Efficacy Estimates for Various COVID-19 Vaccines: What we Know from the Literature and Reports

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May 20, 2021

Abstract

In this report, we provide summary estimates, from publications and reports, of vaccine efficacy (VE) for the COVID-19 vaccines that are being rolled out on a global scale. We find that, on average, the efficacy against any disease with infection is 85% (95% CI: 71 - 93%) after a fully course of vaccination. The VE against severe disease, hospitalization or death averages close to 100%. The average VE against infection, regardless of symptoms, is 84% (95% CI: 70 - 91%). We also find that the average VE against transmission to others for infected vaccinated people is 54% (95% CI: 38 - 66%). Finally, we prove summary estimates of the VE against any disease with infection for some of the variants of concern (VOC). The average VE for the VOC B.1.1.7, B.1.1.28 (P1) and B.1.351 are 86% (95% CI: 65 - 84%), 61% (95% CI: 43 - 73%) and 56% (95% CI: 29 - 73%), respectively.
**Introduction**

In this report, we summarize estimates of vaccine efficacy (VE) for the COVID-19 vaccines that are being rolled out on local and global scales. This includes the Pfizer, Moderna, Johnson & Johnson, AstraZeneca, Sputnik, Novavax, Sinovac, and Sinopharm vaccines. VE estimates are taken from journal articles and media reports for the vaccines that have gone through double-blinded, placebo-controlled, phase III vaccine trials, as well as observational studies. Some of the estimates are based on rigorous, preplanned statistical analyses from double-blinded, placebo-controlled trials, while others are extracted from observational studies with different levels of control. These studies are reported from a variety of sources including publications, reports, and sometimes press releases. Because of this, we do not carry out a formal meta analysis. In all cases, we try to extract estimates for one or more of the triplet of vaccine efficacy parameters ($VE_S, VE_P, VE_I$) [1], where $VE_S$ is VE against infection; $VE_P$ is VE against disease, given infection; and $VE_I$ is VE against transmission to others, given infection. A fourth parameter, $VE_{SP}$, which is VE against disease and infection, tends to be available from vaccine trials, and it is the usual primary outcome for those trials (i.e., cases of disease that are confirmed infections). The $VE_{SP}$ is a function of both the $VE_S$ and $VE_P$. If we believe in a multiplicative and independent relationship, then $VE_{SP} = 1 - (1 - VE_S)(1 - VE_P)$. Thus, if we have two of these VE’s, we can always calculate the third.

In the material that follows, we give estimates of these VE’s as a function of time when protection is believed to begin to occur after the first and second dose for two-dose vaccines, and after the first dose for one-dose vaccines. We also provide $VE_{SP}$ estimates for protection against the variants of concern (VOC) B.1.1.7, B.1.1.28 (P1) and B.1.351. The methods for creating the forest plots are given in the Appendix. The supporting tables for the analysis are also given in the Appendix. Not all estimates described in the tables are given in the figures, as we have tried to extract the essential information without getting lost in too much detail. However, virtually all the complete information is given in the Appendix tables.

**Results**

We first consider VE for the original wild type viruses. Figure 1 (Table A1) give the estimates of the $VE_{SP}$ after the second dose for two-dose vaccines. All the estimates are from double-blinded, placebo-controlled vaccine trials. With the exception of the Sinovac vaccine, they are all over 80%, with a summary estimate of 85% (95% CI: 71 - 93%). The Sinovac $VE_{SP}$ estimate is 51% (95% CI: 36 - 62%).
Figure 1: Forest plot of vaccine efficacy to prevent any disease after dose 2, $VE_{SP}$. * indicates double-blinded, randomized vaccine trial.

The estimated $VE_{SP}$ after one dose, for both two-dose and one-dose vaccines, is given in Figure 2 (Table A2), where the Johnson & Johnson vaccine is the only one-dose vaccine listed. The estimates are generally almost as high as protection after one dose, with summary estimated of 82% (95% CI: 72 - 88%).

