Facemasks and COVID-19 case fatality rate

by

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Acknowledgments

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Abstract

Mask mandates have been a globally used epidemiologic intervention during the ongoing COVID-19 (coronavirus disease 2019) pandemic. Although there is extensive supporting literature on the use of facemask to reduce infection rates, its effect on the individual and course of disease has remained controversial. The purpose of this study was to find if mandatory masking influences the case fatality rate. This study used data on case updates, mask mandates, and demographic status related to the Kansas state, USA. The data were analyzed using a parallelization approach based on county-level data.

The results showed that in Kansas during the summer of 2020, the counties with mask mandate had significantly higher case fatality rates compared to counties without mask mandate, with a risk ratio of 1.85 [1.51–2.10] for death with COVID-19.

Even after adjusting for the number of 'protected persons', i.e., the number of persons who were not infected in the mask-mandated group compared to the no-mask group, the risk ratio remained significantly high at 1.52 [1.24–1.72]. By analyzing the excess mortality in Kansas, this study determines that over 95% of this effect can solely be attributed to COVID-19. The cause of this trend and the possible connection between long-term effects associated with SARS-CoV-2 and facemasks are explained in the theory herein by the 'foegen effect'; i.e., deep reinhalation of pure virions caught in the facemasks as droplets can worsen the prognosis.

This finding suggests that the use of facemasks in COVID-19 pandemic did contribute to an increase in the death toll counterintuitive of its purpose, making mask mandates a highly debatable epidemiologic intervention.

Introduction

The COVID-19 pandemic struck the world with over 100 million confirmed cases and over 2.3 million confirmed deaths worldwide by February 6th, 2021[1], resulting in a case fatality rate (CFR) of about 2.3%. The mortality rate of COVID-19 has been shown to increase with the overall mortality rate of the population[2]. Mortality rate is the most commonly expressed measure of the frequency of occurrence of deaths in a defined population during a specified interval. However, the crude death rate calculates the number of deaths in a geographical area during a given year, per 100,000 mid-year total population of the given geographical area during the same year. Therefore, it is a better parameter to assess death rates among different populations.

Mandatory wearing of masks to cover the nose and mouth is a widely applied strategy in the management of the COVID-19 pandemic across many countries in the world. A lot of focus has been centered on the question whether mask mandates reduce infection rates. A study conducted in the Kansas state of USA showed a reduction in infection rates,[3] while a Danish study did not find any protective effect of wearing masks[4]. A lot less focus has been centered on the course of the disease while using masks. However, the important question should always be "how many lives can be saved?", not "how many infections can be prevented?". There is a common concept that the severity of the disease depends on the number of virions transmitted, and that masks reduce that number and thus the severity of the disease[5,6], which can result in reduced CFR. The opposite of the above concept, an unproven hypothesis, would be that by inhibiting the clearance of virions from the respiratory tract, the facemask might actually worsen any underlying respiratory disease, which would increase the CFR. While that sounds far-fetched at first glance, there are some hints in the literature that might actually support this hypothesis.

An improved clearance of the respiratory system by the use of mucoactive agents has been proven to reduce exacerbations of respiratory tract infections against placebo, be it herbal medicine[7] that has been used for centuries, or newly developed pharmaceutical drugs[8,9]. Certain observations during the ongoing COVID-19 pandemic, especially the high death rate among the medical personnel in Italy during the "first wave" of the pandemic[10] could be attributed to their working for many hours with facemasks, despite being ill. While one might think that obstructing the exhalation pathway in respiratory infections has never been done before, this is actually done regularly when patients develop acute respiratory distress syndrome (ARDS): Patients are not given facemasks but ventilation masks to increase oxygen supply. A study by Frat et al.[11] compared these ventilation masks to a nasal cannula and they found a significant difference in favor of a nasal cannula in a 90-day mortality assessment. A study by Patel et al.[12] compared ventilation masks to an airtight but ventilated helmet around the patient´s head. The trial was stopped early based on predefined criteria for efficacy; the mask group had a significantly worse intubation rate, ventilator-free days, and overall mortality. While the authors discuss a slightly higher positive end-expiratory pressure (PEEP) in the ventilation mask group being responsible for this, a meta-analysis by Guo et al.[13] shows that a high PEEP is actually correlated with better outcome.

