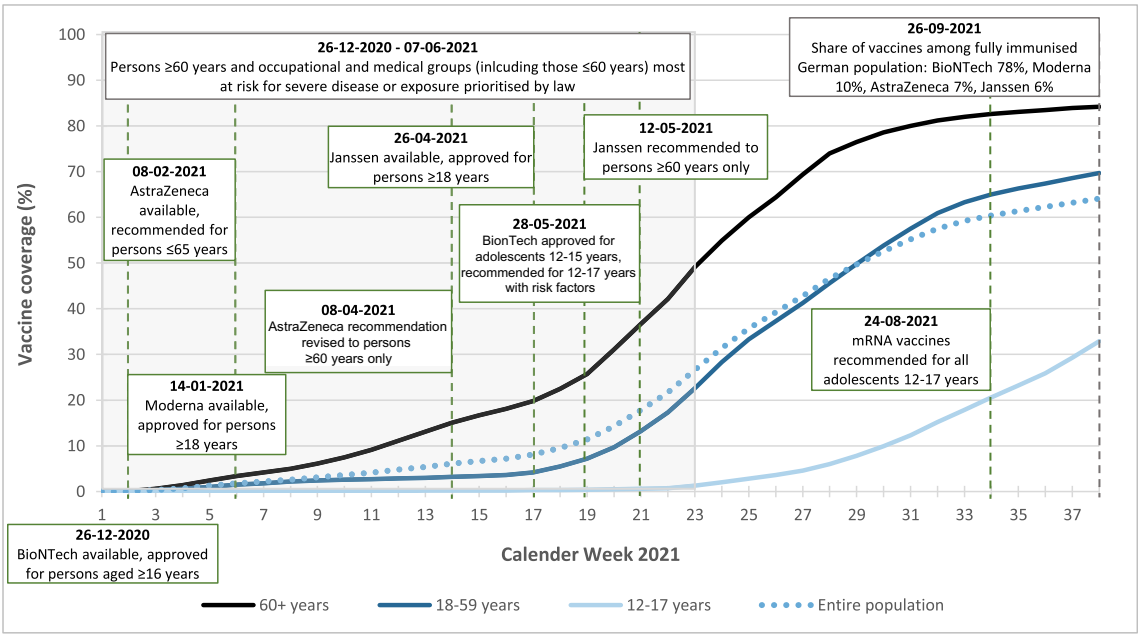

Fig. 1. Weekly COVID-19 vaccination coverage (%) between January 4, 2021 and September 19, 2021 in Germany.