Figure 2: Forest plot of vaccine efficacy to prevent any disease after dose 1, $VE_{SP}$. * indicates double-blinded, randomized vaccine trial.
Figure 3 (Table A3) give the estimates of the $VE_{SP}^S$ (VE for severe disease with infection) after the second dose for two-dose vaccines. The estimates are very high, and generally close to 100%, with relatively poor precision.

| Vaccine   | Vaccine efficacy          |
|-----------|---------------------------|
| AstraZeneca* | 1.000 [CI not reported]  |
| Moderna*     | 1.000 [CI not reported]  |
| Novavax*     | 1.000 [CI not reported]  |
| Sinovac*     | 1.000 [0.534, 1.000]     |
| Pfizer       | 0.920 [0.750, 1.000]     |

**Figure 3:** Forest plot of vaccine efficacy to prevent severe disease after dose 2, $VE_{SP}^S$. * indicates double-blinded, randomized vaccine trial.
Figure 4 (Table A4) give the estimates of the $VE_{SP}^S$ (VE for severe disease with infection) after the first dose for two-dose vaccines and one dose for the one-dose vaccine. The summary estimated is quite high at 86% (95% CI: 39 - 97%).

![Forest plot of vaccine efficacy to prevent severe disease after dose 1, $VE_{SP}^S$. * indicates double-blinded, randomized vaccine trial.](image)

VE against hospitalization and death were quite high, as shown in Figures 5 and 6 (Tables A5 and A6).

![Forest plot of vaccine efficacy to prevent hospitalization, $VE_{SP}^H$. * indicates double-blinded, randomized vaccine trial.](image)
Figure 6: Forest plot of vaccine efficacy to prevent death, $VE_{SP}^D$. * indicates double-blinded, randomized vaccine trial.

Figure 7 (Table A7) give the estimates of the $VE_S$, i.e., VE against infection. The estimates were quite high, with a summary estimate of 84% (95% CI: 70 - 91%).

Figure 7: Forest plot of vaccine efficacy to prevent infection, $VE_S$. * indicates double-blinded, randomized vaccine trial.
Figure 8 (Table A8) give estimates of the $VE_I$, i.e., VE against infectiousness or direct transmission to others. The summary measure is 54% (95% CI: 38 - 66%), indicating the vaccination reduces the transmission to others by 54% when vaccinated people are infected, compared to unvaccinated people who become infected.

![Forest plot of vaccine efficacy to prevent infectiousness to others](image)

**Figure 8: Forest plot of vaccine efficacy to prevent infectiousness to others,** $VE_I$ *indicates double-blinded, randomized vaccine trial.*

Now we consider VE’s for the variants of concern (VOC). Estimates are available for the $VE_{SP}$, mostly after the first dose for the one dose vaccine and the second dose for the two dose vaccines. These estimates are given in Figure 9 (Tables A9-A11). For B.1.1.7, VE is 86% (95% CI: 65 - 84%), which is just somewhat reduced compared to the wild type virus, but this VOC does not have a mutation that affects immunity. In contrast, the two other variants B.1.1.28 (P1) and B.1.351 have summary estimates of VE’s of 61% (95% CI: 43 - 73%) and 56% (95% CI: 29 - 73%), respectively, that is considerably lower than the VE’s for the wild type viruses. Both of these VOC’s have mutations that affect immune function.
Discussion

We have presented the relevant VE estimates for the COVID-19 vaccines that are being rolled out on a global scale and for which there is sufficient quality data. We provide estimates of VE against disease with confirmed infection, infection, and transmission to others. The VE estimates against disease are stratified by disease severity, hospitalization and death. We have also provided VE estimates for three of the VOC.

These estimates should be useful for constructing mathematical models for vaccination impact and for making policy decisions involving vaccination. We plan to keep updating this report as more information becomes available.
Methods

For each vaccine efficacy measure (e.g., severe disease, infection), we first obtained log odds ratios and corresponding sampling variances from each vaccine efficacy estimate and 95% confidence interval (CI). We then fit random-effects models to these data to estimate average log odds ratios, which we back-transformed to obtain VE summary estimates and 95% CIs. All analyses were done in R version 4.0.2 using the package metafor (R Project for Statistical Computing) [2,3].

Funding

This work was partially funded by NIH grants R01AI139761 and R56AI148284.
Appendix

Here we give the details about the studies and data that are summarized in the figures.

