Spironolactone reduces COVID-19 risk: real-time meta analysis of 12 studies

@CovidAnalysis, July 2025, Version 13
https://c19early.org/spmeta.html

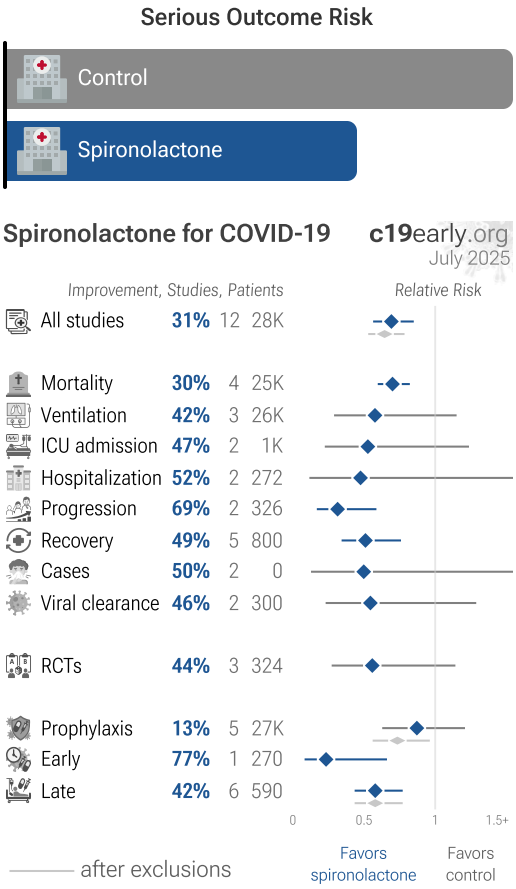
Abstract

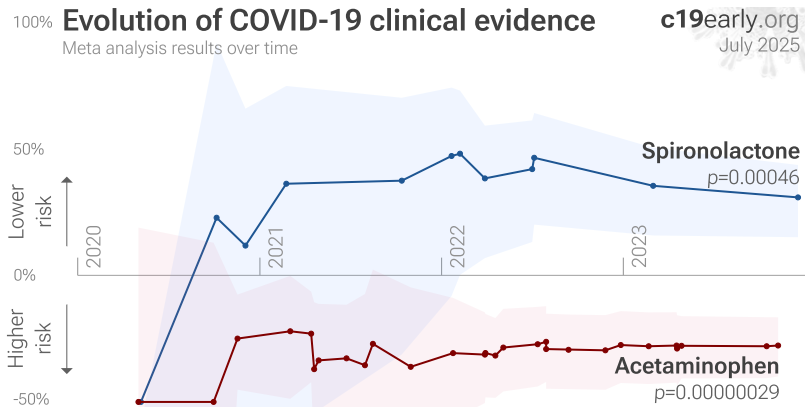
Significantly lower risk is seen for mortality, progression, and recovery. 11 studies from 10 independent teams in 8 countries show significant benefit.

Meta analysis using the most serious outcome reported shows 31% [15-44%] lower risk. Results are similar for Randomized Controlled Trials, higher quality studies, and peer-reviewed studies. Early treatment is more effective than late treatment.

Results are robust — in exclusion sensitivity analysis 4 of 12 studies must be excluded to avoid finding statistically significant efficacy in pooled analysis.

No treatment is 100% effective. Protocols combine safe and effective options with individual risk/benefit analysis and monitoring. Other treatments are more effective. All data and sources to reproduce this analysis are in the appendix.