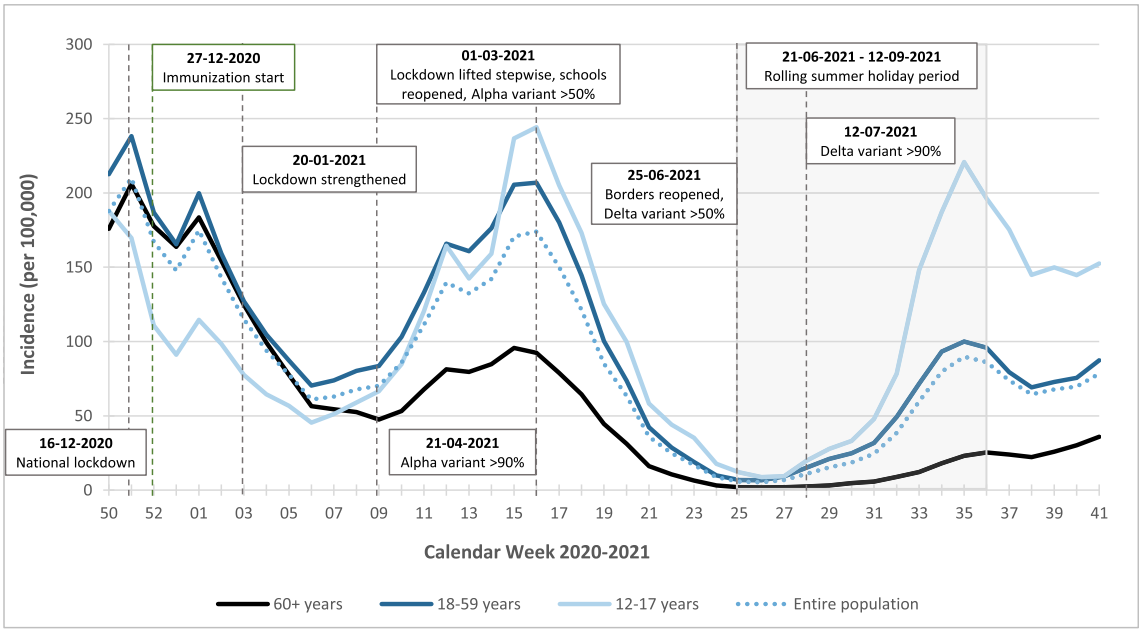

Fig. 2. Average weekly COVID-19 incidence (per 100,000 population) between December 7, 2020 and October 17, 2021 in Germany.

age group declined substantially over the course of 2021, with the rate being 8 deaths per 100,000 in CW15-CW17/2021 (first 2021 peak) and then falling further to 2 deaths per 100,000 in CW37/2021 (second 2021 peak).

Among the other age groups, deaths due to COVID-19 remained consistently very low during the entire study period; the rate in the overall population decreased from 10 deaths per 100,000 population in CW52/2020 to less than 1 per 100,000 by CW37/2021.

4. Discussion

COVID-19 is a complex disease that countries have to combat by using multifaceted strategies. In Germany, measures to reduce social contacts, border controls, mask-wearing, regular testing, and contact tracing are just some of the many anti-pandemic measures that have been in place from almost the beginning of the pandemic. Immunisation joined this list of measures in December 2020. Our analysis attempts to tease out the potential impact of the COVID-19 immunisation campaign in Germany as it was being implemented in parallel to other anti-pandemic measures.

Due to the stepwise ramp-up of the immunisation campaign by age group, with older adults being prioritised, we investigated the change in COVID-19 incidence, hospitalisations, and deaths by age group over time, with the assumption that the effects of other anti-pandemic measures remained somewhat constant between age groups within the same time periods. All three parameters had been on an upward trajectory in Germany for all age groups due

