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# Covid-19 after vaccination in haemodialysis patients

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**Abstract:** Introduction

Patients receiving haemodialysis are at high risk from Covid-19, and demonstrate impaired immune responses to vaccines. There have been several descriptions of their immunological responses to SARS-CoV-2 vaccination, but few studies have described the clinical efficacy of vaccination in haemodialysis patients.

Methods
In a multi-centre observational study of the London haemodialysis population undergoing surveillance PCR testing during the period of vaccine roll-out with BNT162b2 and AZD1222, all those positive for SARS-CoV-2 were identified. Clinical outcomes were analysed according to predictor variables including vaccination status.
Results
SARS-CoV-2 infection was identified in 1323 patients of different ethnicities (Asian/other 30%, Black 38% and White 32%) including 1047 (79%) unvaccinated, 86 (7%) post-first-dose, and 190 (14%) post-second-dose vaccination. The majority of patients had a mild course but 515 (39%) were hospitalised and 172 (13%) died. Older age, diabetes and immune suppression were associated with greater illness severity. In regression models adjusted for age, comorbidity and time period, prior two-dose vaccination was associated with a 75% (95%CI: 56-86) reduction in admissions and 88% (95%CI: 70-95) reduction in deaths compared to unvaccinated patients. No loss of protection was seen in patients over 65 years, or with increasing time since vaccination, and no difference was seen between vaccine types.
Discussion
These data demonstrate a substantial reduction in the risk of severe Covid-19 after vaccination in this vulnerable population.

# Covid-19 after vaccination in haemodialysis patients

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**Significance Statement**

Patients receiving in-centre haemodialysis are particularly susceptible to SARS-CoV-2 infection, partly due to impaired immune responses, which may also reduce vaccine effectiveness.

A large multi-centre haemodialysis population was observed clinically, and with weekly PCR screening, over the period when vaccination became available. Predictors of clinical events following a diagnosis of SARS-CoV-2 infection were analysed with regression models.

Covid-19 was still observed after vaccination, but compared to unvaccinated patients, hospital admission, respiratory support and death were all less frequent. Vaccination in this group appears protective against adverse clinical outcomes including hospitalisation and death.

## Abstract

### Introduction

Patients receiving haemodialysis are at high risk from Covid-19, and demonstrate impaired immune responses to vaccines. There have been several descriptions of their immunological responses to SARS-CoV-2 vaccination, but few studies have described the clinical efficacy of vaccination in haemodialysis patients.

### Methods

In a multi-centre observational study of the London haemodialysis population undergoing surveillance PCR testing during the period of vaccine roll-out with BNT162b2 and AZD1222, all those positive for SARS-CoV-2 were identified. Clinical outcomes were analysed according to predictor variables including vaccination status.

### Results

SARS-CoV-2 infection was identified in 1323 patients of different ethnicities (Asian/other 30%, Black 38% and White 32%) including 1047 (79%) unvaccinated, 86 (7%) post-first-dose, and 190 (14%) post-second-dose vaccination. The majority of patients had a mild course but 515 (39%) were hospitalised and 172 (13%) died. Older age, diabetes and immune suppression were associated with greater illness severity. In regression models adjusted for age, comorbidity and time period, prior two-dose vaccination was associated with a 75% (95%CI: 56-86) reduction in admissions and 88% (95%CI: 70-95) reduction in deaths compared to unvaccinated patients. No loss of protection was seen in patients over 65 years, or with increasing time since vaccination, and no difference was seen between vaccine types.

### Discussion

These data demonstrate a substantial reduction in the risk of severe Covid-19 after vaccination in this vulnerable population.

## Introduction

In-centre haemodialysis patients face a dual hazard from SARS-CoV-2: firstly, whilst the majority of the population are able to adhere to lockdown measures, the need to attend dialysis creates a greater likelihood of exposure to infection; secondly, as a group with comorbidity and impaired immune responses, infection is more severe once acquired [1,2]. As a consequence, in these patients there is a high relative risk of death across all age groups [3].