Note: ⋆ indicates that the VE estimate is based on double-blinded, randomized trials.

Table 1: Vaccine efficacy to prevent any disease after dose 2, $VE_{SP}$

| Company          | Efficacy%, (95% CI), time frame of estimate | References |
|------------------|--------------------------------------------|------------|
| Moderna          | 94.5*, (86.5, 97.8), 14 or more days after dose 2 | [4]        |
| Pfizer           | 94.2*, (88.7, 97.2), 14 or more days after dose 2 | [5]        |
| Johnson & Johnson | One dose vaccine                           | n/a        |
| AstraZeneca      | 81.5*, (67.9, 89.4), 14 or more days after dose 2 | [6]        |
| Novavax          | 89.3*, (75.2, 95.4), 7 or more days after dose 2 | [7]        |
| Sputnik V        | Not reported                               | n/a        |
| Sinovac          | 50.7*, (35.7, 62.2), time frame not reported | [8]        |
| Sinopharm        | 78.1*, (64.9, 86.3), median follow-up time 112 days | [9]        |
Table 2: Vaccine efficacy to prevent any disease after dose 1, $V_{ESP}$

| Company          | Efficacy%, (95% CI), time frame of estimate | References |
|------------------|---------------------------------------------|------------|
| Moderna          | 92.1* (68.8, 99.1), more than 14 days after dose 1 | [4]        |
| Pfizer           | 82.0* (75.6, 86.9), after dose 1             | [5]        |
|                  | 57.0, (50.0, 60.0), 14-20 day period after dose 1 | [10]       |
| Johnson & Johnson| 66.9* (59.1, 73.4), 14 or more days after vaccination | [11,12]    |
|                  | 66.5* (55.5, 75.1), 28 or more days after vaccination | [11,12]    |
| AstraZeneca      | 76.0* (59.0, 86.0), 22-90 day period after dose 1 | [7]        |
| Novavax          | 83.4* (73.6, 89.5), 14 or more days after dose 1 | [13]       |
| Sputnik V        | 91.6* (85.6, 95.2), 21 days after dose 1      | [14]       |
| Sinovac          | Not reported                                | n/a        |
| Sinopharm        | Not reported                                | n/a        |
### Table 3: Vaccine efficacy to prevent severe disease after dose 2, $V E_{SP}^S$

| Company               | Efficacy%, (95% CI), time frame of estimate | References |
|-----------------------|--------------------------------------------|------------|
| Moderna               | 100.0*, (CI not reported), 14 or more days after dose 2 | [4]        |
| Pfizer                | 92.0, (75.0, 100.0), 7 or more days after dose 2 | [10]       |
| Johnson & Johnson     | One dose vaccine                           | n/a        |
| AstraZeneca           | 100.0*, (CI not reported), time frame not reported | [7]        |
| Novavax               | 100.0*, (CI not reported), time frame not reported | [7]        |
| Sputnik V             | Not reported                               | n/a        |
| Sinovac               | 100.0*, (53.4, 100.0)$^a$, time frame not reported | [8]        |
| Sinopharm             | Not reported                               | n/a        |

$^a$ Combined estimate of VE against hospitalization, severe disease, and death
Table 4: Vaccine efficacy to prevent severe disease after dose 1, $V E_{SP}^S$

| Company       | Efficacy%, (95% CI), time frame of estimate | References |
|---------------|--------------------------------------------|------------|
| Moderna       | 42.6*, (-300.8, 94.8), 14 or more days after dose 1 | [4]        |
| Pfizer        | 88.9*, (20.1, 99.7), after dose 1           | [5]        |
|               | 62.0, (39.0, 80.0), 14-20 day period after dose 1 | [10]       |
| Johnson & Johnson | 76.7*, (54.6, 89.9), 14 or more days after vaccination | [11, 12]   |
|               | 85.4*, (54.2, 96.9), 28 or more days after vaccination | [11, 12]   |
| AstraZeneca   | 100.0*, (CI not reported), more than 22 days after dose 1 | [15]       |
| Novavax       | Not reported                               | n/a        |
| Sputnik V     | 100.0*, (94.4, 100.0), 21 or more days after dose 1 | [16]       |
| Sinovac       | Not reported                               | n/a        |
| Sinopharm     | Not reported                               | n/a        |
Table 5: Vaccine efficacy to prevent hospitalization, $V_{SP}^H$