Therefore, the aim of this study was to prove whether one of these concepts can be confirmed by comparing the CFR between two groups, one with and the other without mask mandates. The corresponding two-sided hypothesis is that mask mandates change the CFR.

The state of Kansas, USA has over 2.8 million residents. During the summer of 2020, Kansas State issued a mask mandate, but it allowed its 105 counties to either opt out or issue their own mask mandate. Out of the 81 counties that had opted out and did not issue their own mask mandate, 8 large cities from seven counties, had issued a mask mandate. The comparison of infection rates among these counties has already been done by Van Dyke et al[3], showing a benefit of mask mandates. This current study focused on the CFR, and whether mask mandates actually saved or cost lives during the COVID-19 pandemic.

Method

This study applied secondary data on case updates, mask mandates, and demographic status related to the Kansas state, USA. A 3+2 step model was applied for the analysis of these data.

Step 1: The counties were split in two groups, mask-mandated counties (MMC) and counties without mask mandates (noMMC). *Step 2:* The two groups were parallelized to eliminate confounding by old age and illness. *Step 3:* The data was analyzed, including the calculation of a risk ratio (RR) for MMC compared to noMMC. If a significant RR was obtained, further evaluation was performed to check for bias and confounders (steps 4a and 4b):

Step 4a: Check for infection rate correlated bias (Does a difference in infection rate or a testing bias between the groups negate the significant effect of RR?)
Step 4b: Confounder check (Can the difference in RR be explained by something other than SARS-CoV-2?)

Step 1: Categorizing the counties in two groups

Using the information on counties with facemasks from the study by Van Dyke et al.[3], which used data from the Kansas Health Institute and CDC, the 105 counties were categorized into MMC and noMMC groups. Further, I checked the noMMC group that had known cities with mask mandates[14] to assess the percentage of the county population[15] that was represented by these cities[16].
If the city's population was within +/-20% of half of the county's population (that is, between 30% and 70%), the county was excluded. If the city's population represented more than 70% of the county, it was moved to the MMC group. If the city's population represented less than 30% of the county, the counties remained in noMMC group.
The cut-off percentage of +/-20% was chosen to keep counties that could dilute the results out of evaluation, guaranteeing that the cities with mask mandates constituted of more than twice of or more than half of the county's population not under a mask mandate.

Step 2: Parallelizing the groups

I parallelized the counties for comparison based on the crude death rate (CDR) as it represents age and pre-existing illness in the underlying population; in this process counties that could not be aligned were excluded. This process of parallelization is a customized modification of the usual process used in parallel studies. It is based on larger groups (county population) instead of individuals while likewise aiming to eliminate the aforementioned confounder.
Old age and pre-existing illness are the most important known factors for death in COVID-19. Therefore, both groups need to have almost the same CDR to be comparable. A comparison of raw CDR[16] showed that it varied from 575.8 to 2010.1 (deaths per 100,000 people per year) among

Kansas' counties.

Further, the CDR of each county for 2019 was modified by subtracting deaths from causes that are clearly not a risk factor for COVID-19 to prevent statistical anomalies when comparing CDR, like deaths from other causes that are related to neither old age nor pre-existing illness. These included pregnancy complications, birth defects, conditions of the perinatal period (early infancy), sudden infant death syndrome, motor vehicle accidents, all other accidents and adverse effects, suicide, homicide, and other external causes[17].

This modified crude death rate (mCDR) of the counties was then population-weighted (multiplied with population of county divided by population of group) and added up to calculate the mCDR (total number of expected deaths per 100,000 people per year) of both the MMC and noMMC groups.

In order to have almost the same mCDR in both groups, counties with the lowest mCDR in the group with a lower mCDR and the counties with the highest mCDR in the group with a higher mCDR were excluded until both groups had the same mCDR.

Therefore, I used a lower cut-off limit of mCDR for one group and an upper cut-off limit of mCDR for the other, trying to reduce this difference while at the same time trying to keep the percentage of Kansas population included as big as possible.

Note: mCDR was only used for parallelization; it was not used in calculations beyond step 2.

Step 3: Analyzing the data

As the mask mandate was issued on July 3rd, August 1st was considered as the start date to allow counties, cities, residents, institutions, shops, and all business undertakings to adjust to the mask mandate and prevent overlap with time before the mask mandate as the effect of mask mandates may not be visible immediately.