Whilst the development of vaccines has been shown to induce robust immune responses and protect individuals against infection in the general population [4,5], haemodialysis patients have generally been excluded from these trials. Several studies have investigated either humoral [6-8] or cellular immune responses [9] to vaccination in dialysis patients, but there has been limited evidence of clinical effectiveness, aside from comparative vaccine efficacy [10].

The clinical effectiveness of vaccination remains a pressing concern in this group of vulnerable patients [11] and is vital for supporting vaccine promotion amongst hesitant patients. This study aims to estimate the clinical efficacy of vaccination in preventing severe disease in haemodialysis patients developing SARS-CoV-2 infection.

## Methods

This cohort study of SARS-CoV-2 infections in prevalent haemodialysis patients included all patients with positive PCR on surveillance or otherwise indicated testing, between 1st December 2020 and 26th September 2021. Dates were chosen to include as many first and second doses as possible, running from the start of the vaccination program, until third doses were offered to this patient group in the UK. The study was sponsored by St George's Hospital and received approval from the National Research Ethics Service (IRAS Ref 283130).

In-centre haemodialysis is provided to approximately 5500 patients in London across seven renal centres, with enhanced infection surveillance and isolation of cases during the pandemic, described elsewhere [2]. During the study period all centres had a policy of temperature / symptom screening at every dialysis session, SARS-CoV-2 RNA testing of all patients on a weekly basis, and additional RNA testing of contacts of cases. Cases otherwise identified, for example presenting to emergency services, were also included. Patients

receiving home dialysis were excluded, as were those receiving short-term dialysis for recoverable kidney disease. SARS-CoV-2 infection date was defined by the date of the first positive RNA during the observation period. Prior infection was defined if there was positive RNA more than 90 days previously, whereas cases following prior infection within 90 days were regarded as persistent viral shedding rather than new infection, and excluded.

Clinical severity definitions included any hospital admission within 14 days (including a small number of infections acquired in patients already hospitalised), any period of sustained oxygen use within 28 days, any ventilatory support (including non-invasive methods) within 28 days, and death from any cause within 28 days (with or without hospital admission). These outcomes were defined hierarchically so that each category includes more severe outcomes. In a secondary analysis Covid-19 deaths were identified by excluding deaths due to an alternative pathology, to which SARS-CoV-2 was non-contributory. Immune suppression was defined if at the onset of infection patients were receiving steroids (equivalent to prednisolone >10mg daily), tacrolimus, mycophenolate or azathioprine, or if they had received cytotoxic chemotherapy or immunomodulating biologic agents within the last six months. Differences in Covid-19 outcomes have been reported so ethnicity from electronic records was collected and grouped as Asian/other, Black and White.

Time period of infection was included as a predictor variable to account for secular trends, based on month, amalgamating those with few cases, making 6 time periods. The dominant SARS-CoV-2 variant in London was Alpha (B.1.1.7) during periods 1-3, and Delta (B.1.617.2) during periods 4-6 [12]. Only two vaccines were used in this period: BNT162b2 (Pfizer-BioNTech) or AZD1222 (Oxford-Astra-Zeneca). Data were missing for vaccine type in three cases, but complete for comorbidity and clinical outcome. Patient status was coded as vaccinated (first or second dose) 10 days after vaccine administration.

Predictors of clinical outcome were analysed using mixed logistic regression models, with fixed effects including age, gender, ethnicity, diabetes, immune suppression, prior SARS-CoV-2 and time period, with renal centre as a random effect. Effect sizes were expressed as odds ratios with 95% confidence interval, and estimated vaccine efficacy was defined as 1 - odds ratio. Sub-group analyses were performed to estimate the effect of age, vaccine type and time since vaccination, with boundaries chosen to give roughly equal group sizes. Sensitivity

analyses were performed in which patients with prior SARS-CoV-2 were excluded, time reduced to just two periods (periods 1-3 and 4-6), and infections prior to 15th January (when the earliest patients reached 10 days post second-dose vaccination) were excluded.