| Company          | Efficacy%, (95% CI), time frame of estimate | References |
|------------------|--------------------------------------------|------------|
| Moderna          | 89.0, (13.0, 99.0), time frame not reported | [17]       |
| Pfizer           | 87.0, (55.0, 100.0), 7 or more days after dose 2 | [10]       |
|                  | 74.0, (56.0, 86.0), 14-20 days after dose 1 | [10]       |
|                  | 91.0, (85.0, 94.0), 28-34 days after a single dose | [18]       |
| Johnson & Johnson| 93.1*, (72.7, 99.2), 14 or more days after vaccination | [11,12]   |
|                  | 100.0*, (74.3, 100.0), 28 or more days after vaccination | [11,12]   |
| AstraZeneca      | 100.0*, (CI not reported), more than 22 days after dose 1 | [15]       |
|                  | 88.0, (75.0, 94.0), 28-34 days after a single dose | [18]       |
| Novavax          | 100.0*, (CI not reported), time frame not reported | [13]       |
| Sputnik V        | Not reported                               | n/a        |
| Sinovac          | 83.7*, (58.0, 93.7), time frame not reported | [8]        |
| Sinopharm        | 78.7*, (26.0, 93.9), median follow-up time 112 days | [9]        |
Table 6: Vaccine efficacy to prevent death, $VE_{SP}^{D}$

| Company          | Efficacy%, (95% CI), time frame of estimate      | References |
|------------------|-------------------------------------------------|------------|
| Moderna          | Not reported                                    | n/a        |
| Pfizer           | 72.0, (19.0, 100.0), 14-20 days after dose 1    | [10]       |
| Johnson & Johnson| 100.0*, (CI not reported), time frame not reported | [11]       |
| AstraZeneca      | 100.0*, (CI not reported), time frame not reported | [6]        |
| Novavax          | 100.0*, (CI not reported), time frame not reported | [13]       |
| Sputnik V        | Not reported                                   | n/a        |
| Sinovac          | 100.0*, (53.4, 100.0)*, time frame not reported | [8]        |
| Sinopharm        | Not reported                                  | n/a        |

* Combined estimate of VE against hospitalization, severe disease, and death

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| Company          | Efficacy%, (95% CI), time frame of estimate                                      | References |
|------------------|--------------------------------------------------------------------------------|------------|
| Moderna          | 89.0\(^b\), (CI not reported), more than 7 days after dose 2                   | [19, 20]  |
|                  | 90.0, (68.0, 97.0\(^c\)), 14 or more days after dose 2                         | [21]       |
|                  | 80.0, (59.0, 90.0\(^c\)), 14 or more days after dose 1 but before dose 2      | [21]       |
| Pfizer           | 70.0, (55.0, 85.0\(^d\)), 21 days after dose 1                                 | [22]       |
|                  | 85.0, (74.0, 96.0\(^d\)), 7 days after dose 2                                 | [22]       |
|                  | 90.0, (68.0, 97.0\(^c\)), 14 or more days after dose 2                         | [21]       |
|                  | 80.0, (59.0, 90.0\(^c\)), 14 or more days after dose 1 but before dose 2      | [21]       |
| Johnson & Johnson| Not reported                                                                  | n/a        |
| AstraZeneca      | 77.3\(^*\), (65.4, 85.0\(^e\)), more than 14 days after dose 2               | [6]        |
|                  | 51.9, (42.0, 60.1\(^d\)), time frame not reported                             | [22]       |
| Novavax          | Not reported                                                                  | n/a        |
| Sputnik V        | Not reported                                                                  | n/a        |
| Sinovac          | Not reported                                                                  | n/a        |
| Sinopharm        | Not reported                                                                  | n/a        |
Combined measurement of Moderna and Pfizer vaccine against both symptomatic and asymptomatic infections.

mRNA vaccine effectiveness for prevention of infection.

VE against all (symptomatic and asymptomatic) infection.