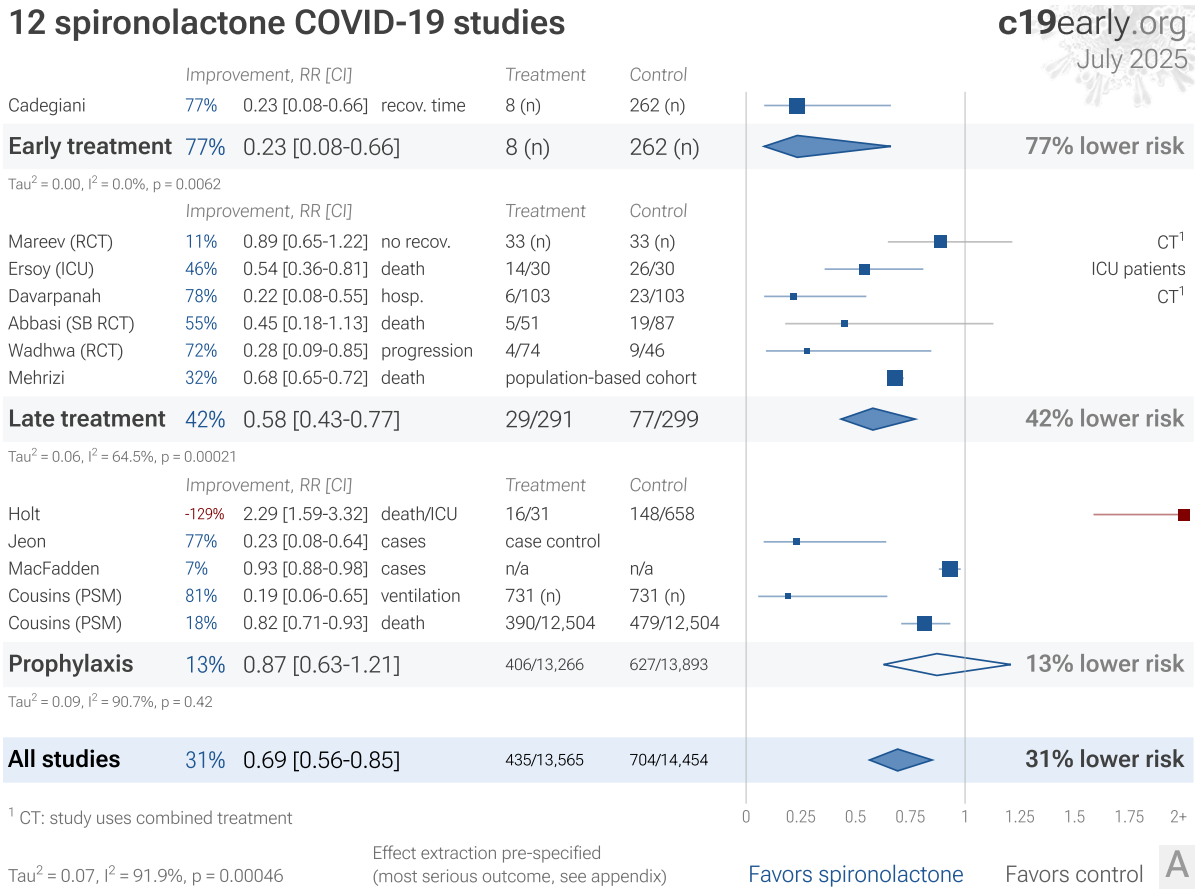
SPIRONOLACTONE FOR COVID-19 — HIGHLIGHTS

Spironolactone reduces risk with very high confidence for mortality, recovery, and in pooled analysis, low confidence for ventilation and progression, and very low confidence for ICU admission and viral clearance.

Early treatment is more effective than late treatment.

36th treatment shown effective in February 2022, now with $p = 0.00046$ from 12 studies.

Real-time updates and corrections with a consistent protocol for 172 treatments. Outcome specific analysis and combined evidence from all studies including treatment delay, a primary confounding factor.



