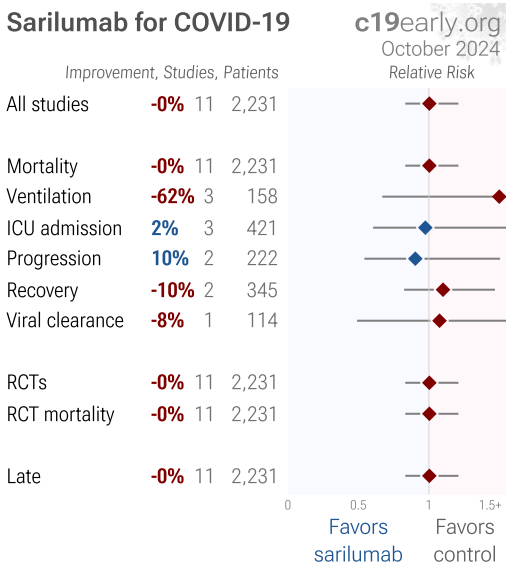
Sarilumab for COVID-19: real-time meta analysis of 11 studies

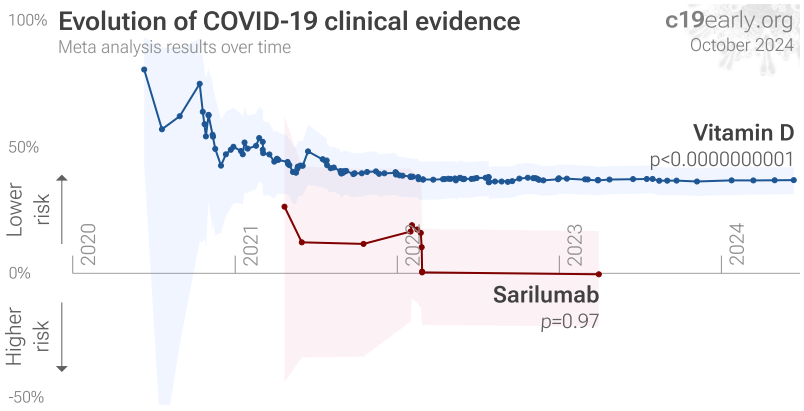
@CovidAnalysis, October 2024, Version 10
https://c19early.org/sarmeta.html

Abstract

Meta analysis using the most serious outcome reported shows 0% [-17-21%] higher risk, without reaching statistical significance. Currently all studies are RCTs.

All data to reproduce this paper and sources are in the appendix.

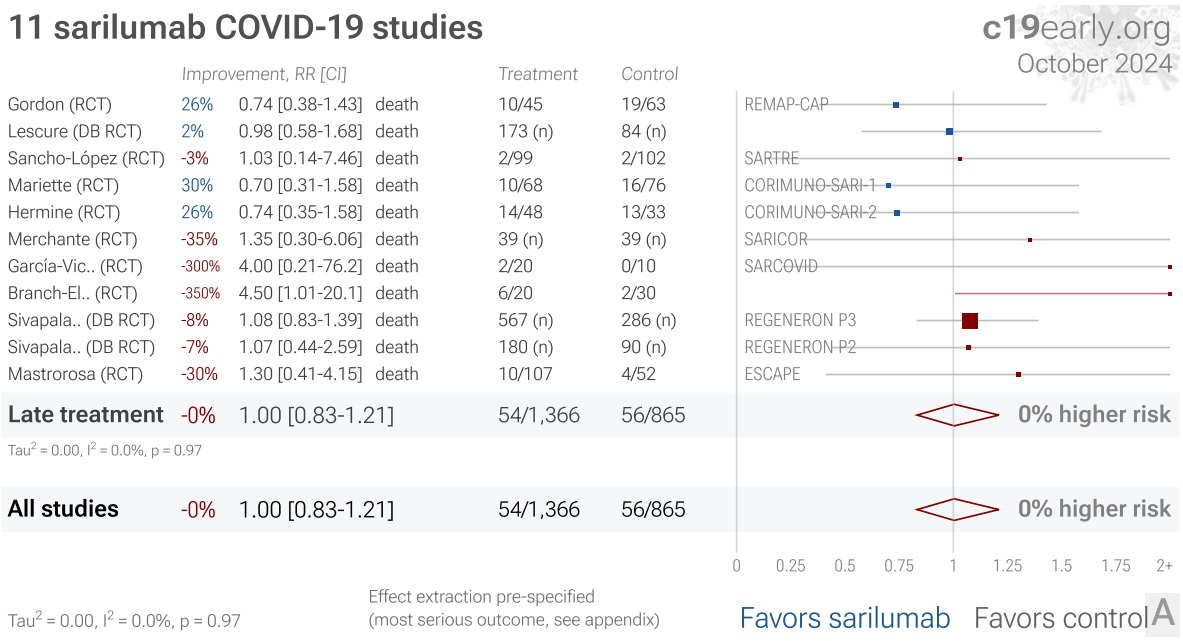




SARILUMAB FOR COVID-19 — HIGHLIGHTS

Meta analysis of studies to date shows no significant improvements with sarilumab.

Real-time updates and corrections, transparent analysis with all results in the same format, consistent protocol for 98 treatments, outcome specific analyses and combined evidence from all studies.



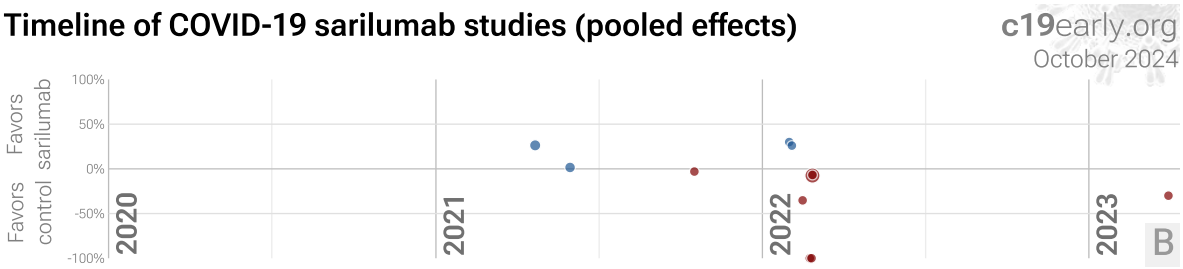


***Figure 1.* A. Random effects meta-analysis.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome reported. For details see the appendix. **B. Timeline of results in sarilumab studies.**

Introduction

Immediate treatment recommended. SARS-CoV-2 infection primarily begins in the upper respiratory tract and may progress to the lower respiratory tract, other tissues, and the nervous and cardiovascular systems, which may lead to cytokine storm, pneumonia, ARDS, neurological injury[1-10] and cognitive deficits[3,8], cardiovascular complications[11-13], organ failure, and death. Minimizing replication as early as possible is recommended.

Many treatments are expected to modulate infection. SARS-CoV-2 infection and replication involves the complex interplay of 50+ host and viral proteins and other factors[A,14-18], providing many therapeutic targets for which many existing compounds have known activity. Scientists have predicted that over 8,000 compounds may reduce COVID-19 risk[19], either by directly minimizing infection or replication, by supporting immune system function, or by minimizing secondary complications.

Analysis. We analyze all significant controlled studies of sarilumab for COVID-19. Search methods, inclusion criteria, effect extraction criteria (more serious outcomes have priority), all individual study data, PRISMA answers, and statistical methods are detailed in Appendix 1. We present random effects meta-analysis results for all studies, individual outcomes, and Randomized Controlled Trials (RCTs).

Treatment timing. Figure 2 shows stages of possible treatment for COVID-19. **Prophylaxis** refers to regularly taking medication before becoming sick, in order to prevent or minimize infection. **Early Treatment** refers to treatment immediately or soon after symptoms appear, while **Late Treatment** refers to more delayed treatment. Currently all sarilumab studies use late treatment.

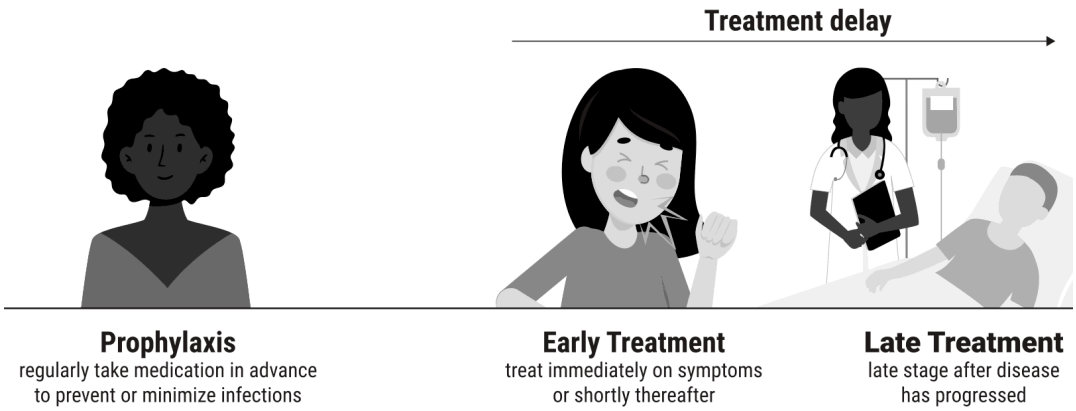


Figure 2. Treatment stages.

Results

Table 1 summarizes the results for all studies, for Randomized Controlled Trials, and for specific outcomes. Figure 3, 4, 5, 6, 7, 8, and 9 show forest plots for random effects meta-analysis of all studies with pooled effects, mortality results, ventilation, ICU admission, progression, recovery, and viral clearance.

	Improvement	*Studies*	*Patients*	*Authors*
All studies	**-0%** [-21-17%]	11	2,231	332
Randomized Controlled Trials	**-0%** [-21-17%]	11	2,231	332
Mortality	**-0%** [-21-17%]	11	2,231	332
Ventilation	**-62%** [-290-33%]	3	158	54
ICU admission	**2%** [-57-40%]	3	421	51
Recovery	**-10%** [-47-18%]	2	345	28
RCT mortality	**-0%** [-21-17%]	11	2,231	332

Table 1. **Random effects meta-analysis for all studies, for Randomized Controlled Trials, and for specific outcomes.** Results show the percentage improvement with treatment and the 95% confidence interval.

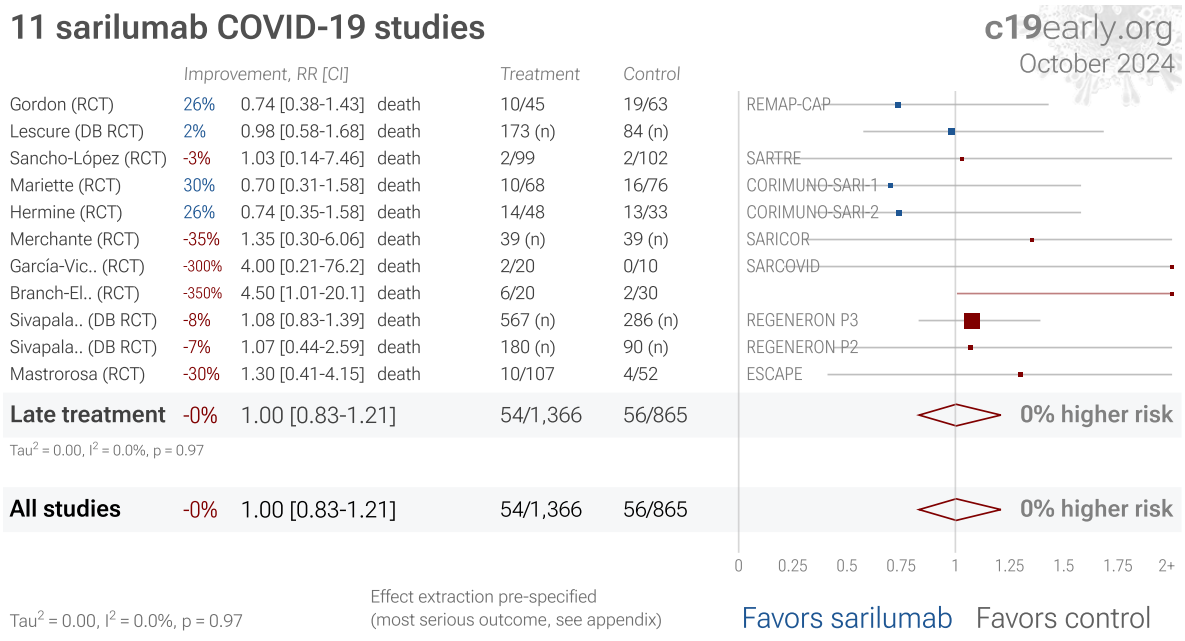


Figure 3. **Random effects meta-analysis for all studies.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome reported. For details see the appendix.