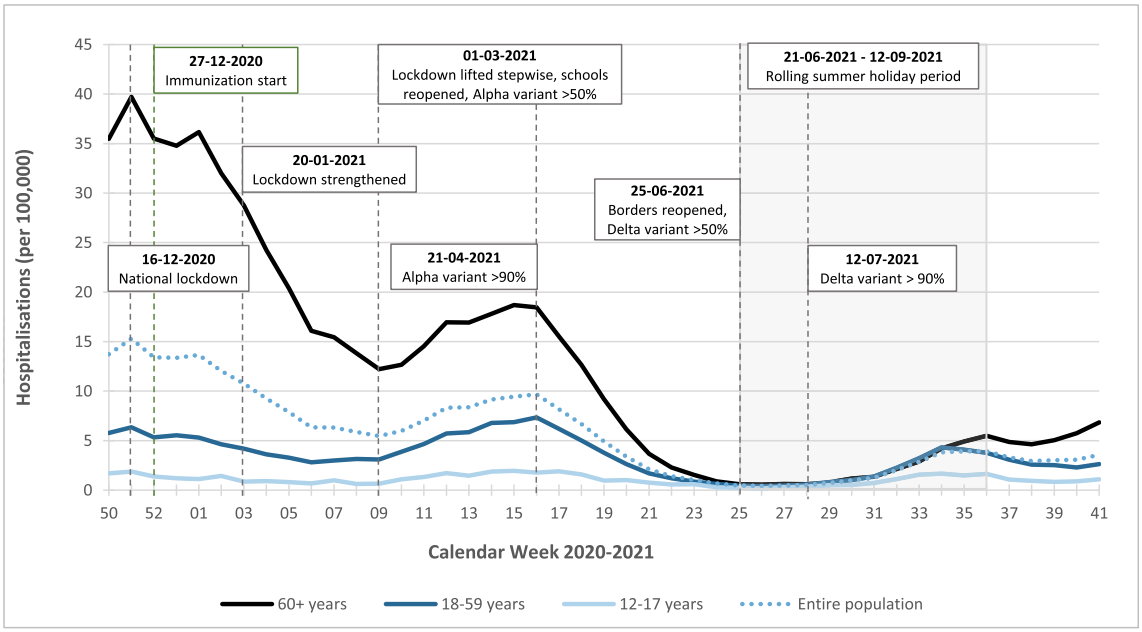

Fig. 3. Average weekly COVID-19 hospitalisations (per 100,000 population) between December 7, 2020 and October 17, 2021 in Germany.

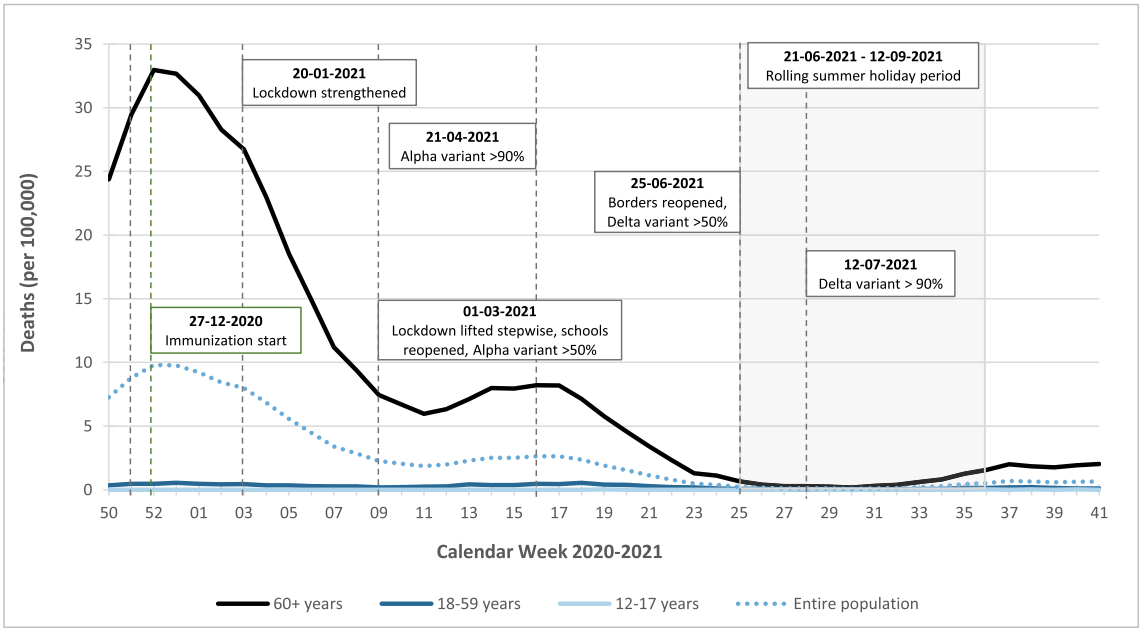

Fig. 4. Average weekly COVID-19 deaths (per 100,000 population) between December 7, 2020 and October 17, 2021 in Germany.