Moreover, October 15th was fixed as the end date as proof of mask mandates was available up to that point, and the existent mask mandates were revised a few weeks after that date. The number of infected cases[18] was calculated for this period.

The COVID-19 death count in Kansas[19] is not personalized, meaning for each death counted there is no information on the person's infection date. After referring to the study by Khalili et. al.[20], the calculation of deaths was delayed to 14 days after the COVID-19 infection time period. In order to mitigate the influence of the start and end of the time interval, the number of deaths as the average of death differences between August 7th and October 22nd, August 14th and October 29th, as well as August 21st and November 5th was calculated. This way, both infection and death data were obtained for a span of 76 days. Based on these numbers, infection rates and CFR were calculated for both groups.

A fourfold table was applied for the Chi square test (α=0.05) and RR (MMC to noMMC), and 95%CIs were calculated to determine whether the mask mandates significantly increased or decreased the CFR by COVID-19.

All statistical calculations were done using LibreOffice 4.1. (The Document Foundation, Berlin, Germany).

Step 4a: Infection rate correlated bias check (when applicable)

If the RR was significant, it was verified whether a difference in infection rate explains the difference in the CFR. For this, $\lambda_{low\text{-}CFR}$ was considered the infection rate of the group with a lower CFR, and $\lambda_{high\text{-}CFR}$ was considered the infection rate of group with a higher CFR.

The two possibilities were:

1) The group with low CFR also has a lower infection rate.

If $\lambda_{low\text{-}CFR} < \lambda_{high\text{-}CFR}$, there might be a testing bias.

The hypothesis to this would be that if both groups had been tested equally and both had equal infection rates, the CFR would not be significant. In order to prove this hypothesis, the number of deaths in the group with a lower CFR was reduced by multiplying it with the factor (λ_{low} / λ_{high}), the fourfold table from step 3 was revised, and a repeat calculation of the Chi-square, RR, and 95%CI was done.

2) The group with lower CFR has a higher infection rate.

If $\lambda_{low\text{-}CFR} > \lambda_{high\text{-}CFR}$, there might be a bias by protection.

The hypothesis would be that if those protected by a reduced infection rate were counted as survivors (although they could still be infected later), the CFR would not be significant.

In order to prove this hypothesis, the number of infected people in the group with a higher CFR was increased by multiplying it with the factor (λ_{low} / λ_{high}), the fourfold table from step 3 was corrected, and calculation of Chi square, RR, and 95%CI was revised.

Step 4b: Confounder check (when applicable)

If the RR was significant, further analysis was performed to find whether a confounder caused the RR (for MMC) to increase or decrease independently of SARS-CoV-2 infection. The hypothesis would be that a confounder in MMC causes increase or decrease in the RR independently from SARS-CoV-2. If this were true, the effect of masks would occur not only in the infected population but also among the not infected population under mask mandate. This can be proven wrong if the potential effect does not align with overall excess mortality in Kansas. Figure 1 illustrates this process in the case of an increase in the RR.

Figure 1	Graphic illustration of the confounder check (for RR increase)	
	MMC	noMMC
Infected Population	XXOOOOOOOOOOXXXXX	XXOOOOOOOOOOXXXOO
	XXOOOOOOOOOOXXXXX	XXOOOOOOOOOOXXXOO
	XXOOOOOOOOOOXXXXX	XXOOOOOOOOOOXXXOO
Noninfected Population	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO
	XXOOOOOOOOOOOOOXX	XXOOOOOOOOOOOOOOO

This illustration shows survivors as O and dead as X.
Orange and red X represent known COVID-19 deaths.
The hypothesis would be that red X are caused by a confounder, not COVID-19.
Under this hypothesis, we would expect the blue X to appear.
Red X represent the *additional deaths*, calculated as:

$$| (1/\Phi-1) * death_{MMC} |$$

where Φ is RR (or the values of both ends of its 95% CI).
Blue *and* red X represent the *expected additional deaths* (if hypothesis was true), calculated as:

$$\text{additional deaths} * Population_{MMC} / Infected_{MMC}$$

Finally, the proportion of RR increase that can be explained by the hypothesis, i.e. the proportion of RR increase that is *not* related to COVID-19, is calculated as:

Kansas non-COVID-19 excess deaths / expected additional deaths

Therefore, it was necessary to calculate the additional deaths by mask mandates or the reduced death by mask mandates (for RR and both ends of its 95% CI as in step 3).