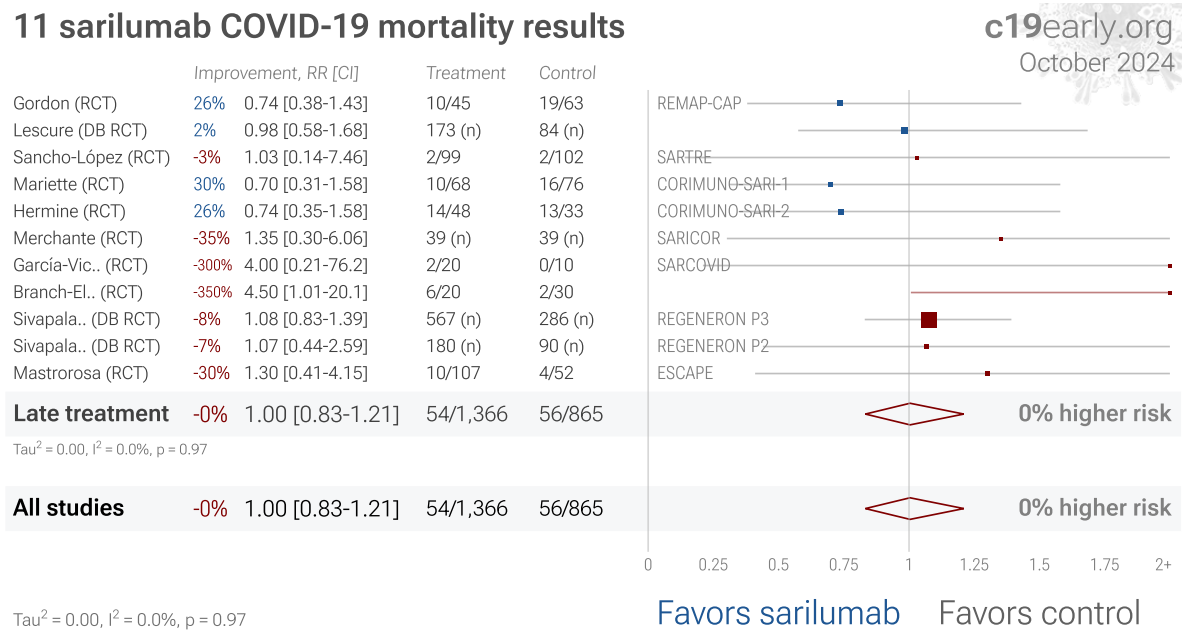


Figure 4. **Random effects meta-analysis for mortality results.**

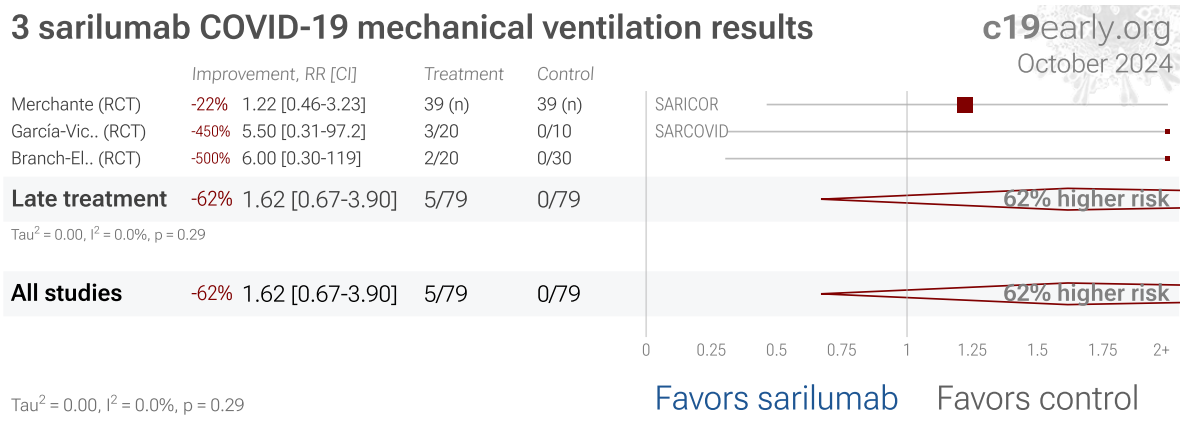


Figure 5. Random effects meta-analysis for ventilation.

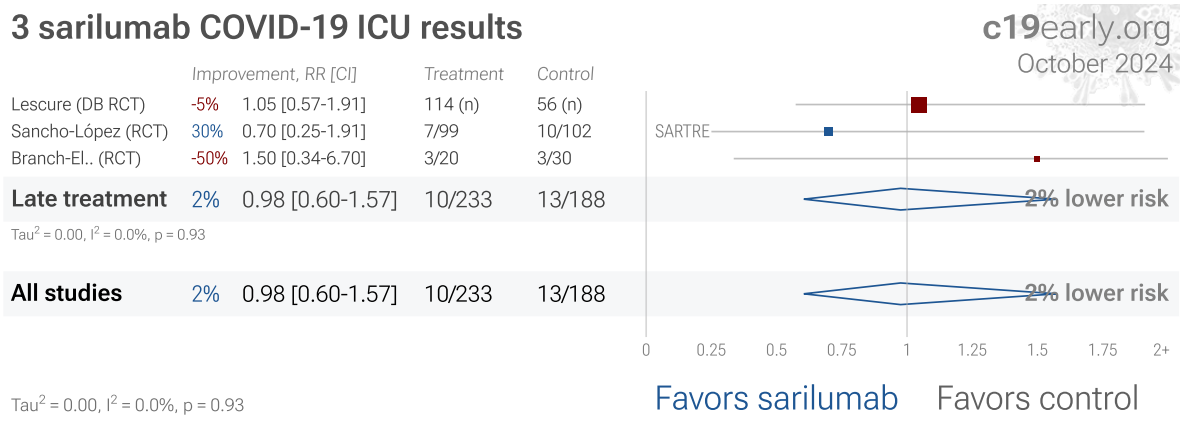


Figure 6. Random effects meta-analysis for ICU admission.

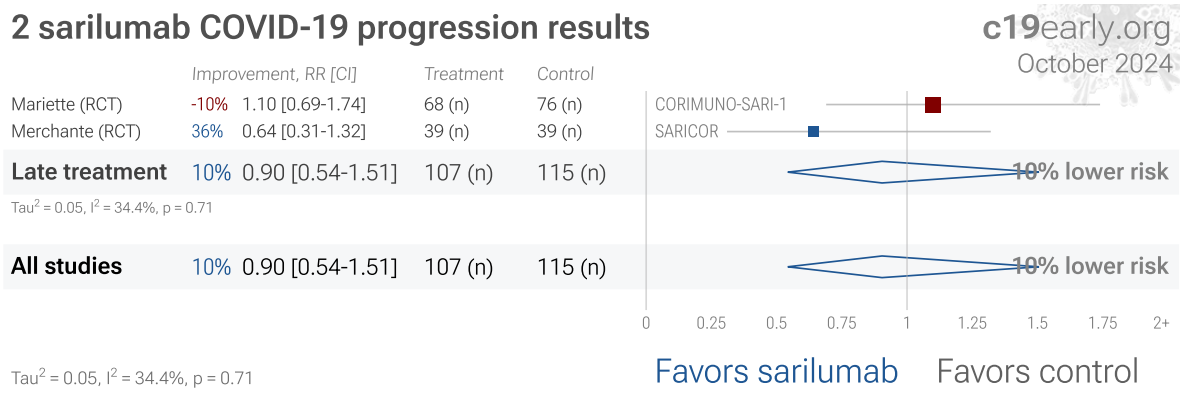


Figure 7. Random effects meta-analysis for progression.

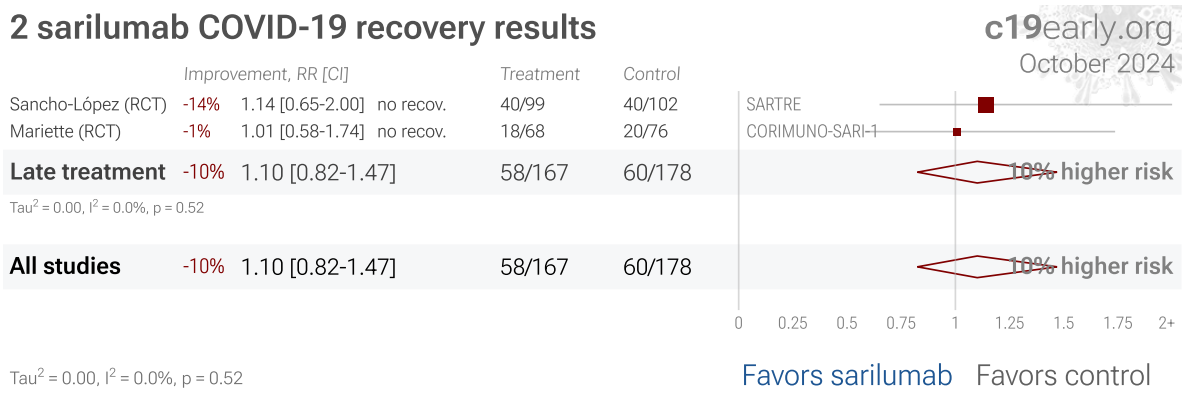


Figure 8. Random effects meta-analysis for recovery.

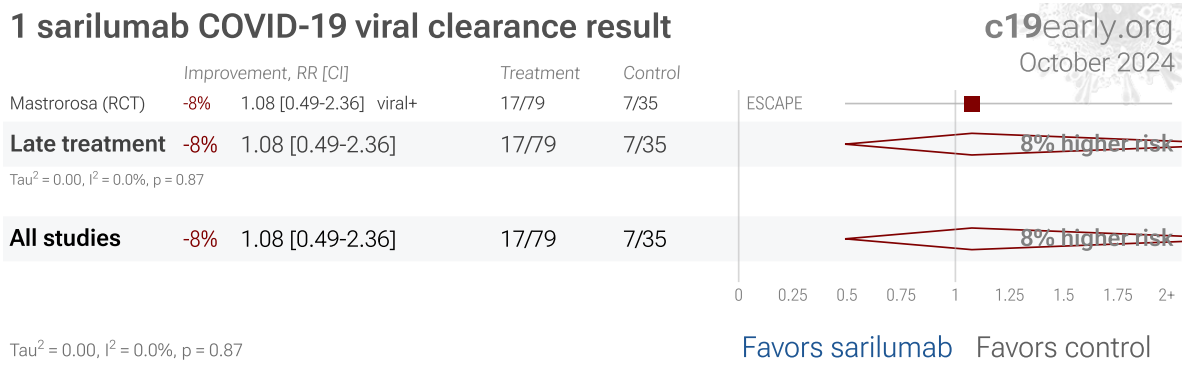


Figure 9. Random effects meta-analysis for viral clearance.