**Results**

Between 1st December 2020 and 26th September 2021, SARS-CoV-2 infection was detected by PCR in 1323 haemodialysis patients (aged 18-95 years, 60% male, with ethnicity grouped as Asian/other 30%, Black 38% and White 32%) with a bimodal epidemic time course (Figure 1). Patients began receiving first-dose vaccination from 10th December and second-dose vaccination from 5th January.

At the time of diagnosis, 1047 patients (79.1%) were unvaccinated, 86 (6.5%) were at least 10 days beyond their first dose, and 190 (14.4%) were at least 10 days beyond their second dose. The majority of PCR samples were taken in the dialysis unit as part of weekly surveillance, or in response to exposure or symptoms, but 6% were taken on a Sunday, therefore at least this many were taken in an emergency healthcare setting. Immune suppressing treatments were taken by 164 patients (12.4%), of which 44% were on tacrolimus or cyclosporin monotherapy, 20% were on monotherapy with steroids, azathioprine or mycophenolate, 19% were on combinations of these, and 17% had been receiving cytotoxic chemotherapy or biologic agents. Further patient characteristics are given in Table 1.

A mild course was observed in 808 patients (61.1%) who did not require admission, but 378 (28.6%) at least required oxygen and 172 (13.0%) died before 28 days. SARS-CoV-2 was thought incidental to the illness and death in 22 cases, so that Covid-19 was the cause of death in 150 cases (11.3% of all cases, 87.2% of deaths within 28 days). The performance of clinical variables in predicting disease severity is shown in Table 2: older age, diabetes and immune suppressing treatment were associated with greater illness severity, as were later time periods (when Delta emerged as the dominant SARS-CoV-2 strain in London).

Compared to unvaccinated patients, adverse clinical outcomes were observed less than half as often in patients testing positive for SARS-CoV-2 at least 10 days after the second dose. In logistic regression models adjusted for demographics, comorbidity and time period, more substantial effects were seen with vaccination associated with a 75% (95%CI: 56-86)

reduction in admissions and an 88% (95%CI: 70-95) reduction in deaths (Table 2). Modest differences were observed after just the first dose, with a 45% (95%CI: 3-69) reduction in admissions.

The protection associated with vaccination was most obvious in patients over 65 years, in whom severe outcomes were reduced at least as much after vaccination as in their younger peers. No difference was seen in vaccine associated protection with respect to vaccine type, and neither was there any waning effect observed over time, with similar reductions in severe outcomes observed following second doses given less or more than 4 months previously (following vaccine by median(IQR) 3.0(2.2-3.5) or 5.0(4.5-5.5) months respectively, Figure 2, Supplementary Table 1).

In sensitivity analyses, very similar vaccine effects were seen when those with prior SARS-CoV-2 were excluded, when time was reduced to two periods, or when infections prior to 15th January were excluded (Supplementary Table 2).

## Discussion

In this multi-centre study of haemodialysis patients with SARS-CoV-2 infection, significant protection from severe disease was seen after two-dose vaccination, with hospitalisations reduced by 75% (95%CI: 56-86) and deaths by 88% (95%CI: 70-95). This suggests a substantial clinical benefit from vaccination in a population which is particularly vulnerable. Some efficacy was seen after a single dose, underlining the importance of early vaccination in vulnerable groups.

Although several studies have examined immunogenicity, very few have estimated the clinical efficacy of vaccination in haemodialysis patients. In an early study, the majority of patients in one UK haemodialysis unit were vaccinated with BNT162b2 on 7th-8th January 2021 [13]. Over two month's observation, two patients developed asymptomatic SARS-CoV-2 infection, compared to nine fatal cases occurring in the unit in the previous two months. However, there was no adjustment for community case load, which was falling in the UK during this time. Perhaps the best data come from a French study in which two national haemodialysis registries were cross referenced [14]. Over one month, new SARS-CoV-2 infections were identified in 1.98, 0.65 and 0.25% of unvaccinated, post-first-dose and post-second-dose

patients respectively, though again, local community risk was not included. Mortality remained high in vaccinated patients at 11%, however, comparing 125 cases post-second-dose vaccination, to 1122 cases in unvaccinated patients, severe illness and death were reduced by around half.