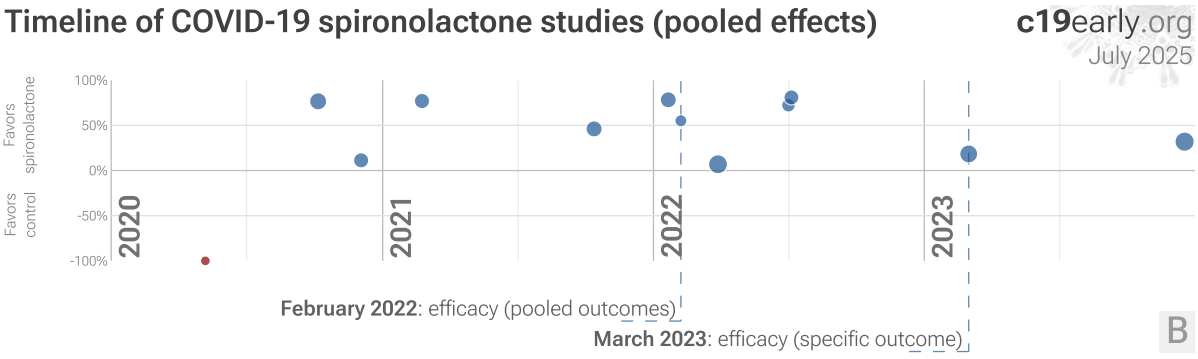


***Figure 1.* A. Random effects meta-analysis.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome reported. For details see the appendix. **B. Timeline of results in spironolactone studies.** The marked dates indicate the time when efficacy was known with a statistically significant improvement of ≥10% from ≥3 studies for pooled outcomes and one or more specific outcome. Efficacy based on specific outcomes was delayed by 12.7 months, compared to using pooled outcomes.

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[2-14] and cognitive deficits[5,10], cardiovascular complications[15-19], organ failure, and death. Even mild untreated infections may result in persistent cognitive deficits[20]—the spike protein binds to fibrin leading to fibrinolysis-resistant blood clots, thromboinflammation, and neuropathology. Minimizing replication as early as possible is recommended.

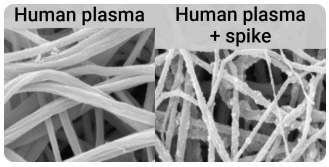


Figure 2. **SARS-CoV-2 spike protein fibrin binding leads to thromboinflammation and neuropathology, from[1].**

Many treatments are expected to modulate infection

SARS-CoV-2 infection and replication involves the complex interplay of 100+ host and viral proteins and other factors[A,21-28], providing many therapeutic targets for which many existing compounds have known activity. Scientists have predicted that over 9,000 compounds may reduce COVID-19 risk[29], 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 spironolactone 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, studies within each treatment stage, individual outcomes, peer-reviewed studies, Randomized Controlled Trials (RCTs), and higher quality studies.

Treatment timing

Figure 3 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.