Randomized Controlled Trials (RCTs)

Currently all studies are RCTs.

Heterogeneity

Heterogeneity in COVID-19 studies arises from many factors including:

Treatment delay. The time between infection or the onset of symptoms and treatment may critically affect how well a treatment works. For example an antiviral may be very effective when used early but may not be effective in late stage disease, and may even be harmful. Oseltamivir, for example, is generally only considered effective for influenza when used within 0-36 or 0-48 hours[20,21]. Baloxavir marboxil studies for influenza also show that treatment delay is critical — *Ikematsu et al.* report an 86% reduction in cases for post-exposure prophylaxis, *Hayden et al.* show a 33 hour reduction in the time to alleviation of symptoms for treatment within 24 hours and a reduction of 13 hours for treatment within 24-48 hours, and *Kumar et al.* report only 2.5 hours improvement for inpatient treatment.

Treatment delay	*Result*
Post-exposure prophylaxis	86% fewer cases [22]
<24 hours	-33 hours symptoms [23]
24-48 hours	-13 hours symptoms [23]
Inpatients	-2.5 hours to improvement [24]

Table 2. **Studies of baloxavir marboxil for influenza show that early treatment is more effective.**

Figure 10 shows a mixed-effects meta-regression for efficacy as a function of treatment delay in COVID-19 studies from 98 treatments, showing that efficacy declines rapidly with treatment delay. Early treatment is critical for COVID-19.

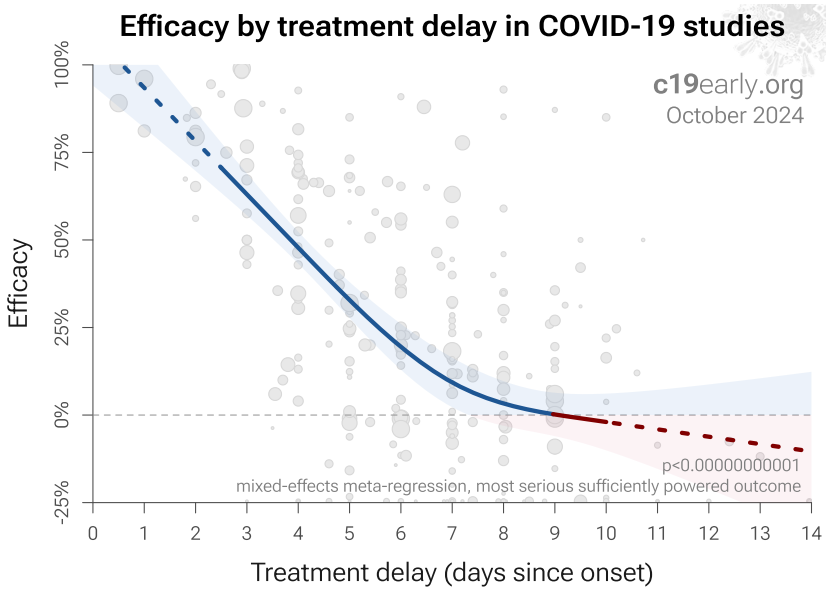


Figure 10. **Early treatment is more effective.** Meta-regression showing efficacy as a function of treatment delay in COVID-19 studies from 98 treatments.

Patient demographics. Details of the patient population including age and comorbidities may critically affect how well a treatment works. For example, many COVID-19 studies with relatively young low-comorbidity patients show all patients recovering quickly with or without treatment. In such cases, there is little room for an effective treatment to improve results, for example as in *López-Medina et al.*

Variants. Efficacy may depend critically on the distribution of SARS-CoV-2 variants encountered by patients. Risk varies significantly across variants [26], for example the Gamma variant shows significantly different characteristics [27-30]. Different mechanisms of action may be more or less effective depending on variants, for example the degree to which TMPRSS2 contributes to viral entry can differ across variants [31,32].

Regimen. Effectiveness may depend strongly on the dosage and treatment regimen.

Other treatments. The use of other treatments may significantly affect outcomes, including supplements, other medications, or other interventions such as prone positioning. Treatments may be synergistic [33-43], therefore efficacy may depend strongly on combined treatments.

Medication quality. The quality of medications may vary significantly between manufacturers and production batches, which may significantly affect efficacy and safety. *Williams et al.* analyze ivermectin from 11 different sources, showing highly variable antiparasitic efficacy across different manufacturers. *Xu et al.* analyze a treatment from two different manufacturers, showing 9 different impurities, with significantly different concentrations for each manufacturer.

Effect measured. Across all studies there is a strong association between different outcomes, for example improved recovery is strongly associated with lower mortality. However, efficacy may differ depending on the effect measured, for example a treatment may be more effective against secondary complications and have minimal effect on viral clearance.

Meta analysis. The distribution of studies will alter the outcome of a meta analysis. Consider a simplified example where everything is equal except for the treatment delay, and effectiveness decreases to zero or below with increasing delay. If there are many studies using very late treatment, the outcome may be negative, even though early treatment is very effective. All meta analyses combine heterogeneous studies, varying in population, variants, and potentially all factors above, and therefore may obscure efficacy by including studies where treatment is less effective. Generally, we expect the estimated effect size from meta analysis to be less than that for the optimal case. Looking at all studies is valuable for providing an overview of all research, important to avoid cherry-picking, and informative when a positive result is found despite combining less-optimal situations. However, the resulting estimate does not apply to specific cases such as early treatment in high-risk populations. While we present results for all studies, we also present treatment time and individual outcome analyses, which may be more informative for specific use cases.

Pooled Effects

Combining studies is required. For COVID-19, delay in clinical results translates into additional death and morbidity, as well as additional economic and societal damage. Combining the results of studies reporting different outcomes is required. There may be no mortality in a trial with low-risk patients, however a reduction in severity or improved viral clearance may translate into lower mortality in a high-risk population. Different studies may report lower severity, improved recovery, and lower mortality, and the significance may be very high when combining the results. *"The studies reported different outcomes"* is not a good reason for disregarding results.

Specific outcome and pooled analyses. We present both specific outcome and pooled analyses. In order to combine the results of studies reporting different outcomes we use the most serious outcome reported in each study, based on the thesis that improvement in the most serious outcome provides comparable measures of efficacy for a treatment. A critical advantage of this approach is simplicity and transparency. There are many other ways to combine evidence for different outcomes, along with additional evidence such as dose-response relationships, however these increase complexity.

Using more information. Another way to view pooled analysis is that we are using more of the available information. Logically we should, and do, use additional information. For example dose-response and treatment delay-response relationships provide significant additional evidence of efficacy that is considered when reviewing the evidence for a treatment.

Ethical and practical issues limit high-risk trials. Trials with high-risk patients may be restricted due to ethics for treatments that are known or expected to be effective, and they increase difficulty for recruiting. Using less severe outcomes as a proxy for more serious outcomes allows faster collection of evidence.

Improvement across outcomes. For many COVID-19 treatments, a reduction in mortality logically follows from a reduction in hospitalization, which follows from a reduction in symptomatic cases, which follows from a reduction in PCR positivity. We can directly test this for COVID-19.

Validating pooled outcome analysis for COVID-19. Analysis of the the association between different outcomes across studies from all 98 treatments we cover confirms the validity of pooled outcome analysis for COVID-19. Figure 11 shows that lower hospitalization is very strongly associated with lower mortality ($p < 0.000000000001$). Similarly,

Figure 12 shows that improved recovery is very strongly associated with lower mortality ($p < 0.000000000001$). Considering the extremes, *Singh et al.* show an association between viral clearance and hospitalization or death, with $p = 0.003$ after excluding one large outlier from a mutagenic treatment, and based on 44 RCTs including 52,384 patients. Figure 13 shows that improved viral clearance is strongly associated with fewer serious outcomes. The association is very similar to *Singh et al.*, with higher confidence due to the larger number of studies. As with *Singh et al.*, the confidence increases when excluding the outlier treatment, from $p = 0.00000053$ to $p = 0.000000028$.

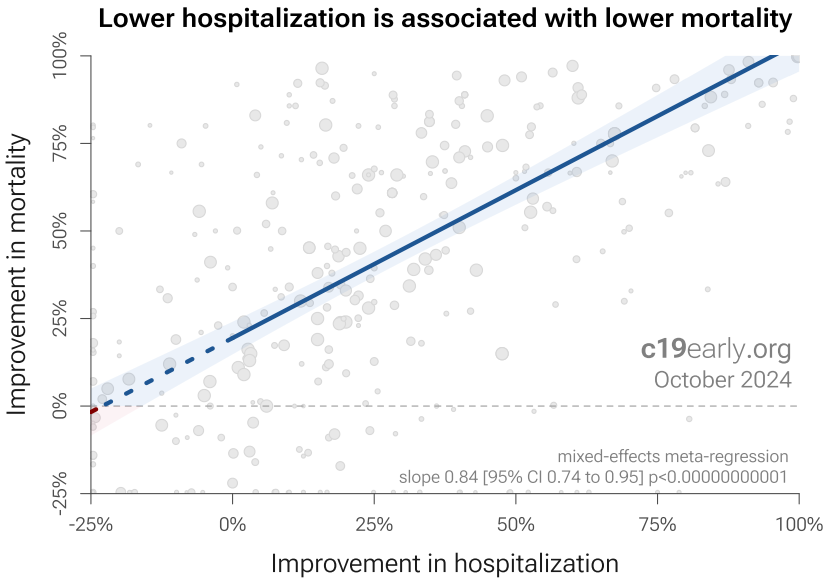


Figure 11. Lower hospitalization is associated with lower mortality, supporting pooled outcome analysis.

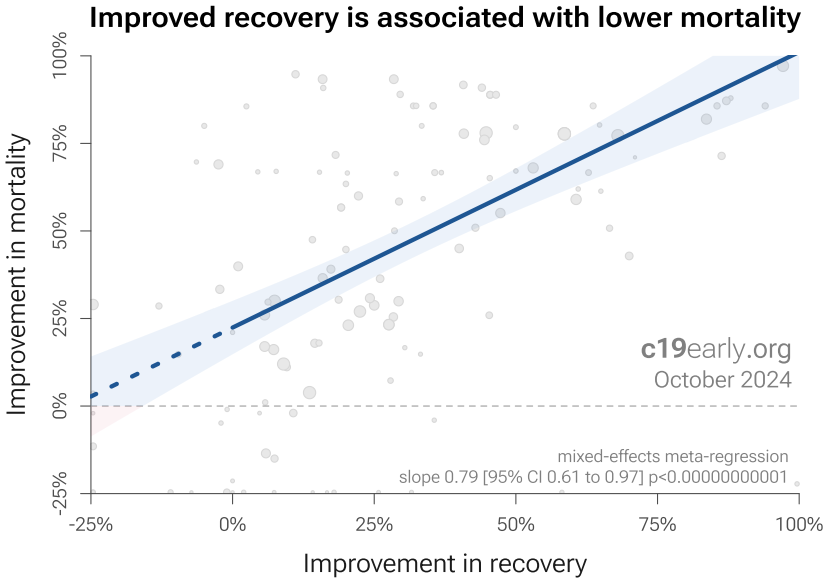


Figure 12. Improved recovery is associated with lower mortality, supporting pooled outcome analysis.