However, clinical efficacy of vaccination is critically dependent on diagnostic threshold, since severe events are easy to detect whereas asymptomatic infection is often missed. This study, in which all cases came from a population screened weekly by PCR, so that few infections would be missed, therefore improves on prior studies, providing reliable and fully adjusted estimates of the effect of vaccination on disease severity. Without vaccination, outcomes are poor in haemodialysis patients [2], therefore, whilst substantially protected compared to their unvaccinated peers, vaccinated haemodialysis patients remain at high risk for adverse outcomes when compared to individuals without kidney disease.

Alongside clinical efficacy, the effect of vaccination can also be measured by immunogenicity: the ability of a vaccine to induce antibody and cellular immune responses in patients. Although one step removed from clinical outcome, immune characterisation provides a more mechanistic understanding of protection, and responses can be measured at an individual level, potentially indicating individual risk. But impaired immunogenicity in a vulnerable group compared to healthy controls, does not imply reduced clinical efficacy, which relies on comparison with unvaccinated members of the same vulnerable group.

Following vaccination with two doses of BNT162b2 in previously uninfected dialysis patients, neutralising antibody levels were comparable with those of healthy controls, though this was not the case for AZD1222, after which titres were less effective in neutralising most variants, including Delta [6]. The lack of difference between vaccine types in the current study doesn't exclude such an effect, but it is reassuring that despite poorer immunogenicity, AZD1222 was clearly associated with clinical protection.

It is also somewhat reassuring to note the persistence of effect, albeit over short time frames (75% of cases occurring over 4 months after their second dose, were still within 5.5 months). when there is concern that vaccine responses may wane over time [15]. Antibody levels also wane after prior infection, though this does not necessarily diminish clinical protection: Clarke

observed 129 seropositive haemodialysis patients over 6 months, finding antibody no longer detectable in 10 of 111 patients with paired serology, but robust protection from re-infection in the group [16]. No protective effect was seen due to prior infection in the current study, perhaps since this group was small (N=45). This could be due to misclassification, since those with asymptomatic infection before the study period may not have been tested, or due to protection from re-infection in those with prior SARS-CoV-2.

It is also reassuring that older patients appeared to benefit as much as their younger peers. Studies assessing protection from symptomatic infection in healthy individuals have reported either reduced efficacy in older people, for example from BNT162b2 in those over 70 [17], or similar efficacy, for example from AZD1222 (efficacy 84(54-91)% in those over 65 vs 73(63-80)% in those under 65) [18]. Protection from more severe outcomes such as admission appears similar, for example first-dose vaccination was 83% effective in preventing admission in those over 80 [19].

Noticeable in this study was the increase in mortality over time, which may reflect emergence of Delta, associated with more severe outcomes [20], as the dominant variant in London [12]. While differences in vaccine type could be postulated, BNT162b2 and AZD1222 appear similar in their effect on Alpha and Delta variants [21]. A large study of UK haemodialysis patients found no clear difference between variants in neutralization titres after two vaccine doses [6].

This study has several important limitations, in particular only addressing clinical severity once individuals are infected, without addressing the likelihood of acquiring infection. Prevention of infection has been demonstrated in household contacts with BNT162b2 appearing 80% effective [22].

These results are relevant to vaccine uptake and third dose policy. Vaccine hesitancy remains a problem in this population, and in a US survey, many dialysis patients identified with the statement “I am concerned that the vaccine will not work” [23]. This study may therefore be useful in reducing vaccine hesitancy, which has resulted in low uptake in some countries, for example Australia, where almost a quarter of dialysis patients declined [24]. Dialysis patients remain vulnerable, and this study does nothing to diminish enthusiasm for third doses, which appear beneficial as two-dose protection starts to wane: in a healthy population during a

Delta predominant phase, third doses of BNT162b2 were estimated to be 81% effective in preventing death, compared to two doses at least 5 months earlier [25].

This study therefore demonstrates that vaccination is associated with a substantially lower risk of severe clinical outcomes in haemodialysis patients with SARS-CoV-2 infection. Although significant vulnerability remains, this population have much to gain from vaccination, regardless of age or vaccine type. These results support a policy of promoting and prioritising vaccination in this vulnerable group.