These additional/reduced deaths were calculated as the absolute value of

$$(1/\phi - 1) * death_{MMC}$$

where ϕ is RR (or the values of both ends of its 95% CI), and $death_{MMC}$ is the number of deaths in MMC. Further, the expected additional/reduced deaths (in all infected and non-infected) in all MMC counties were calculated by dividing by the number of infected persons in MMC (as obtained in step 3) and multiplying with the total population in all MMC (from step 1).

This result was compared to the (total) Kansas non-COVID-19 excess mortality during the corresponding weeks as already calculated by the CDC[21]. This is done by calculating and adding up the difference between non-COVID-19 deaths and the average expected number of deaths for each given week. The resultant value is the non-COVID-19 excess deaths.

By dividing this number with the expected additional/reduced deaths in all non-infected in all MMC countries, it is possible to estimate the proportion of the RR increase/decrease calculated in step 3 that is *not* related to COVID-19 and thus indicating the influence of possible confounders.

Results

Step 1: Categorizing the counties in two groups

Figure 2 gives an overview of the mask mandates in Kansas counties.

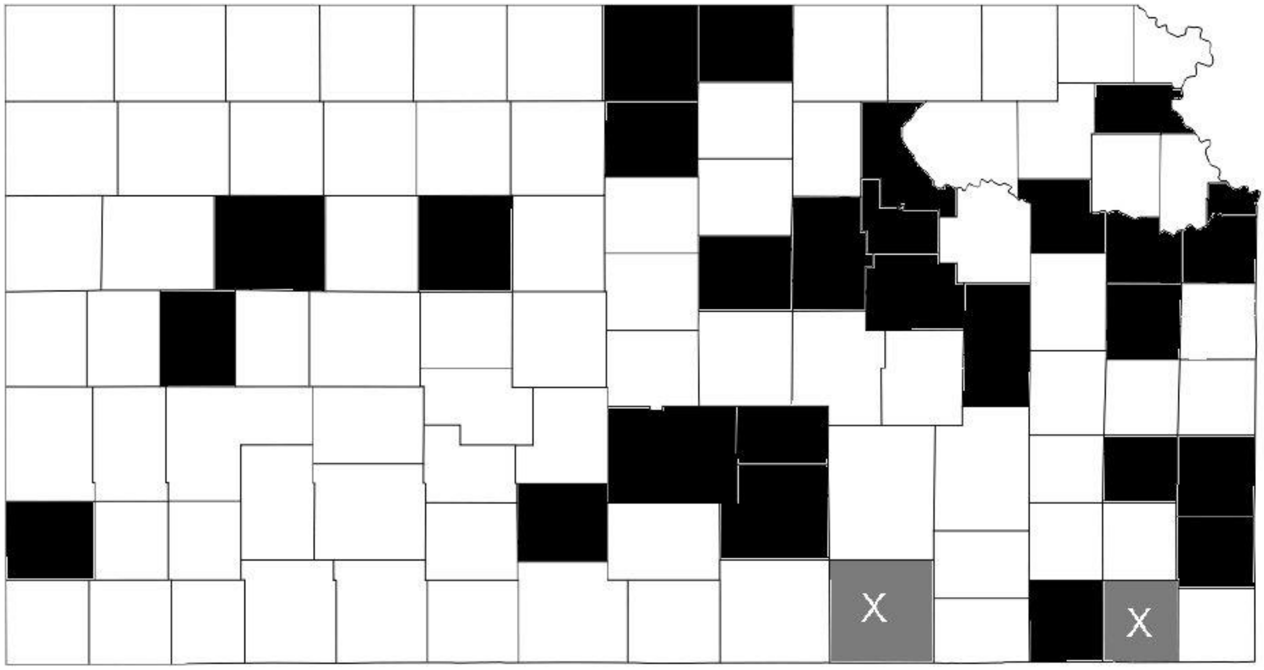
Figure 2 Mask mandates in Kansas counties

black: county with mask mandate
grey: larger city with mask mandate in county without mask mandate
white: county without mask mandate

Evaluation of the cities with mask mandates in noMMC is shown in Table S1 (supplemental appendix).