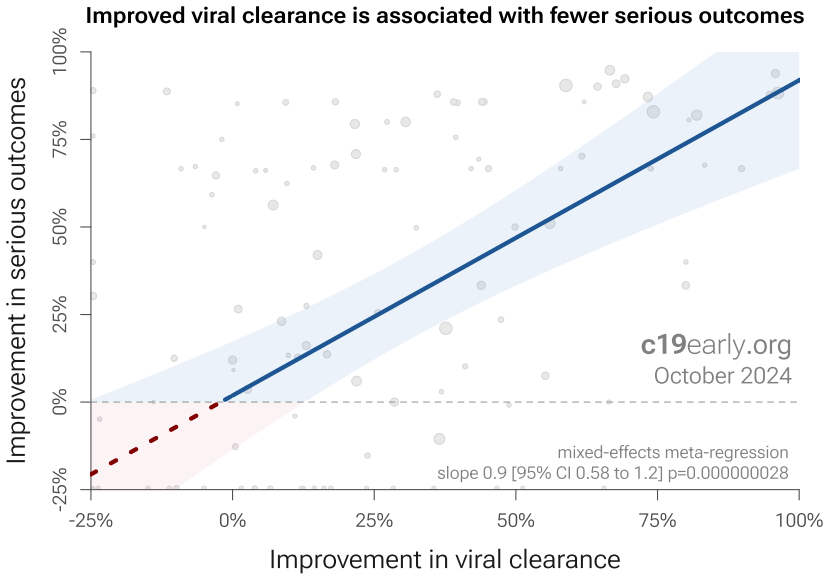


Figure 11. **Improved viral clearance is associated with fewer serious outcomes, supporting pooled outcome analysis.**

Pooled outcomes identify efficacy 5 months faster (6 months for RCTs). Currently, 48 of the treatments we analyze show statistically significant efficacy or harm, defined as ≥10% decreased risk or >0% increased risk from ≥3 studies. 89% of these have been confirmed with one or more specific outcomes, with a mean delay of 5.1 months. When restricting to RCTs only, 56% of treatments showing statistically significant efficacy/harm with pooled effects have been confirmed with one or more specific outcomes, with a mean delay of 6.4 months. Figure 14 shows when treatments were found effective during the pandemic. Pooled outcomes often resulted in earlier detection of efficacy.

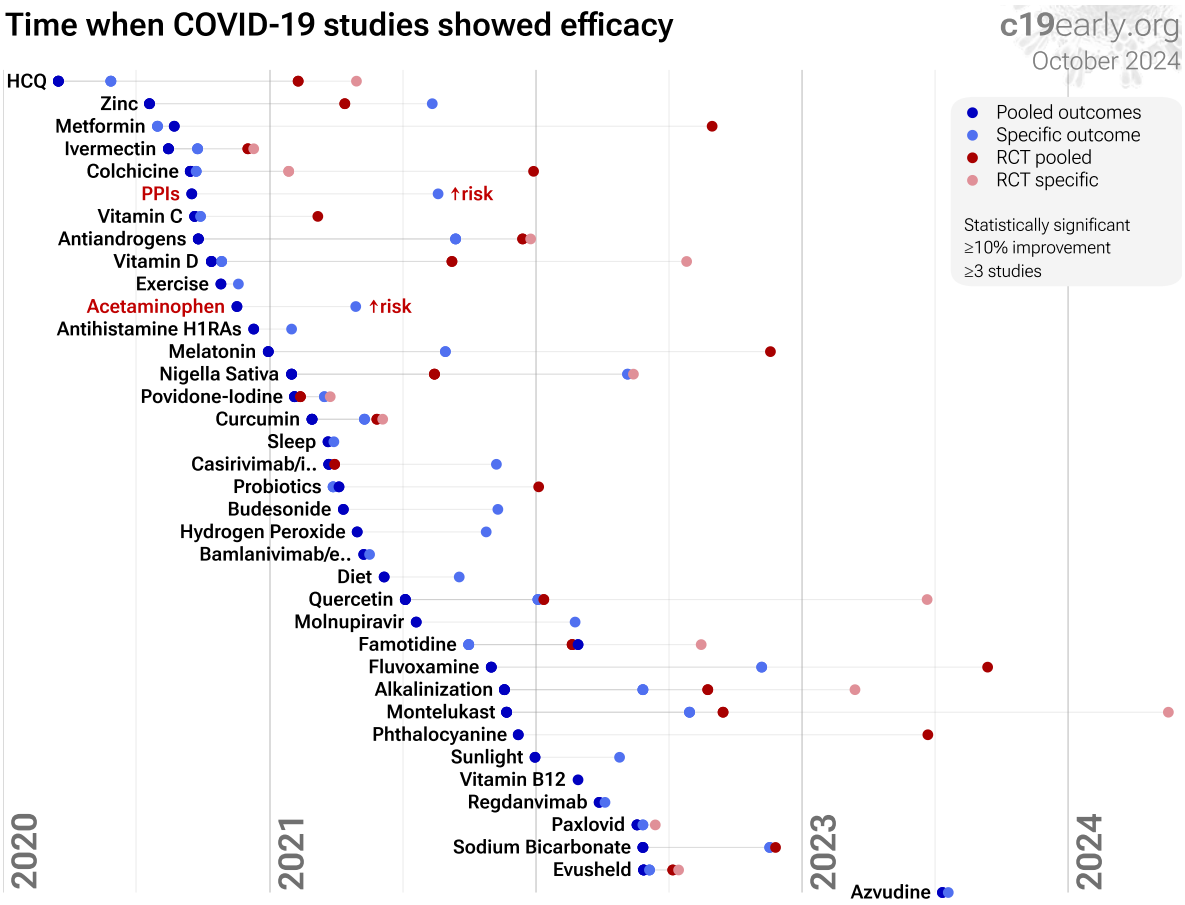


Figure 14. **The time when studies showed that treatments were effective, defined as statistically significant improvement of ≥10% from ≥3 studies.** Pooled results typically show efficacy earlier than specific outcome results. Results from all studies often shows efficacy much earlier than when restricting to RCTs. Results reflect conditions as used in trials to date, these depend on the population treated, treatment delay, and treatment regimen.

Limitations. Pooled analysis could hide efficacy, for example a treatment that is beneficial for late stage patients but has no effect on viral clearance may show no efficacy if most studies only examine viral clearance. In practice, it is rare for a non-antiviral treatment to report viral clearance and to not report clinical outcomes; and in practice other sources of heterogeneity such as difference in treatment delay is more likely to hide efficacy.

Summary. Analysis validates the use of pooled effects and shows significantly faster detection of efficacy on average. However, as with all meta analyses, it is important to review the different studies included. We also present individual outcome analyses, which may be more informative for specific use cases.

Discussion

Publication bias. Publishing is often biased towards positive results. Trials with patented drugs may have a financial conflict of interest that results in positive studies being more likely to be published, or bias towards more positive results. For example with molnupiravir, trials with negative results remain unpublished to date (CTRI/2021/05/033864 and CTRI/2021/08/0354242). For sarilumab, there is currently not enough data to evaluate publication bias with high confidence.

Funnel plot analysis. Funnel plots have traditionally been used for analyzing publication bias. This is invalid for COVID-19 acute treatment trials — the underlying assumptions are invalid, which we can demonstrate with a simple example. Consider a set of hypothetical perfect trials with no bias. Figure 15 plot A shows a funnel plot for a simulation of 80 perfect trials, with random group sizes, and each patient's outcome randomly sampled (10% control event probability, and a 30% effect size for treatment). Analysis shows no asymmetry ($p > 0.05$). In plot B, we add a

single typical variation in COVID-19 treatment trials — treatment delay. Consider that efficacy varies from 90% for treatment within 24 hours, reducing to 10% when treatment is delayed 3 days. In plot B, each trial's treatment delay is randomly selected. Analysis now shows highly significant asymmetry, $p < 0.0001$, with six variants of Egger's test all showing $p < 0.05$[47-54]. Note that these tests fail even though treatment delay is uniformly distributed. In reality treatment delay is more complex — each trial has a different distribution of delays across patients, and the distribution across trials may be biased (e.g., late treatment trials may be more common). Similarly, many other variations in trials may produce asymmetry, including dose, administration, duration of treatment, differences in SOC, comorbidities, age, variants, and bias in design, implementation, analysis, and reporting.

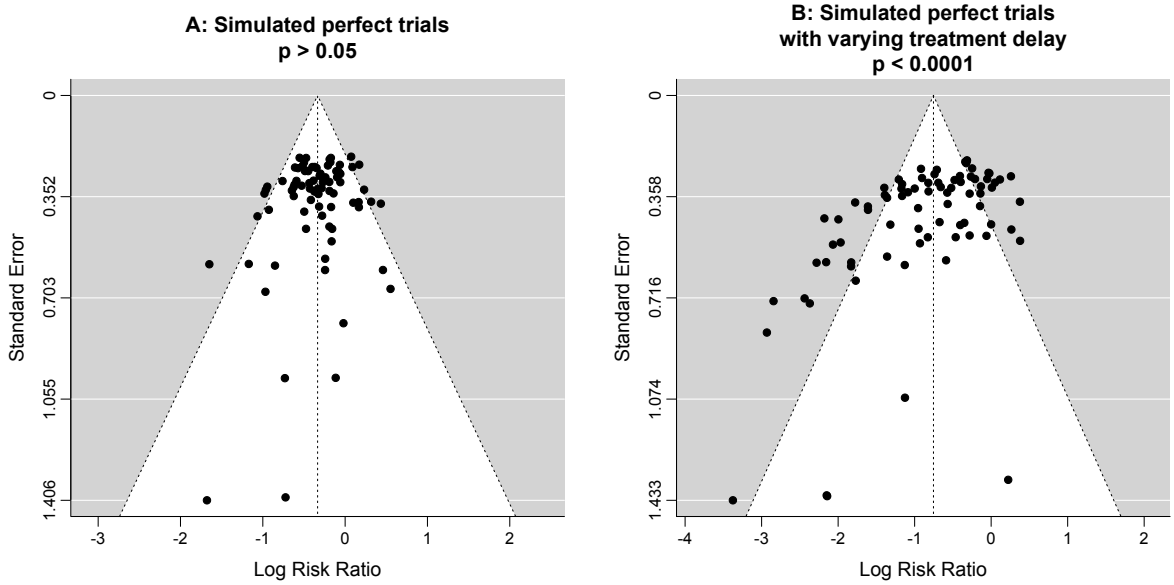


Figure 15. **Example funnel plot analysis for simulated perfect trials.**

Limitations. Summary statistics from meta analysis necessarily lose information. As with all meta analyses, studies are heterogeneous, with differences in treatment delay, treatment regimen, patient demographics, variants, conflicts of interest, standard of care, and other factors. We provide analyses for specific outcomes and by treatment delay, and we aim to identify key characteristics in the forest plots and summaries. Results should be viewed in the context of study characteristics.

Some analyses classify treatment based on early or late administration, as done here, while others distinguish between mild, moderate, and severe cases. Viral load does not indicate degree of symptoms — for example patients may have a high viral load while being asymptomatic. With regard to treatments that have antiviral properties, timing of treatment is critical — late administration may be less helpful regardless of severity.

Details of treatment delay per patient is often not available. For example, a study may treat 90% of patients relatively early, but the events driving the outcome may come from 10% of patients treated very late. Our 5 day cutoff for early treatment may be too conservative, 5 days may be too late in many cases.

Comparison across treatments is confounded by differences in the studies performed, for example dose, variants, and conflicts of interest. Trials with conflicts of interest may use designs better suited to the preferred outcome.

In some cases, the most serious outcome has very few events, resulting in lower confidence results being used in pooled analysis, however the method is simpler and more transparent. This is less critical as the number of studies increases. Restriction to outcomes with sufficient power may be beneficial in pooled analysis and improve accuracy when there are few studies, however we maintain our pre-specified method to avoid any retrospective changes.