**Author Contributions**

DA, BC, DB and AS conceived the study;
All authors curated the data;
DA, BC and RC analysed the data;
DA and RC drafted the paper which was modified by other authors;
All authors approved the final version of the manuscript

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**Disclosures**

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consultancy agreements with Novartis Pharmaceuticals; receiving honoraria from Napp Pharmaceuticals; and speakers bureau for Napp Pharmaceuticals. All remaining authors have nothing to disclose.

**Supplementary materials**

Contents

Supplementary Table 1. Association of second-dose vaccination with clinical outcome in subgroups with SARS-CoV-2 infection.

Supplementary Table 2. Association of second-dose vaccination with clinical outcome in sensitivity analyses.

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**Table 1.** Characteristics and outcome of patients with SARS-CoV-2 infection stratified by vaccination status.

| | | Unvaccinated | First dose (>10d post) | Second dose (>10d post) | Total |
|---|---|---|---|---|---|
| N | | 1047 | 86 | 190 | 1323 |
| Days after dose, median(IQR) | | | 25.5 (18-52) | 126.5 (95-153) | |
| Age, median(IQR) | | 61 (53-72) | 70.5 (58-79) | 63 (52-73) | 62 (53-73) |
| Gender | Male | 622 (59.4) | 58 (67.4) | 117 (61.6) | 797 (60.2) |
| Ethnicity | Asian/other | 332 (31.7) | 16 (18.6) | 50 (26.3) | 398 (30.1) |
| | Black | 401 (38.3) | 28 (32.6) | 79 (41.6) | 508 (38.4) |
| | White | 314 (30.0) | 42 (48.8) | 61 (32.1) | 417 (31.5) |
| Diabetes | | 484 (46.2) | 42 (48.8) | 93 (48.9) | 619 (46.8) |
| Immune suppression[a] | | 117 (11.2) | 14 (16.3) | 33 (17.4) | 164 (12.4) |
| Prior SARS-CoV-2[b] | | 29 (2.8) | 4 (4.7) | 12 (6.3) | 45 (3.4) |
| Outcome | Admission <14 days | 436 (41.6) | 33 (38.4) | 46 (24.2) | 515 (38.9) |
| | Oxygen <28 days | 329 (31.4) | 23 (26.7) | 26 (13.7) | 378 (28.6) |
| | Ventilation <28 days | 185 (17.7) | 17 (19.8) | 18 (9.5) | 220 (16.6) |
| | Death <28 days | 148 (14.1) | 12 (14.0) | 12 (6.3) | 172 (13.0) |

Except where stated data are N (%)

[a]Any immune suppression treatment including steroids, tacrolimus, mycophenolate, azathioprine, cytotoxic and biologic agents