VE against all (symptomatic and asymptomatic) infection caused by non-B.1.1.7 variants. Asymptomatic infections were detected by weekly swabbing.
### Table 8: Vaccine efficacy to prevent infectiousness to others, $V E_I$

| Company         | Efficacy%, (95% CI), time frame of estimate | References |
|-----------------|--------------------------------------------|------------|
| Moderna         | 80.0\(^f\), (CI not reported), 0 days after dose 2 | [20,23]    |
|                 | 61.0, (31.0, 79.0)\(^g\), after a single dose | [24]       |
| Pfizer          | 80.0\(^f\), (CI not reported), 0 days after dose 2 | [20,23]    |
|                 | 94.0\(^h\), (CI not reported), 14 days after dose 2 | [20,25]    |
|                 | 75.0\(^i\), (CI not reported), 12 days after dose 1 | [20,26]    |
| Johnson & Johnson | 65.5\(^*\), (39.9, 81.1)\(^j\) | [12]       |
| AstraZeneca     | 50.0\(^*\), (38.0, 59.0)\(^k\), after dose 2 | [15]       |
|                 | 67.0\(^*\), (49.0, 78.0)\(^l\), after dose 1 | [15]       |
| Novavax         | Not reported                                | n/a        |
| Sputnik V       | Not reported                                | n/a        |
| Sinovac         | Not reported                                | n/a        |
| Sinopharm       | Not reported                                | n/a        |

\(^{f}\) Combined measurement of Moderna and Pfizer vaccine effectiveness against asymptomatic infection and transmission.

\(^{g}\) It is estimated that one dose of the Moderna vaccine reduces virus transmission by at least 61%.

\(^{h}\) Measurement of vaccine effectiveness against asymptomatic infection with the potential to reduce asympto-
tomatic transmission of the virus.

\(^i\) (VE_T = 1 - \frac{1}{4} = 0.75)\) Estimated measurement of vaccine efficacy against transmission based on preliminary data from an observational study in Israel. According to a CDC Science Brief, the data from Israel “suggest that people vaccinated with Pfizer-BioNTech COVID-19 vaccine who develop COVID-19 have a four-fold lower viral load than unvaccinated people. This observation may indicate reduced transmissibility, as viral load has been identified as a key driver of transmission” [20,26].

\(^j\) According to Sadoff et al., “The analysis of vaccine efficacy against asymptomatic infection included all of the participants with a newly positive N-immunoassay result at day 71 (i.e., those who had been seronegative or had no result available at day 29 and who were seropositive at day 71). Only 2650 patients had an N-immunoassay result available at day 71, and therefore only a preliminary analysis could be performed. A total of 18 asymptomatic infections were identified in the vaccine group and 50 in the placebo group” [12].

\(^k\) The reduction in PCR positive readings after the two dose regimen.

\(^l\) Measurement of vaccine effectiveness against asymptomatic infection and transmission based on weekly swabs.
Table 9: Vaccine efficacy and viral neutralization of the B.1.1.7 (UK) variant as compared with preexisting variants

| Company          | Neutralization by pseudovirion or live viral plaque assay | VE against B.1.1.7 variant (%) | References |
|------------------|-----------------------------------------------------------|-------------------------------|------------|
| Moderna          | Decrease by 1.8x                                          | Unknown<sup>m</sup>           | [27]       |
| Pfizer           | Decrease by 2x                                            | 29.5, (22.9, 35.5)<sup>n</sup>, after dose 1 | [27, 28]   |
|                  |                                                            | 89.5, (85.9, 92.3)<sup>n</sup>, 14 or more days after dose 2 | [28]       |
|                  |                                                            | 54.1, (26.1, 71.9)<sup>u</sup>, after dose 1 | [28]       |
|                  |                                                            | 100.0, (81.7, 100.0)<sup>u</sup>, 14 or more days after dose 2 | [28]       |
| Johnson & Johnson| Unknown                                                   | Unknown<sup>p</sup>          | [27]       |
| AstraZeneca      | Decrease by 9x                                            | 74.6*, (41.6, 88.9)<sup>a</sup> | [29, 30]   |
|                  |                                                            | 61.7*, (36.7, 76.9)<sup>r</sup> | [6]        |
| Novavax          | Decrease by 1.8x                                          | 85.6*<sup>q</sup>            | [27, 31]   |
| Sputnik V        | Unknown                                                   | Unknown                       | n/a        |
| Sinovac          | Unknown                                                   | Unknown                       | n/a        |
| Sinopharm        | Unknown                                                   | Unknown                       | n/a        |
Although a VE estimate is unknown, numerous studies have reported that the Moderna vaccine offers protection against the B.1.1.7 variant [31–33].