Studies show that combinations of treatments can be highly synergistic and may result in many times greater efficacy than individual treatments alone[33-43]. Therefore standard of care may be critical and benefits may diminish or disappear if standard of care does not include certain treatments.

This real-time analysis is constantly updated based on submissions. Accuracy benefits from widespread review and submission of updates and corrections from reviewers. Less popular treatments may receive fewer reviews.

No treatment or intervention is 100% available and effective for all current and future variants. Efficacy may vary significantly with different variants and within different populations. All treatments have potential side effects. Propensity to experience side effects may be predicted in advance by qualified physicians. We do not provide medical advice. Before taking any medication, consult a qualified physician who can compare all options, provide personalized advice, and provide details of risks and benefits based on individual medical history and situations.

Reviews. *Abraham et al.* present a review covering sarilumab for COVID-19.

Perspective

Results compared with other treatments. SARS-CoV-2 infection and replication involves a complex interplay of 50+ host and viral proteins and other factors[14-18], providing many therapeutic targets. Over 8,000 compounds have been predicted to reduce COVID-19 risk[19], either by directly minimizing infection or replication, by supporting immune system function, or by minimizing secondary complications. Figure 16 shows an overview of the results for sarilumab in the context of multiple COVID-19 treatments, and Figure 17 shows a plot of efficacy vs. cost for COVID-19 treatments.

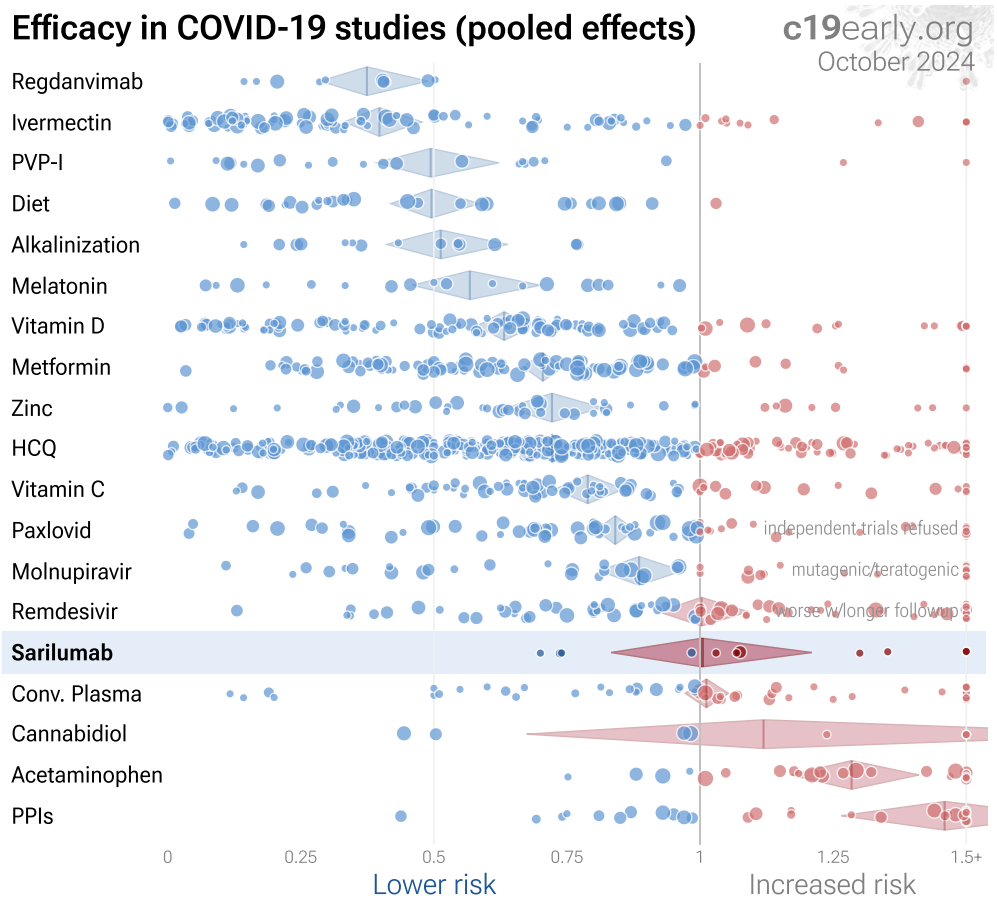


Figure 16. **Scatter plot showing results within the context of multiple COVID-19 treatments.** Diamonds shows the results of random effects meta-analysis. 0.6% of 8,000+ proposed treatments show efficacy[56].

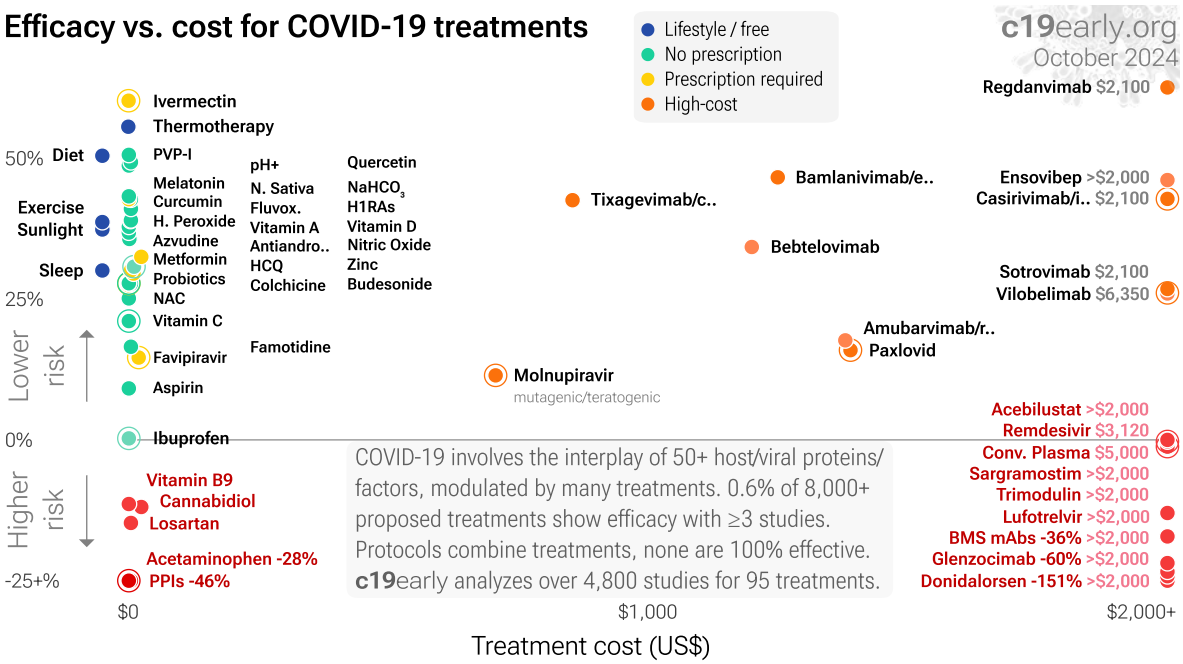


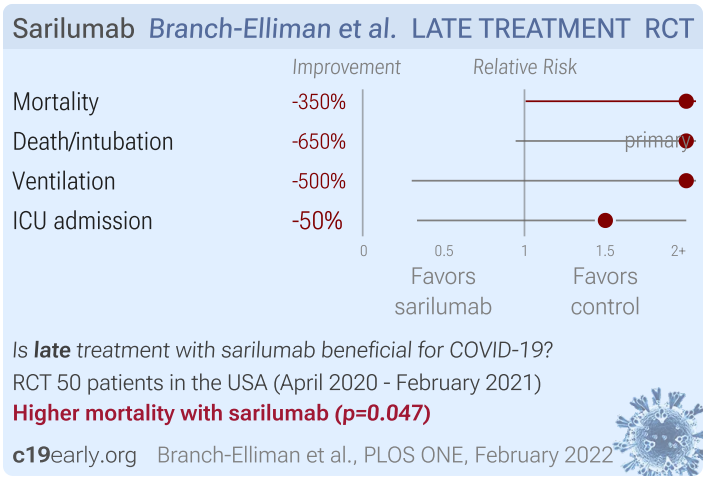
Figure 17. **Efficacy vs. cost for COVID-19 treatments.**

Conclusion

Meta analysis using the most serious outcome reported shows 0% [-17-21%] higher risk, without reaching statistical significance. Currently all studies are RCTs.

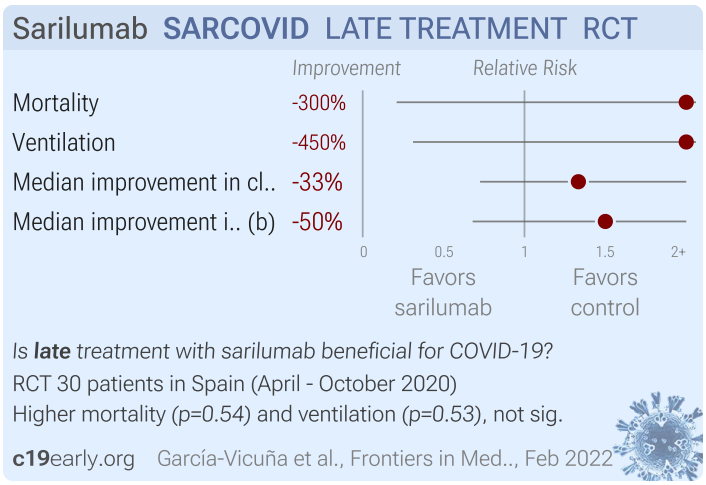
Study Notes

Branch-Elliman



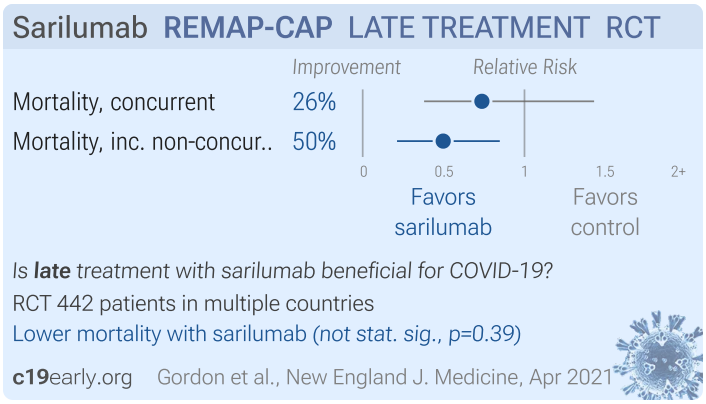
Branch-Elliman: RCT 50 hospitalized moderate-to-severe COVID-19 patients showing higher mortality with subcutaneous sarilumab compared to standard of care. The study was stopped early due to a high probability of futility and potential harm.

García-Vicuña



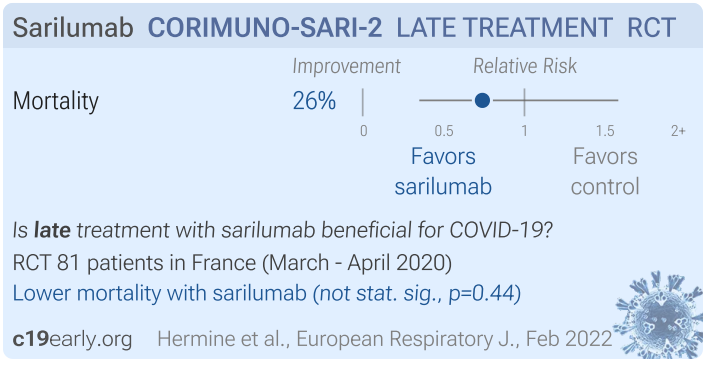
García-Vicuña: RCT 30 hospitalized moderate-to-severe COVID-19 patients showing no significant difference in 30-day mortality, clinical improvement at day 7, or time to discharge with sarilumab compared to standard care.