to the spread of the Alpha variant prior to the immunisation campaign [7], prompting the implementation of a nationwide lockdown in mid-December 2020. The lockdown and other anti-pandemic measures led in the following weeks to sharply declining COVID-19 incidences in all age groups in Germany, as also seen elsewhere [8]. However, as these restrictions were eased in CW09/2021, near simultaneous and steep increases in COVID-19 incidence were observed in all age groups, with the exception of those aged 60+ years. Among this age group, which had the highest vaccination coverage among all age groups by CW09/2021, the magnitude of incidence increase was substantially lower. Similarly, considerable declines in COVID-19 related hospitalisations and deaths among those aged 60+ years were seen in the weeks following the start of the lockdown. Although hospitalisations and deaths increased once again as lockdown measures were eased, during the study period their rates did not reach the peak levels observed in 2020 just prior to the immunisation campaign. Combined together, these findings potentially indicate that increasing immunisation coverage likely played an important role in controlling the burden of COVID-19 among the oldest, most vulnerable age group in Germany, when paired together with a raft of other, non-pharmaceutical interventions (NPIs). Similar differences in incidence and vaccination coverage between adolescents and adults at the CW35/2021-peak underscore this observation.

Our study results are in line with those of a similar ecological study on the initial impact of the COVID-19 immunisation campaign in Israel [9]. In that study, age groups prioritised for vaccination showed clear declines in COVID-19 morbidity and mortality that were in addition to the declines contributed by other external factors. Among these was a national lockdown that was imple-

mented during the immunisation campaign due to the rapid emergence and spread of the Alpha variant [9], a situation mirroring that of Germany. The Alpha variant became the dominant variant among the German population by the beginning of CW09/2021, when national lockdown restrictions began to be lifted, and spread in parallel to the ongoing immunisation campaign [4]. Despite the Alpha variant having a higher transmissibility rate [10] and leading to higher mortality [11] in comparison to previous strains, the overall steep declines in COVID-19 incidence and deaths among the 60+ year-olds during this time period in Germany provide another indication of the positive impact of the immunisation campaign.

This hypothesis is supported further by the lower COVID-19 incidence observed among age groups with higher vaccination coverage, i.e. 18–59 year-olds and 60+ year-olds, at CW35/2021, despite the dominantly circulating Delta variant [12], which is more transmissible than the Alpha variant [13]. The Delta variant is also associated with increased risk of hospitalisation; however, hospitalisation rate among the 60+ years age group during the Delta-driven peak remained substantially lower in comparison to previous peaks [14]. These results align well with outcomes from other studies that show that vaccine protection against more severe disease outcomes continues to remain high, despite changing external factors [15].

A major limitation of our study is that it is ecological in nature and that it investigates the impact of immunisation coverage on COVID-19 outcomes at the population level. This descriptive method prevents us from making any causal inferences, since the effects of other factors, such as NPIs [16,17] and behavioural changes [18], in reducing the burden of COVID-19 differentially by age group cannot be overlooked. Seasonal aspects of COVID-19 [19,20] likely influenced the overall trends in incidence over the study period, but were not separately investigated. Moreover, we utilized passive disease surveillance data, rather than data that were actively collected and verified for our study purposes. Therefore, issues such as under-reporting, data incompleteness, and misclassification of clinical outcomes could have influenced our findings, especially during periods of high incidence. Nonetheless, despite its simple methodology, the study reveals successive patterns of decline in COVID-19 incidence, hospitalisation, and deaths in Germany in the first year of the immunisation campaign, a finding that likely cannot be attributed to NPIs and seasonality alone.

Our study presents the first results on the impact of the COVID-19 immunisation campaign in Germany using real-world data. Future studies should use more detailed individual-level data in order to assess the effectiveness of the vaccination campaign and to confirm the findings of this ecological study. This is especially crucial in light of recent evidence regarding the waning of vaccine-induced protection over time, as well as the possible lower effectiveness of vaccines against the Omicron variant.

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Authors' contributions

NP, ASt, and ASi conceived the study. NP, Ast, and AU contributed equally to secondary data collection and the data analysis. All authors contributed to the interpretation of the results. NP wrote the first manuscript draft. All authors contributed to the revised manuscript and approved the final version for publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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