Figure 3 shows the result of these evaluations. There were 27 counties in the MMC group, 76 in the noMMC group, and 2 were excluded.

Figure 3 Counties after evaluating the major cities with mask mandates in the noMMC



black: MMC (mask mandate counties)
white: noMMC (no mask mandate counties)
'X': county excluded

Step 2: Parallelizing the groups

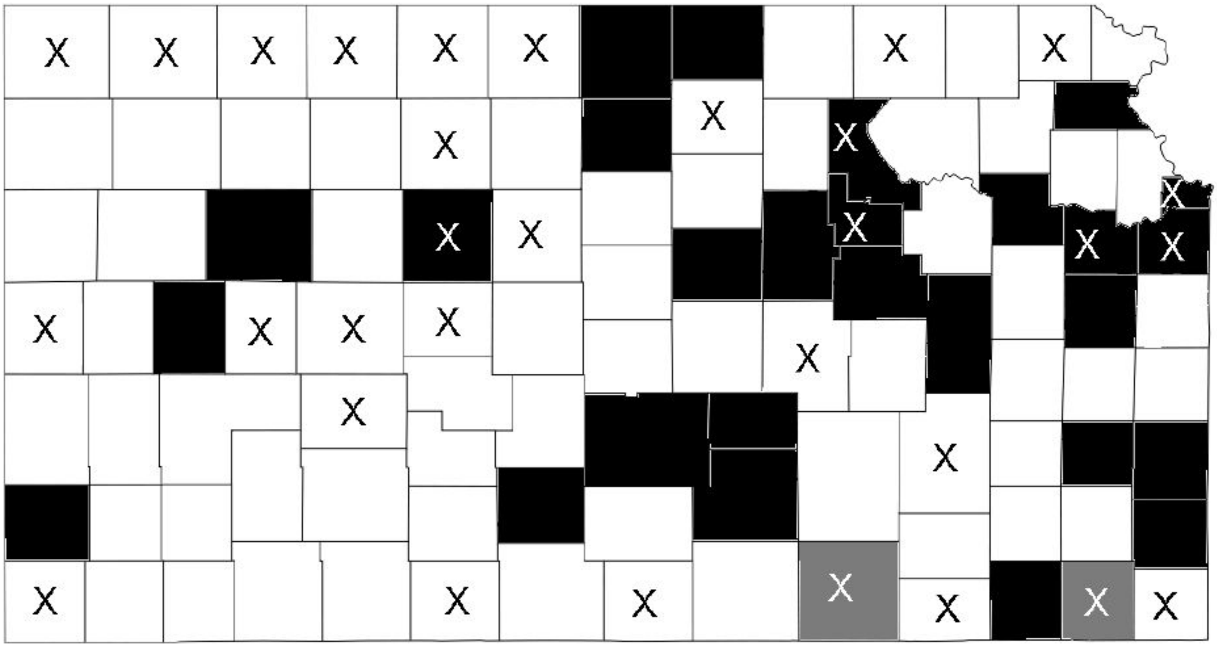
Before parallelizing, the mCDR of noMMC group was 1,012.6 deaths per 100,000, while the MMC had an mCDR of 782.5 deaths per 100,000.

Figure S1 (supplemental appendix) shows the scatterplot of mCDR and CFR by county and after step 1.

After parallelizing both groups in terms of mCDR, by fixing the cut-off limits of mCDR to > 800 deaths per 100,000 for MMC and <1,350 deaths per 100,000 for noMMC, the difference in mCDR between both groups became 0.5 deaths per 100,000 (926.2 vs. 925.7) which resulted in adequate parallelization of the groups.

These cut-off limits eliminated 31 counties (mostly small counties from noMMC category) and 41.3% of the population (mostly from MMC). Note that Sedgwick county with 516,042 people and an mCDR 802.5 deaths per 100,000 got narrowly included in the analysis. Figure 4 shows the counties after step 2.

Figure 4 Kansas counties that were finally included in the analysis



black: MMC (mask mandate counties)
white: noMMC (no mask mandate counties)
'X': county excluded

The names of these final counties and their corresponding group are shown in Table S2 (supplemental appendix).