Gordon



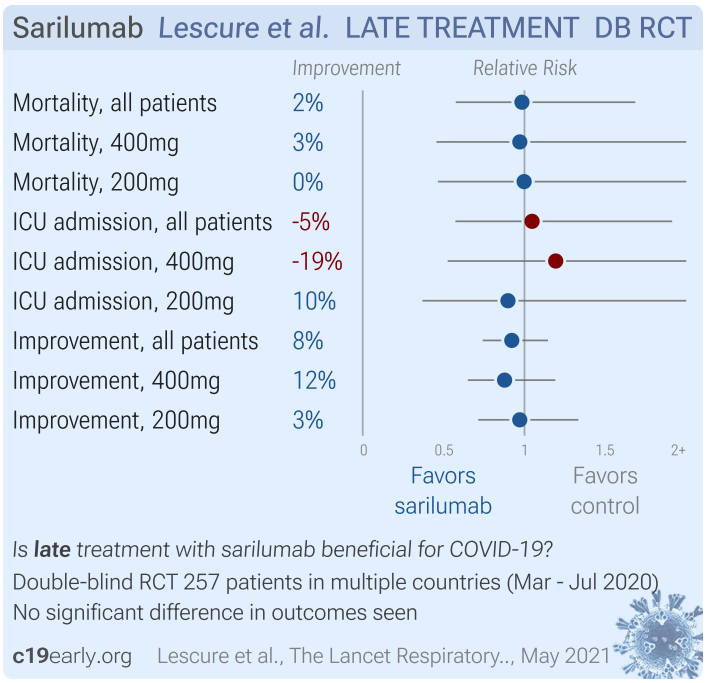
Gordon: RCT 803 critically ill COVID-19 patients showing improved outcomes with tocilizumab and sarilumab. There was only 48 sarilumab patients and the model used shrinks the posterior distribution for each intervention effect toward the overall estimate for the combined drugs. The concurrent event counts for sarilumab may be more accurate.

Hermine



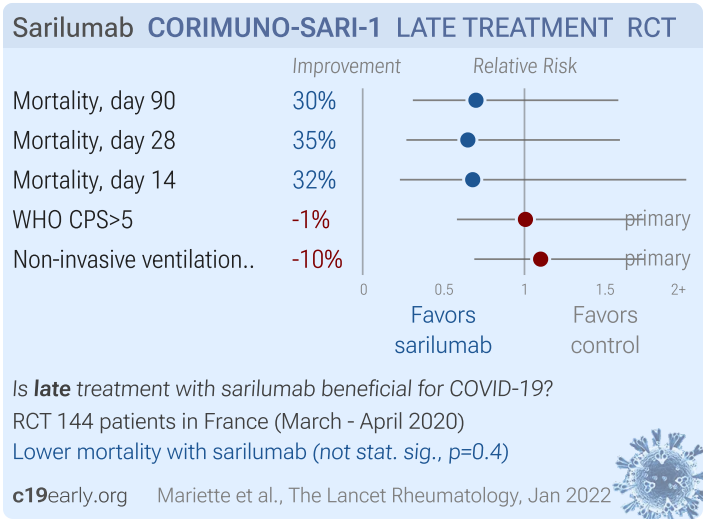
Hermine: Two open-label RCTs of 97 and 91 critically ill COVID-19 patients in France showing no significant differences with tocilizumab or sarilumab.

Lescure



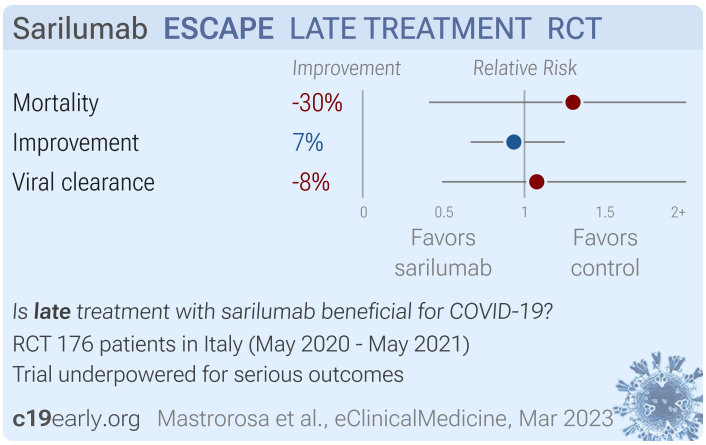
Lescure: RCT 416 hospitalized severe or critical COVID-19 patients showing no significant difference with intravenous sarilumab compared to placebo for clinical improvement, survival at day 29, or other secondary outcomes.

Mariette



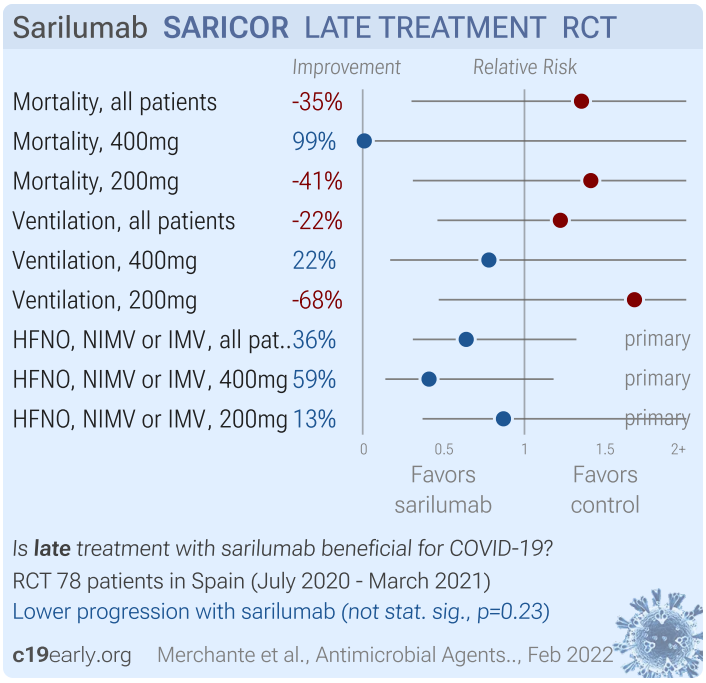
Mariette: RCT 148 hospitalized patients with moderate-to-severe COVID-19 pneumonia in France showing no significant differences with sarilumab treatment.

Mastrorosa



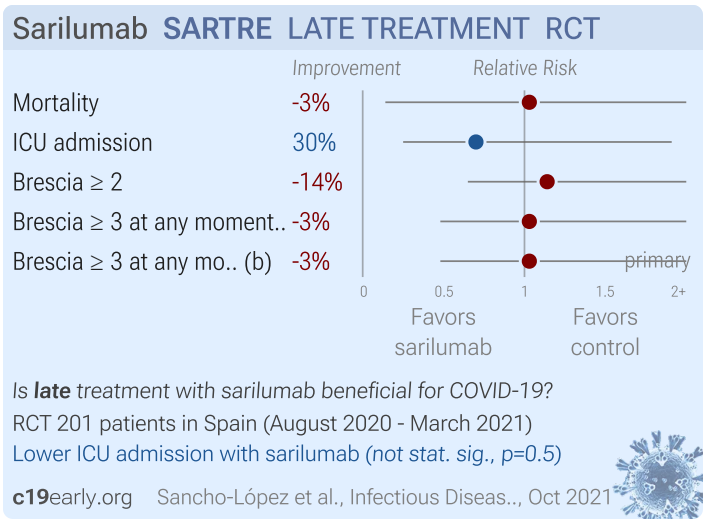
Mastrorosa: RCT with 176 severe COVID-19 patients showing no significant difference in time to clinical improvement or 30 day mortality with sarilumab treatment.

Merchante



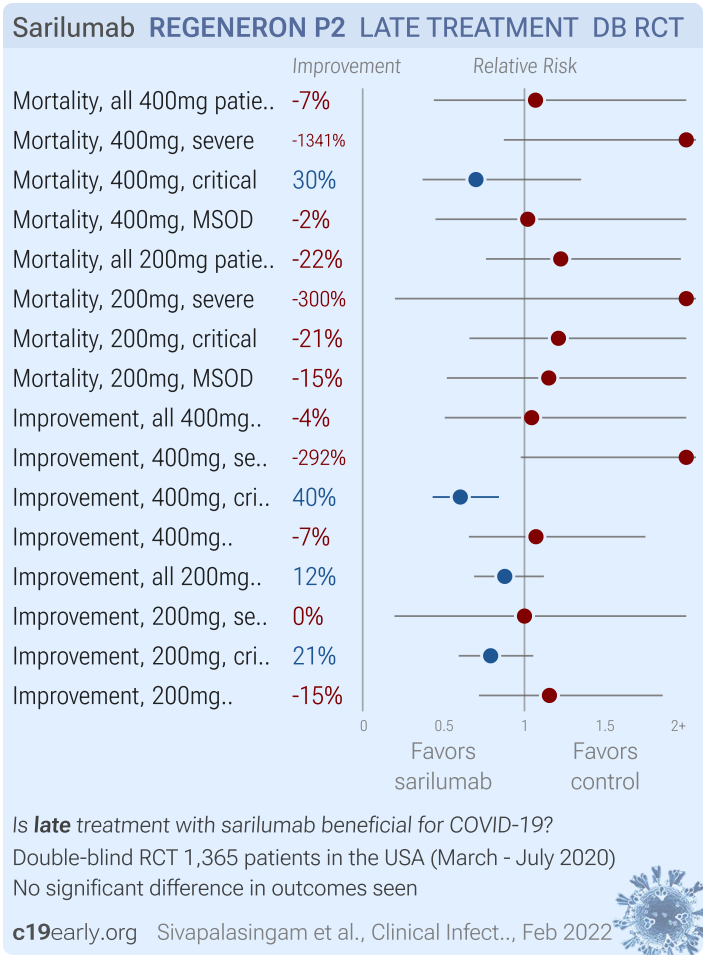
Merchante: RCT 115 hospitalized COVID-19 pneumonia patients in Spain showing a trend towards reduced progression to severe respiratory failure requiring high-flow oxygen, non-invasive ventilation, or mechanical ventilation, and reduced mortality, with sarilumab 400mg compared to standard of care.