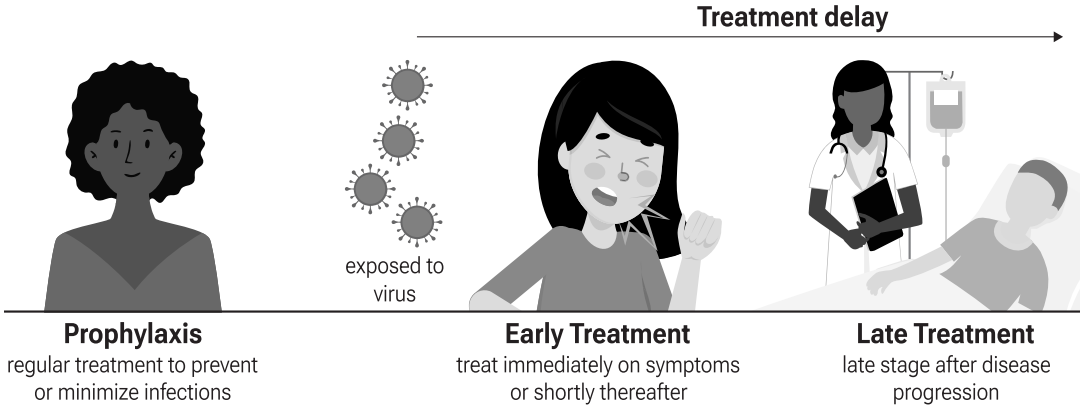


Figure 3. **Treatment stages.**

Results

Table 1 summarizes the results for all stages combined, for Randomized Controlled Trials, for peer-reviewed studies, after exclusions, and for specific outcomes. Table 2 shows results by treatment stage. Figure 4 plots individual results by treatment stage. Figure 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14 show forest plots for random effects meta-analysis of all studies with pooled effects, mortality results, ventilation, ICU admission, hospitalization, progression, recovery, cases, viral clearance, and peer reviewed studies.

	Relative Risk	Studies	Patients
All studies	0.69 [0.56-0.85] ***	12	20K
After exclusions	0.64 [0.53-0.78] ****	10	20K
Peer-reviewed	0.74 [0.60-0.91] **	10	20K
RCTs	0.56 [0.27-1.14]	3	324
Mortality	0.70 [0.60-0.82] ****	4	20K
Ventilation	0.58 [0.29-1.15]	3	20K
ICU admission	0.53 [0.22-1.24]	2	1,600
Hospitalization	0.48 [0.12-1.95]	2	272
Recovery	0.51 [0.34-0.76] ***	5	800
Cases	0.50 [0.13-1.94]	2	0
Viral	0.54 [0.23-1.29]	2	300

***Table 1.* Random effects meta-analysis for all stages combined, for Randomized Controlled Trials, for peer-reviewed studies, after exclusions, and for specific outcomes.** Results show the relative risk with treatment and the 95% confidence interval. * $p<0.05$ ** $p<0.01$ *** $p<0.001$ **** $p<0.0001$.

	Early treatment	Late treatment	Prophylaxis
All studies	0.23 [0.08-0.66] **	0.58 [0.43-0.77] ***	0.87 [0.63-1.21]
After exclusions		0.58 [0.43-0.77] ***	0.73 [0.56-0.96] *
Peer-reviewed		0.61 [0.46-0.81] ***	0.87 [0.63-1.21]
RCTs		0.56 [0.27-1.14]	
Mortality		0.68 [0.64-0.71] ****	0.82 [0.71-0.93] **
Ventilation		0.66 [0.30-1.48]	0.45 [0.11-1.88]
ICU admission		0.81 [0.42-1.59]	0.34 [0.17-0.68] **
Hospitalization		0.48 [0.12-1.95]	
Recovery	0.23 [0.08-0.66] **	0.56 [0.38-0.83] **	
Cases			0.50 [0.13-1.94]
Viral	0.62 [0.42-0.91] *	0.13 [0.01-2.25]	

***Table 2.* Random effects meta-analysis results by treatment stage.** Results show the relative risk with treatment and the 95% confidence interval. * $p<0.05$ ** $p<0.01$ *** $p<0.001$ **** $p<0.0001$.

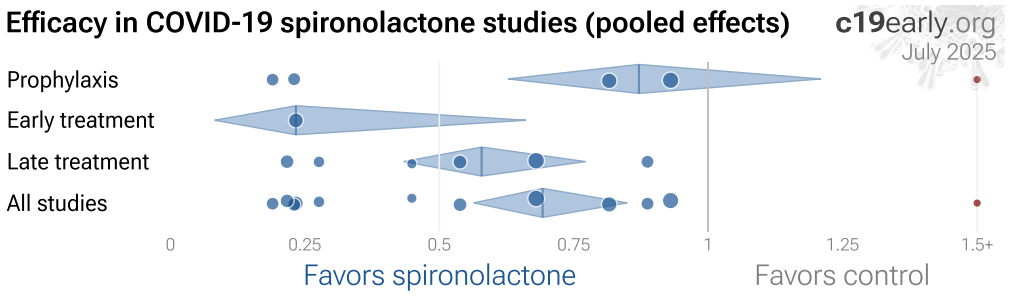


Figure 4. **Scatter plot showing the most serious outcome in all studies, and for studies within each stage.** Diamonds shows the results of random effects meta-analysis.