VE against PCR-confirmed infection with the B.1.1.7 variant.

VE against severe, critical, or fatal disease caused by the B.1.1.7 variant.

There is no VE estimate reported, but it is important to note that the Johnson & Johnson vaccine was tested in the US after the B.1.1.7 variant was circulating.

VE against symptomatic COVID-19

VE against all (symptomatic and asymptomatic) infection caused by the B.1.1.7 variant. Asymptomatic infections were detected by weekly swabbing.
Table 10: Vaccine efficacy and viral neutralization of the P.1 (Brazil) variant as compared with preexisting variants

| Company          | Neutralization by pseudovirion or live viral plaque assay | VE against P.1 variant (%)                                                                 | References |
|------------------|------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------|
| Moderna          | Decrease by 4.5x                                           | Unknown                                                                                   | [27]       |
| Pfizer           | Decrease by 6.7x                                           | Unknown                                                                                   | [27]       |
| Johnson & Johnson| Unknown                                                    | 66.2*, (51.0, 77.1)*, 14 or more days after vaccination                                   | [12]       |
|                  |                                                            | 68.1*, (48.8, 80.7)*, 28 or more days after vaccination                                   | [12]       |
| AstraZeneca      | Unknown                                                    | Unknown                                                                                   | n/a        |
| Novavax          | Unknown                                                    | Unknown                                                                                   | n/a        |
| Sputnik V        | Unknown                                                    | Unknown                                                                                   | n/a        |
| Sinovac          | Unknown                                                    | 49.6, (11.3, 71.4)*, 14 or more days after dose 1                                          | [34]       |
| Sinopharm        | Unknown                                                    | Unknown                                                                                   | n/a        |

* VE against moderate to severe Covid-19 caused by the variant from the P.2 lineage carrying the E484K mutation.

† VE against symptomatic infection
| Company              | Neutralization by pseudovirion or live viral plaque assay | VE against B.1.351 variant (%) | References |
|----------------------|----------------------------------------------------------|--------------------------------|------------|
| Moderna              | Decrease by ≤ 8.6x                                        | Unknown                        | [27]       |
| Pfizer               | Decrease by ≤ 6.5x                                        | 16.9, (10.4, 23.0)\(^n\), after dose 1 | [27, 28]  |
|                      |                                                          | 75.0, (70.5, 78.9)\(^n\), 14 or more days after dose 2 | [28]       |
|                      |                                                          | 0.0, (0.0, 19.0)\(^u\), after dose 1 | [28]       |
|                      |                                                          | 100.0, (73.7, 100.0), 14 or more days after dose 2 | [28]       |
| Johnson & Johnson    | Unknown                                                  | 52.0*, (30.3, 67.4)\(^w\), 14 or more days after vaccination | [12]       |
|                      |                                                          | 64.0*, (41.2, 78.7)\(^w\), 28 or more days after vaccination | [12]       |
| AstraZeneca          | Decrease by ≤ 86% to complete immune escape              | 21.9\(^q\), (-49.9, 59.8)      | [27, 29]  |
| Novavax              | Unknown                                                  | 49.4\(^q\), (6.1, 72.8)\(^q\), 7 days after dose 2 (Day 28) | [27, 35]  |
| Sputnik V            | Unknown                                                  | Unknown                        | n/a        |
| Sinovac              | Unknown                                                  | Unknown                        | n/a        |
| Sinopharm            | Unknown                                                  | Unknown                        | n/a        |
n VE against PCR-confirmed infection with the B.1.351 variant.

u VE against severe, critical, or fatal disease caused by the B.1.351 variant.

w VE against moderate to severe COVID-19

q VE against symptomatic COVID-19
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