Sancho-López



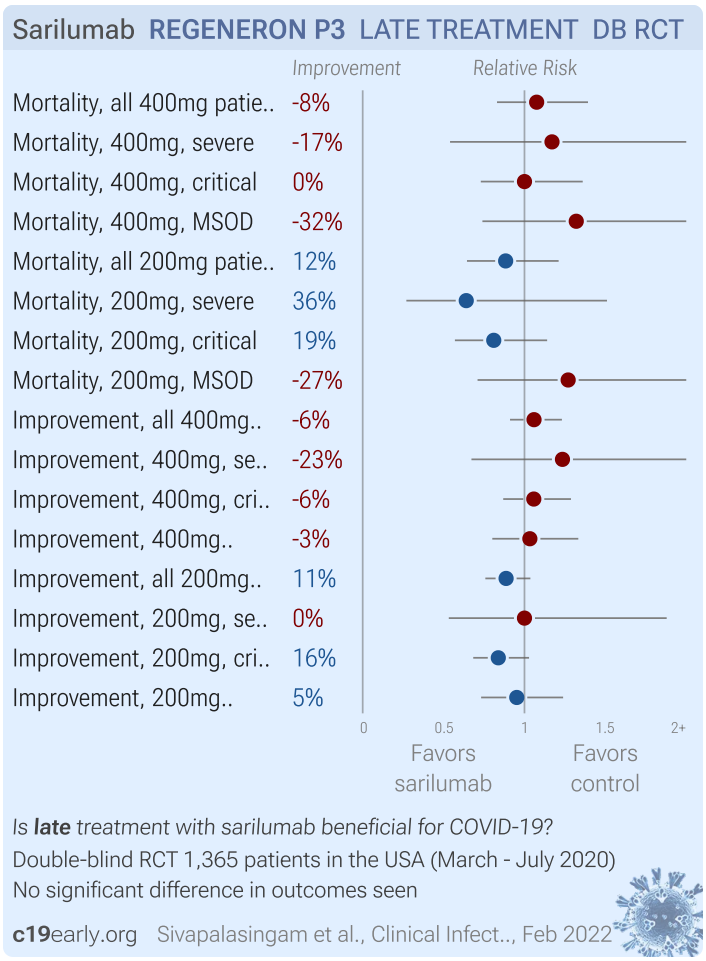
Sancho-López: RCT 201 hospitalized COVID-19 pneumonia patients under standard oxygen therapy in Spain showing no significant difference with sarilumab treatment.

Sivapalasingam



Sivapalasingam: Phase 2 and phase 3 RCTs with 1,365 hospitalized COVID-19 patients showing no significant improvement with sarilumab vs placebo. Post-hoc analysis suggests a potential mortality benefit with sarilumab in mechanically ventilated patients receiving corticosteroids at baseline. Phase 2 and phase 3 results are listed separately[66,67].

Sivapalasingam



Sivapalasingam (B): Phase 2 and phase 3 RCTs with 1,365 hospitalized COVID-19 patients showing no significant improvement with sarilumab vs placebo. Post-hoc analysis suggests a potential mortality benefit with sarilumab in mechanically ventilated patients receiving corticosteroids at baseline. Phase 2 and phase 3 results are listed separately[66,67].

Zulueta

Zulueta: Estimated 60 patient sarilumab late treatment study with results not reported over 3 years after estimated completion.

Appendix 1. Methods and Data

We perform ongoing searches of PubMed, medRxiv, Europe PMC, ClinicalTrials.gov, The Cochrane Library, Google Scholar, Research Square, ScienceDirect, Oxford University Press, the reference lists of other studies and meta-analyses, and submissions to the site c19early.org. Search terms are sarilumab and COVID-19 or SARS-CoV-2. Automated searches are performed twice daily, with all matches reviewed for inclusion. All studies regarding the use of sarilumab for COVID-19 that report a comparison with a control group are included in the main analysis. This is a living analysis and is updated regularly.

We extracted effect sizes and associated data from all studies. If studies report multiple kinds of effects then the most serious outcome is used in pooled analysis, while other outcomes are included in the outcome specific analyses. For example, if effects for mortality and cases are both reported, the effect for mortality is used, this may be different to the effect that a study focused on. If symptomatic results are reported at multiple times, we used the latest time, for

example if mortality results are provided at 14 days and 28 days, the results at 28 days have preference. Mortality alone is preferred over combined outcomes. Outcomes with zero events in both arms are not used, the next most serious outcome with one or more events is used. For example, in low-risk populations with no mortality, a reduction in mortality with treatment is not possible, however a reduction in hospitalization, for example, is still valuable. Clinical outcomes are considered more important than viral test status. When basically all patients recover in both treatment and control groups, preference for viral clearance and recovery is given to results mid-recovery where available. After most or all patients have recovered there is little or no room for an effective treatment to do better, however faster recovery is valuable. If only individual symptom data is available, the most serious symptom has priority, for example difficulty breathing or low SpO_2 is more important than cough. When results provide an odds ratio, we compute the relative risk when possible, or convert to a relative risk according to [69]. Reported confidence intervals and *p*-values were used when available, using adjusted values when provided. If multiple types of adjustments are reported propensity score matching and multivariable regression has preference over propensity score matching or weighting, which has preference over multivariable regression. Adjusted results have preference over unadjusted results for a more serious outcome when the adjustments significantly alter results. When needed, conversion between reported *p*-values and confidence intervals followed *Altman, Altman (B)*, and Fisher's exact test was used to calculate *p*-values for event data. If continuity correction for zero values is required, we use the reciprocal of the opposite arm with the sum of the correction factors equal to 1 [72]. Results are expressed with RR < 1.0 favoring treatment, and using the risk of a negative outcome when applicable (for example, the risk of death rather than the risk of survival). If studies only report relative continuous values such as relative times, the ratio of the time for the treatment group versus the time for the control group is used. Calculations are done in Python (3.12.7) with scipy (1.14.1), pythonmeta (1.26), numpy (1.26.4), statsmodels (0.14.4), and plotly (5.24.1).

Forest plots are computed using PythonMeta [73] with the DerSimonian and Laird random effects model (the fixed effect assumption is not plausible in this case) and inverse variance weighting. Results are presented with 95% confidence intervals. Heterogeneity among studies was assessed using the I^2 statistic. Mixed-effects meta-regression results are computed with R (4.4.0) using the metafor (4.6-0) and rms (6.8-0) packages, and using the most serious sufficiently powered outcome. For all statistical tests, a *p*-value less than 0.05 was considered statistically significant. Grobid 0.8.0 is used to parse PDF documents.

We have classified studies as early treatment if most patients are not already at a severe stage at the time of treatment (for example based on oxygen status or lung involvement), and treatment started within 5 days of the onset of symptoms. If studies contain a mix of early treatment and late treatment patients, we consider the treatment time of patients contributing most to the events (for example, consider a study where most patients are treated early but late treatment patients are included, and all mortality events were observed with late treatment patients). We note that a shorter time may be preferable. Antivirals are typically only considered effective when used within a shorter timeframe, for example 0-36 or 0-48 hours for oseltamivir, with longer delays not being effective [20,21].

We received no funding, this research is done in our spare time. We have no affiliations with any pharmaceutical companies or political parties.

A summary of study results is below. Please submit updates and corrections at https://c19early.org/sarmeta.html.

Late treatment

Effect extraction follows pre-specified rules as detailed above and gives priority to more serious outcomes. For pooled analyses, the first (most serious) outcome is used, which may differ from the effect a paper focuses on. Other outcomes are used in outcome specific analyses.

Branch-Elliman, 2/25/2022, Randomized Controlled Trial, USA, peer-reviewed, mean age 72.3, 21 authors, study period 10 April, 2020 - 3 February, 2021, trial NCT04359901 (history).	risk of death, 350.0% higher, RR 4.50, *p* = 0.047, treatment 6 of 20 (30.0%), control 2 of 30 (6.7%), day 30.
	risk of death/intubation, 650.0% higher, RR 7.50, *p* = 0.03, treatment 5 of 20 (25.0%), control 1 of 30 (3.3%), day 14, primary outcome.

	risk of mechanical ventilation, 500.0% higher, RR 6.00, *p* = 0.16, treatment 2 of 20 (10.0%), control 0 of 30 (0.0%), continuity correction due to zero event (with reciprocal of the contrasting arm), day 14.
	risk of ICU admission, 50.0% higher, RR 1.50, *p* = 0.67, treatment 3 of 20 (15.0%), control 3 of 30 (10.0%), day 30.
García-Vicuña, 2/23/2022, Randomized Controlled Trial, Spain, peer-reviewed, median age 61.5, 13 authors, study period 13 April, 2020 - 30 October, 2020, trial NCT04357808 (history) (SARCOVID).	risk of death, 300.0% higher, RR 4.00, *p* = 0.54, treatment 2 of 20 (10.0%), control 0 of 10 (0.0%), continuity correction due to zero event (with reciprocal of the contrasting arm).
	risk of mechanical ventilation, 450.0% higher, RR 5.50, *p* = 0.53, treatment 3 of 20 (15.0%), control 0 of 10 (0.0%), continuity correction due to zero event (with reciprocal of the contrasting arm).
	relative median improvement in clinical status, 33.3% worse, RR 1.33, *p* = 0.36, treatment 20, control 10, day 14.
	relative median improvement in clinical status, 50.0% worse, RR 1.50, *p* = 0.32, treatment 20, control 10, day 7.
Gordon, 4/22/2021, Randomized Controlled Trial, multiple countries, peer-reviewed, 62 authors, trial NCT02735707 (history) (REMAP-CAP).	risk of death, 26.3% lower, RR 0.74, *p* = 0.39, treatment 10 of 45 (22.2%), control 19 of 63 (30.2%), NNT 13, concurrent control patients.
	risk of death, 50.2% lower, HR 0.50, *p* = 0.048, treatment 45, control 397, inverted to make HR<1 favor treatment, including non-concurrent control patients.
Hermine, 2/3/2022, Randomized Controlled Trial, France, peer-reviewed, 6 authors, study period 31 March, 2020 - 20 April, 2020, trial NCT04324073 (history) (CORIMUNO-SARI-2).	risk of death, 26.0% lower, HR 0.74, *p* = 0.44, treatment 14 of 48 (29.2%), control 13 of 33 (39.4%), NNT 9.8.
Lescure, 5/31/2021, Double Blind Randomized Controlled Trial, placebo-controlled, multiple countries, peer-reviewed, median age 59.0, 8 authors, study period 28 March, 2020 - 3 July, 2020, trial NCT04327388 (history).	risk of death, 1.6% lower, RR 0.98, *p* = 0.96, treatment 173, control 84, all patients.
	risk of death, 2.9% lower, RR 0.97, *p* = 1.00, treatment 18 of 173 (10.4%), control 9 of 84 (10.7%), NNT 323, 400mg, day 60, Table S6.
	risk of death, 0.2% lower, RR 1.00, *p* = 1.00, treatment 17 of 159 (10.7%), control 9 of 84 (10.7%), NNT 4452, 200mg, day 60, Table S6.
	risk of ICU admission, 4.7% higher, RR 1.05, *p* = 0.89, treatment 114, control 56, all patients.
	risk of ICU admission, 19.3% higher, RR 1.19, *p* = 0.82, treatment 17 of 114 (14.9%), control 7 of 56 (12.5%), 400mg, day 60, Table S6.