[b]PCR positive at least 90 days prior to the current infection

**Table 2.** Factors associated with clinical outcomes in patients with SARS-CoV-2 infection.

| | | Admission <14 days | | Oxygen <28 days | | Ventilation <28 days | | Death <28 days | |
|---|---|---|---|---|---|---|---|---|---|
| Age | /year | **1.028** | (1.019-1.037) | **1.032** | (1.022-1.042) | **1.039** | (1.027-1.052) | **1.057** | (1.042-1.073) |
| Gender | Male | 1.094 | (0.864-1.385) | 0.920 | (0.712-1.188) | 0.891 | (0.655-1.211) | 0.923 | (0.652-1.306) |
| Ethnicity[a] | Asian / other | 0.866 | (0.653-1.147) | 0.825 | (0.606-1.121) | 0.762 | (0.532-1.093) | 0.807 | (0.538-1.211) |
| | Black | 0.999 | (0.740-1.347) | 0.849 | (0.611-1.179) | 0.757 | (0.510-1.124) | 0.704 | (0.446-1.113) |
| Diabetes | | **1.340** | (1.059-1.694) | **1.371** | (1.062-1.769) | 1.321 | (0.973-1.794) | 1.304 | (0.924-1.839) |
| Immune suppression[b] | | **1.632** | (1.141-2.333) | **1.788** | (1.219-2.623) | **1.658** | (1.051-2.618) | 1.465 | (0.852-2.521) |
| Prior SARS-CoV-2[c] | | 0.552 | (0.273-1.118) | 0.526 | (0.233-1.185) | 0.782 | (0.315-1.945) | 0.917 | (0.339-2.485) |
| Time period | 2 | 1.122 | (0.858-1.468) | 1.025 | (0.769-1.366) | 1.161 | (0.818-1.648) | 1.177 | (0.796-1.741) |
| | 3 | 1.375 | (0.789-2.395) | 0.753 | (0.400-1.419) | 0.863 | (0.405-1.840) | 0.725 | (0.292-1.797) |
| | 4 | **2.045** | (1.143-3.659) | 1.619 | (0.863-3.039) | 1.614 | (0.756-3.448) | 1.405 | (0.550-3.590) |
| | 5 | 1.914 | (0.984-3.721) | **2.170** | (1.053-4.473) | **2.347** | (1.011-5.447) | **3.730** | (1.482-9.384) |
| | 6 | 1.573 | (0.805-3.076) | 1.701 | (0.825-3.507) | **2.657** | (1.194-5.913) | **4.397** | (1.851-10.44) |
| Vaccination | >10d post 1st | **0.550** | (0.312-0.970) | 0.632 | (0.340-1.175) | 0.852 | (0.425-1.710) | 0.685 | (0.309-1.522) |
| | >10d post 2nd | **0.247** | (0.139-0.440) | **0.178** | (0.093-0.341) | **0.221** | (0.104-0.470) | **0.122** | (0.051-0.295) |

Odds ratio (95% CI) by multivariable logistic regression model

[a]Reference ethnicity White

[b]Any immune suppression treatment including steroids, tacrolimus, mycophenolate, azathioprine, cytotoxic and biologic agents

[c]PCR positive at least 90 days prior to the current infection

## Figure legends

**Figure 1. Epidemic time course.** Number of new SARS-CoV-2 infections by date and vaccination status.

**Figure 2. Estimated vaccine efficacy.** Reduction in clinical outcomes associated with second-dose vaccination, unadjusted and in adjusted model, and adjusted effectiveness in subgroups. N = number of SARS-CoV-2 infections at least 10 days after the second vaccine dose in each group. Estimated vaccine efficacy calculated as 1 – odds ratio.