It was also possible to exclude Sedgwick county by altering the cut-off limit of mCDR to >805 for MMC and >600 for noMMC, which resulted in a difference of 8.7 deaths per 100,000 in mCDR (less than one percent). Because this option will almost halve the population of MMC, in order to keep the sample size as big as possible, these changes were not applied. However, steps 3, 4a, and 4b were performed by applying these cut-off limits. The results were equally highly significant and did not diverge (Table S3 supplementary appendix).

Step 3: Analyzing the data

NoMMC group included 638,955 people and the MMC group included 1,072,139 people.

The number of infected people in noMMC was 9,880 (infection rate 1.55%) with 95 deaths. The number of people infected in MMC was 13,655 (infection rate 1.27%) and 241 deaths.

Therefore, the resulting CFR by COVID-19 was 0.96% for noMMC and 1.76% for MMC.

Chi square test results indicated a significant difference in the number of deaths between the two groups ($p<0.0001$) with an increased risk (RR) of 1.85 for MMC (95%CI 1.51−2.10).

Step 4a: Infection rate correlated bias check

As the RR was significant and infection rate in noMMC was higher, I checked for protection bias. After correcting as described above in the methods, a revised fourfold table was prepared with 16,578 infected cases instead of 13,655 (which would correspond to a CFR of 241/16,578=1.45% for MMC).

These alternative numbers after checking for infection rate bias still resulted in a highly significant p value ($p = 0.0005$) RR of 1.52 for MMC (95%CI 1.24−1.72).

Step 4b: Confounder check (optional)

The additional deaths among those infected in MMC was 111 (95%CI 82−126). If they were not related to COVID-19, I would expect 17,031 (95%CI 12,582−19,333) additional deaths among non-infected.

The average number of expected all-cause deaths in Kansas totally from August 2nd to November 7th was 6867 (98 days compared to the study's 76 days). There were 7382 deaths without COVID-19, resulting in 515 excess deaths not related to COVID-19.

This evidently means that non-COVID factors (i.e., possible confounders) represent less than 3.0% (95%CI 4.1%−2.7%) of the RR increase, thus looking at other factors that would reduce that percentage even further (noMMC counties among excess deaths and adjusting for the different timespan mentioned above) was unnecessary.

Furthermore, Table S4 (Supplemental Appendix) demonstrates the change of RR under the assumption that of 15% of deaths were not caused by severe complications of COVID-19 as underlying cause of death[13].

Discussion

The objective of this study was to find out whether mask mandates contribute to the COVID-19 CFR by comparing data between Kansas counties that had mask mandates and those that did not have mask mandates during the same time period in the summer of 2020. The comparison of counties within one state has many advantages: Differences in access to and quality of the health system, testing numbers, culture and behavior regarding health and mask usage, climate, and time of infection peaks are all minimal. The most important finding from this study is that contrary to the accepted thought that fewer people are dying because infection rates are reduced by masks, this is not the case. Results from this study strongly suggest that the mask mandates actually caused 1.52 times the number of deaths or 52% more deaths compared to no mask mandates. This means that the risk for the individual wearing the mask is even higher, because there is an unknown number of people in MMC who either do not obey mask mandates, are exempted for medical reasons or who do not go to public places where mask mandates are in effect. These people do not have an increased risk and thus the risk on the remaining people is actually higher.

The mask mandates themselves have increased the CFR by 1.85 or by 85% in counties with mask mandates. It was also found that almost all of these additional deaths were attributed solely to COVID-19. Therefore, this number is most likely underestimated and depends to a large extent on the percentage of people who tested positive for SARS-CoV-2 but did not die with COVID-19 as the underlying cause of death. The study by Cobos-Siles et al.[22] described that 15% of patients with COVID-19 infection died from decompensation due to other pathologies and the cause of death was unrelated to severe complications of COVID-19. The study by Rommel et al.[23] describes that from 38.641 deaths with and by COVID-19 only 31.638 (81.9%) were reported with COVID-19 as underlying cause of death. Correcting for this phenomenon (using the former value by Cobos-Siles) raises the RR for deaths with COVID-19 as the underlying cause to 2.10.