	risk of ICU admission, 10.2% lower, RR 0.90, *p* = 0.80, treatment 11 of 98 (11.2%), control 7 of 56 (12.5%), NNT 78, 200mg, day 60, Table S6.
	risk of no improvement, 7.9% lower, HR 0.92, *p* = 0.47, treatment 173, control 84, all patients.
	risk of no improvement, 12.3% lower, HR 0.88, *p* = 0.40, treatment 173, control 84, inverted to make HR<1 favor treatment, 400mg, day 29, Table 2.
	risk of no improvement, 2.9% lower, HR 0.97, *p* = 0.86, treatment 159, control 84, inverted to make HR<1 favor treatment, 200mg, day 29, Table 2.
Mariette, 1/31/2022, Randomized Controlled Trial, France, peer-reviewed, 6 authors, study period 27 March, 2020 - 6 April, 2020, trial NCT04324073 (history) (CORIMUNO-SARI-1).	risk of death, 30.0% lower, HR 0.70, *p* = 0.40, treatment 10 of 68 (14.7%), control 16 of 76 (21.1%), NNT 16, adjusted per study, day 90.
	risk of death, 35.0% lower, HR 0.65, *p* = 0.35, treatment 8 of 68 (11.8%), control 14 of 76 (18.4%), NNT 15, adjusted per study, day 28.
	risk of death, 32.0% lower, HR 0.68, *p* = 0.50, treatment 6 of 68 (8.8%), control 8 of 76 (10.5%), adjusted per study, day 14.
	WHO CPS>5, 0.6% higher, RR 1.01, *p* = 1.00, treatment 18 of 68 (26.5%), control 20 of 76 (26.3%), day 4, primary outcome.
	non-invasive ventilation, mechanical ventilation, or death, 10.0% higher, HR 1.10, *p* = 0.70, treatment 68, control 76, day 14, primary outcome.
Mastrorosa, 3/31/2023, Randomized Controlled Trial, Italy, peer-reviewed, median age 61.0, 94 authors, study period 11 May, 2020 - 5 May, 2021, ESCAPE trial.	risk of death, 30.0% higher, HR 1.30, *p* = 0.67, treatment 10 of 107 (9.3%), control 4 of 52 (7.7%), Kaplan–Meier, day 30.
	risk of no improvement, 6.5% lower, HR 0.93, *p* = 0.69, treatment 121, control 55, inverted to make HR<1 favor treatment, Kaplan–Meier, day 30.
	risk of no viral clearance, 7.6% higher, RR 1.08, *p* = 1.00, treatment 17 of 79 (21.5%), control 7 of 35 (20.0%), day 30.
Merchante, 2/15/2022, Randomized Controlled Trial, Spain, peer-reviewed, median age 59.0, 20 authors, study period 13 July, 2020 - 5 March, 2021, trial NCT04357860 (history) (SARICOR).	risk of death, 35.2% higher, HR 1.35, *p* = 0.71, treatment 39, control 39, all patients.
	risk of death, 99.0% lower, HR 0.01, *p* = 0.21, treatment 0 of 39 (0.0%), control 3 of 39 (7.7%), relative risk is not 0 because of continuity correction due to zero events (with reciprocal of the contrasting arm), 400mg, Cox proportional hazards, day 28.
	risk of death, 41.0% higher, HR 1.41, *p* = 0.67, treatment 4 of 37 (10.8%), control 3 of 39 (7.7%), 200mg, Cox proportional hazards, day 28.

	risk of mechanical ventilation, 22.2% higher, HR 1.22, *p* = 0.70, treatment 39, control 39, all patients.
	risk of mechanical ventilation, 22.0% lower, HR 0.78, *p* = 0.76, treatment 3 of 39 (7.7%), control 4 of 39 (10.3%), NNT 39, 400mg, Cox proportional hazards, day 28.
	risk of mechanical ventilation, 68.0% higher, HR 1.68, *p* = 0.43, treatment 6 of 37 (16.2%), control 4 of 39 (10.3%), 200mg, Cox proportional hazards, day 28.
	HFNO, NIMV or IMV, 36.0% lower, HR 0.64, *p* = 0.23, treatment 39, control 39, all patients, primary outcome.
	HFNO, NIMV or IMV, 59.0% lower, HR 0.41, *p* = 0.10, treatment 5 of 39 (12.8%), control 11 of 39 (28.2%), NNT 6.5, 400mg, Cox proportional hazards, day 28, primary outcome.
	HFNO, NIMV or IMV, 13.0% lower, HR 0.87, *p* = 0.76, treatment 10 of 37 (27.0%), control 11 of 39 (28.2%), NNT 85, 200mg, Cox proportional hazards, day 28, primary outcome.
Sancho-López, 10/17/2021, Randomized Controlled Trial, Spain, peer-reviewed, median age 60.0, 22 authors, study period 4 August, 2020 - 23 March, 2021, SARTRE trial.	risk of death, 3.0% higher, RR 1.03, *p* = 0.98, treatment 2 of 99 (2.0%), control 2 of 102 (2.0%), adjusted per study, day 28.
	risk of ICU admission, 30.0% lower, RR 0.70, *p* = 0.50, treatment 7 of 99 (7.1%), control 10 of 102 (9.8%), NNT 37, adjusted per study, day 28.
	Brescia ≥ 2, 14.0% higher, RR 1.14, *p* = 0.66, treatment 40 of 99 (40.4%), control 40 of 102 (39.2%), adjusted per study, day 28.
	Brescia ≥ 3 at any moment, 3.0% higher, RR 1.03, *p* = 0.94, treatment 40 of 99 (40.4%), control 40 of 102 (39.2%), adjusted per study, day 28.
	Brescia ≥ 3 at any moment, 3.0% higher, RR 1.03, *p* = 0.94, treatment 40 of 99 (40.4%), control 40 of 102 (39.2%), adjusted per study, day 14, primary outcome.
Sivapalasingam, 2/26/2022, Double Blind Randomized Controlled Trial, placebo-controlled, USA, peer-reviewed, median age 61.0, 40 authors, study period 18 March, 2020 - 2 July, 2020, trial NCT04315298 (history) (REGENERON P2).	risk of death, 6.8% higher, HR 1.07, *p* = 0.89, treatment 180, control 90, adjusted per study, all 400mg patients.
	risk of death, 1341.2% higher, RR 14.41, *p* = 0.03, treatment 9 of 51 (17.6%), control 0 of 25 (0.0%), continuity correction due to zero event (with reciprocal of the contrasting arm), 400mg, severe patients, phase 2, day 60.
	risk of death, 30.0% lower, HR 0.70, *p* = 0.28, treatment 23 of 88 (26.1%), control 15 of 44 (34.1%), NNT 13, adjusted per study, 400mg, critical patients, phase 2, day 60.
	risk of death, 2.0% higher, HR 1.02, *p* = 0.97, treatment 17 of 41 (41.5%), control 9 of 21 (42.9%), NNT 72, adjusted per study, 400mg, MSOD patients, phase 2, day 60.

	risk of death, 22.4% higher, HR 1.22, *p* = 0.41, treatment 187, control 90, adjusted per study, all 200mg patients.
	risk of death, 300.0% higher, HR 4.00, *p* = 0.55, treatment 2 of 50 (4.0%), control 0 of 25 (0.0%), continuity correction due to zero event (with reciprocal of the contrasting arm), 200mg, severe patients, phase 2, day 60.
	risk of death, 21.0% higher, HR 1.21, *p* = 0.55, treatment 38 of 94 (40.4%), control 15 of 44 (34.1%), adjusted per study, 200mg, critical patients, phase 2, day 60.
	risk of death, 15.0% higher, HR 1.15, *p* = 0.74, treatment 20 of 43 (46.5%), control 9 of 21 (42.9%), adjusted per study, 200mg, MSOD patients, phase 2, day 60.
	risk of no improvement, 4.4% higher, RR 1.04, *p* = 0.91, treatment 180, control 90, all 400mg patients.
	risk of no improvement, 292.2% higher, RR 3.92, *p* = 0.04, treatment 16 of 51 (31.4%), control 2 of 25 (8.0%), 400mg, severe patients, phase 2, day 22.
	risk of no improvement, 39.7% lower, RR 0.60, *p* = 0.006, treatment 35 of 88 (39.8%), control 29 of 44 (65.9%), NNT 3.8, 400mg, critical patients, phase 2, day 22.
	risk of no improvement, 7.1% higher, RR 1.07, *p* = 0.79, treatment 23 of 41 (56.1%), control 11 of 21 (52.4%), 400mg, MSOD patients, phase 2, day 22.
	risk of no improvement, 12.2% lower, RR 0.88, *p* = 0.30, treatment 187, control 90, all 200mg patients.
	risk of no improvement, no change, RR 1.00, *p* = 1.00, treatment 4 of 50 (8.0%), control 2 of 25 (8.0%), 200mg, severe patients, phase 2, day 22.
	risk of no improvement, 20.9% lower, RR 0.79, *p* = 0.14, treatment 49 of 94 (52.1%), control 29 of 44 (65.9%), NNT 7.3, 200mg, critical patients, phase 2, day 22.
	risk of no improvement, 15.4% higher, RR 1.15, *p* = 0.60, treatment 26 of 43 (60.5%), control 11 of 21 (52.4%), 200mg, MSOD patients, phase 2, day 22.
Sivapalasingam (B), 2/26/2022, Double Blind Randomized Controlled Trial, placebo-controlled, USA, peer-reviewed, median age 61.0, 40 authors, study period 18 March, 2020 - 2 July, 2020, trial NCT04315298 (history) (REGENERON P3).	risk of death, 7.5% higher, HR 1.08, *p* = 0.59, treatment 567, control 286, adjusted per study, all 400mg patients.
	risk of death, 17.0% higher, HR 1.17, *p* = 0.71, treatment 21 of 137 (15.3%), control 9 of 70 (12.9%), adjusted per study, 400mg, severe patients, phase 3, day 60.
	risk of death, no change, HR 1.00, *p* = 1.00, treatment 114 of 338 (33.7%), control 59 of 170 (34.7%), NNT 102, adjusted per study, 400mg, critical patients, phase 3, day 60.

	risk of death, 32.0% higher, HR 1.32, *p* = 0.35, treatment 40 of 92 (43.5%), control 16 of 46 (34.8%), adjusted per study, 400mg, MSOD patients, phase 3, day 60.
	risk of death, 11.6% lower, HR 0.88, *p* = 0.45, treatment 477, control 286, adjusted per study, all 200mg patients.
	risk of death, 36.0% lower, HR 0.64, *p* = 0.31, treatment 12 of 140 (8.6%), control 9 of 70 (12.9%), NNT 23, adjusted per study, 200mg, severe patients, phase 3, day 60.
	risk of death, 19.0% lower, HR 0.81, *p* = 0.24, treatment 70 of 242 (28.9%), control 59 of 170 (34.7%), NNT 17, adjusted per study, 200mg, critical patients, phase 3, day 60.
	risk of death, 27.0% higher, HR 1.27, *p* = 0.43, treatment 40 of 95 (42.1%), control 16 of 46 (34.8%), adjusted per study, 200mg, MSOD patients, phase 3, day 60.
	risk of no improvement, 5.9% higher, RR 1.06, *p* = 0.47, treatment 567, control 286, all 400mg patients.
	risk of no improvement, 23.5% higher, RR 1.23, *p* = 0.58, treatment 29 of 137 (21.2%), control 12 of 70 (17.1%), 400mg, severe patients, phase 3, day 22.
	risk of no improvement, 5.8% higher, RR 1.06, *p* = 0.64, treatment 164 of 338 (48.5%), control 78 of 170 (45.9%), 400mg, critical patients, phase 3, day 22.
	risk of no improvement, 3.3% higher, RR 1.03, *p* = 0.85, treatment 62 of 92 (67.4%), control 30 of 46 (65.2%), 400mg, MSOD patients, phase 3, day 22.
	risk of no improvement, 11.4% lower, RR 0.89, *p* = 0.13, treatment 477, control 286, all 200mg patients.
	risk of no improvement, no change, RR 1.00, *p* = 1.00, treatment 24 of 140 (17.1%), control 12 of 70 (17.1%), 200mg, severe patients, phase 3, day 22.
	risk of no improvement, 16.2% lower, RR 0.84, *p* = 0.11, treatment 105 of 242 (43.4%), control 88 of 170 (51.8%), NNT 12, 200mg, critical patients, phase 3, day 22.
	risk of no improvement, 4.8% lower, RR 0.95, *p* = 0.85, treatment 59 of 95 (62.1%), control 30 of 46 (65.2%), NNT 32, 200mg, MSOD patients, phase 3, day 22.
Zulueta, 12/30/2020, Spain, trial NCT04661527 (history) (STRIKESARS).	Estimated 60 patient study with results unknown and over 3 years late.

Supplementary Data

Supplementary Data

Footnotes

a. Viral infection and replication involves attachment, entry, uncoating and release, genome replication and transcription, translation and protein processing, assembly and budding, and release. Each step can be disrupted by therapeutics.

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