**Figure 1. Epidemic time course.** Number of new SARS-CoV-2 infections by date and vaccination status.

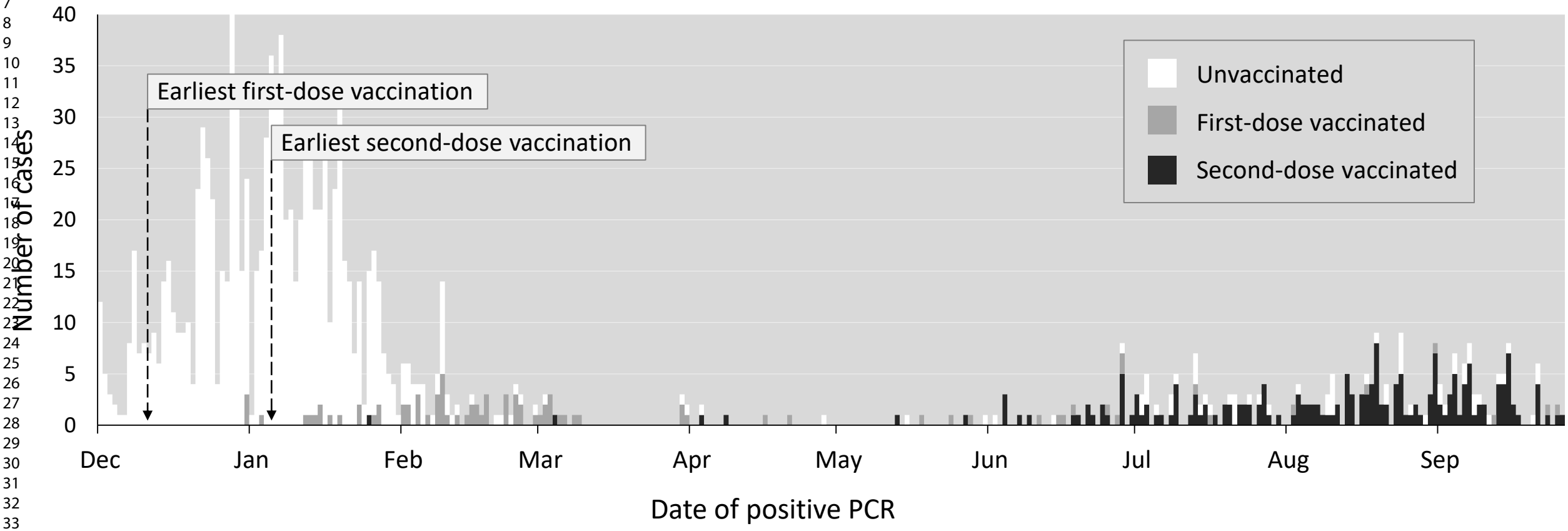
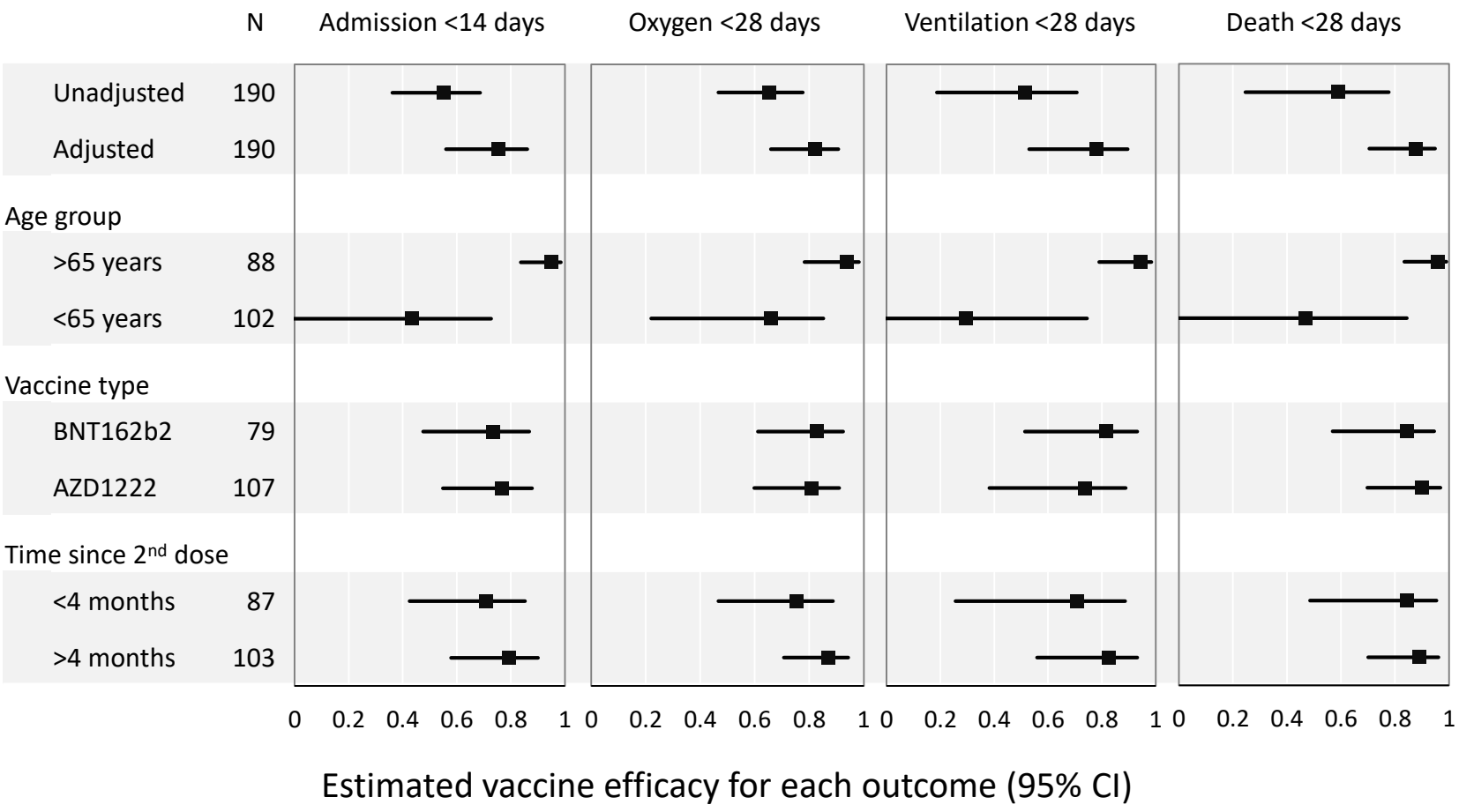