The explanation for the increased RR by masks is probably that virions that enter or those coughed out in droplets are stopped in the facemask tissue, and after quick[24] evaporation of the droplets, pure virions (virions not inside a droplet) are re-inhaled from a very short distance when breathing in. For further reference, I will refer to this process as the ‘foegen effect' as literature review did not yield any results on this effect and it has not been described earlier.

In the ‘foegen effect’ the virions are not only spreading to other areas (like the olfactory nerve, causing loss of smell) but also (because of their smaller size) deeper into the respiratory tract[25]. They bypass the bronchia and are inhaled deep into the alveoli, where they can cause pneumonia instead of bronchitis, which would rather be typical for a virus infection. They also bypass the wall of the multilayer squamous epithelium that they cannot pass in vitro[26] and most likely cannot pass in vivo. Therefore, the only probable way for the virions to enter the blood vessels is through the alveoli.

The study by Chan et al.[27] proves the ‘foegen effect’ in a golden Syrian hamster model without actually discussing its findings. In this study, a significant increase in viral load was observed in the lungs of masked hamsters compared to the naive hamsters ($p<.05$).

The 'foegen effect' also increases overall viral load, because virions that should have been removed from the respiratory tract are returned. The viral reproduction in vivo, including the reproduction of the returned virions, is exponential compared to the linear[28] droplet reduction caused by the mask. Therefore, the number of exhaled or coughed out virions that pass through the facemask will at some point exceed the number of virions shed without facemasks. In addition, the pure virions in the mask might also be blown outwards when breathing out, resulting in aerosol transmission instead of droplet transmission. This is also further reinforced in the golden Syrian hamster model mentioned above, as the result of the ‘foegen effect’ (i.e. an increased viral load in the lung) was also found when only the infected hamster was masked. Moreover, these two effects might be linked to a resurgence of rhinovirus[29].

The use of "better" masks than just a surgical face mask (like FFP2, FFP3) with a higher droplet filtering capacity probably causes an even stronger 'foegen effect', as the number of virions potentially re-inhaled increases the same way that outward shedding is reduced.
Another very important point to consider is that the long-term effects that have been described in association with COVID-19 may all be a direct cause of the 'foegen effect'. With the virus entering the alveoli and blood, and not being restricted to the upper respiratory tract and bronchi (as explained above), it can cause damage by initiating an (auto)immune reaction in most organs.

With respect to the proposed consequences of the ‘foegen effect’, the question is whether the main driver for the global death toll and long-term effects of COVID-19 is the “new” spike protein of SARS-CoV-2 (compared to other *Coronaviridae*) or rather the widespread use of masks as recommended by the WHO.

Limitations and scope

As this study is only based on secondary data analysis, future studies with a prospective design are required to understand this research question more clearly.
Since ethical principles prevent clinical studies from proving the 'foegen effect' *in vivo* in humans, and wearing a mask is not blindable, proving the 'foegen effect' further in humans may be very difficult, especially considering that the helmet trial[12] described above was stopped before completion as the results for the mask group were extremely poor. However, a sick person breathing out through a mask (without inhaling) and a puppet ‘inhaling’ through that same mask into a particle collector shortly after might help prove the ‘foegen effect’.
As far as animal models are concerned, the effect was already observed in a golden hamster model. Research on other animals, especially rhesus monkeys should be conducted. However, it is important to note that the effect was observed on day 5 post-challenge, but not after day 7. This indicates that the duration of the effect is shorter in healthy individuals, which is plausible given

that, the overall access of immune cells to alveola epithelium is better compared to the epithelium of oropharynx. This means that when testing for the 'foegen effect' in animals, multiple endpoints for sacrifice (e.g. daily) should always be considered.

Further research is needed to quantify the number of deaths for which COVID-19 was not the underlying cause, both in populations with and without mask mandates, to further understand the full extent of the effect on CFR explained above.

The consequences which the 'foegen effect' proposes in respect to aerosol transmission and viral load on infection rates should be evaluated in further research.

Conclusion

I conclude that wearing facemasks might impose a great risk on the individual that is **not** mitigated by a reduction in the infection rate. Use of facemasks therefore seems unfit if not contraindicated as an epidemiologic intervention against COVID-19.

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Declaration of conflicts of interest:

The author and his family live in a country with mask mandates (Germany). As a general practitioner, the author is obliged to wear masks at work. There are no conflicts of interests, financial or otherwise to declare.