**Figure 2. Estimated vaccine efficacy.** Reduction in clinical outcomes associated with second-dose vaccination, unadjusted and in adjusted model, and adjusted effectiveness in subgroups. N = number of SARS-CoV-2 infections at least 10 days after the second vaccine dose in each group. Estimated vaccine efficacy calculated as 1 – odds ratio.



**Supplementary materials**

Contents

**Supplementary Table 1.** Association of second-dose vaccination with clinical outcome in subgroups with SARS-CoV-2 infection.

| Subgroup | | N[a] | Admission <14 days | | Oxygen <28 days | | Ventilation <28 days | | Death <28 days | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age group | >65 years | 88 | **0.049** | (0.015-0.163) | **0.063** | (0.018-0.218) | **0.058** | (0.016-0.210) | **0.041** | (0.010-0.165) |
| | <65 years | 102 | 0.566 | (0.273-1.171) | **0.340** | (0.148-0.780) | 0.707 | (0.255-1.961) | 0.531 | (0.156-1.803) |
| Vaccine type | BNT162b2 | 79 | **0.264** | (0.132-0.525) | **0.172** | (0.076-0.388) | **0.184** | (0.069-0.486) | **0.154** | (0.055-0.431) |
| | AZD1222 | 107 | **0.234** | (0.121-0.452) | **0.190** | (0.090-0.402) | **0.263** | (0.112-0.618) | **0.098** | (0.032-0.302) |
| Time since[b] | <4 months | 87 | **0.292** | (0.148-0.575) | **0.245** | (0.113-0.534) | **0.292** | (0.114-0.744) | **0.154** | (0.046-0.515) |
| | >4 months | 103 | **0.206** | (0.100-0.421) | **0.129** | (0.057-0.293) | **0.175** | (0.069-0.441) | **0.108** | (0.039-0.299) |

Odds ratio (95% CI), including variables in Table 2, within subgroup comparing second-dose with no vaccination

[a]Number of infections >10 days after second dose within subgroup

[b]Time since second dose

**Supplementary Table 2.** Association of second-dose vaccination with clinical outcome in sensitivity analyses.

| Condition | N[a] | Admission <14 days | | Oxygen <28 days | | Ventilation <28 days | | Death <28 days | |
|---|---|---|---|---|---|---|---|---|---|
| Prior SARS-CoV-2 excluded | 178 / 1278 | **0.241** | (0.133-0.436) | **0.172** | (0.089-0.335) | **0.199** | (0.092-0.431) | **0.119** | (0.049-0.290) |
| Two time periods | 190 / 1323 | **0.254** | (0.144-0.447) | **0.179** | (0.095-0.337) | **0.231** | (0.111-0.479) | **0.141** | (0.061-0.327) |
| Before 15th January excluded | 190 / 636 | **0.260** | (0.144-0.469) | **0.184** | (0.094-0.359) | **0.259** | (0.121-0.553) | **0.127** | (0.051-0.318) |

Odds ratio (95% CI), including variables in Table 2, comparing second-dose with no vaccination, under condition specified

[a]Number of infections >10 days after second dose / total group size