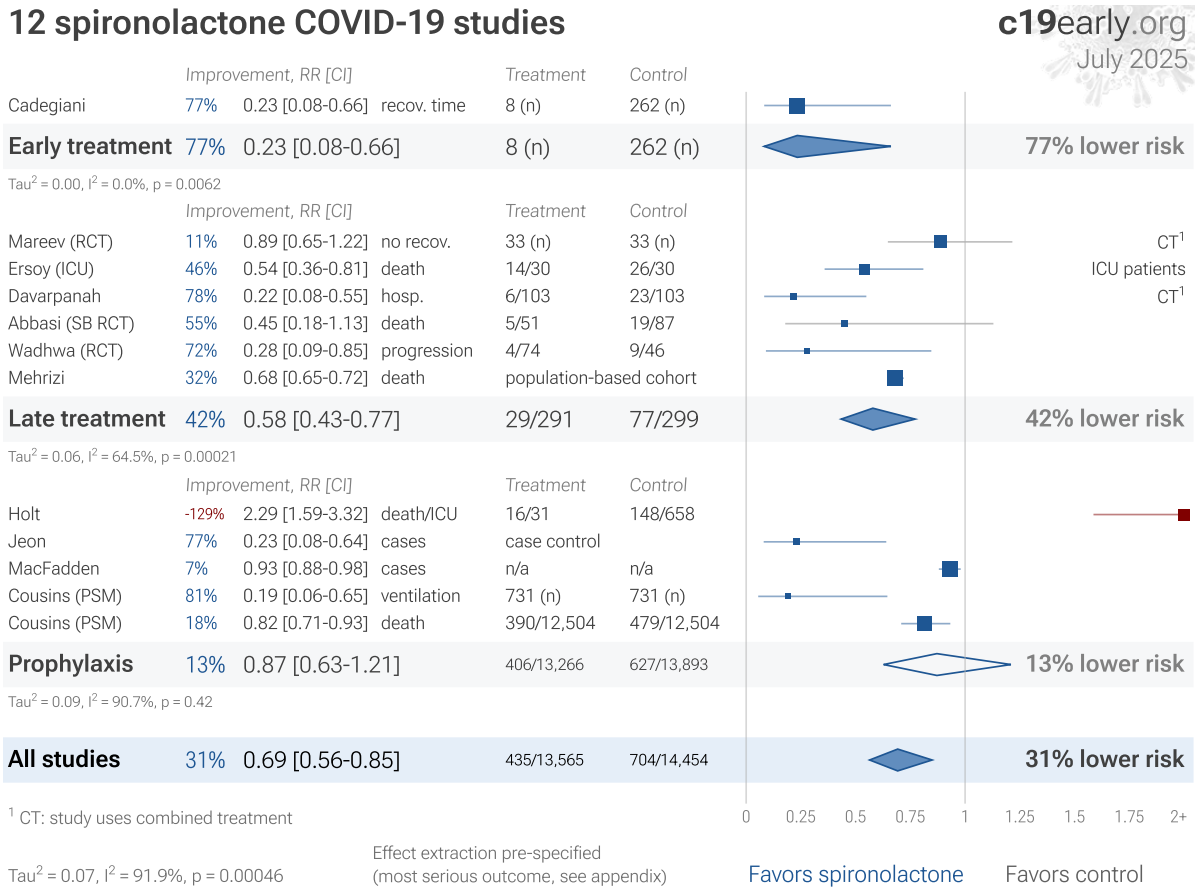


Figure 5. **Random effects meta-analysis for all studies.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome reported. For details see the appendix.

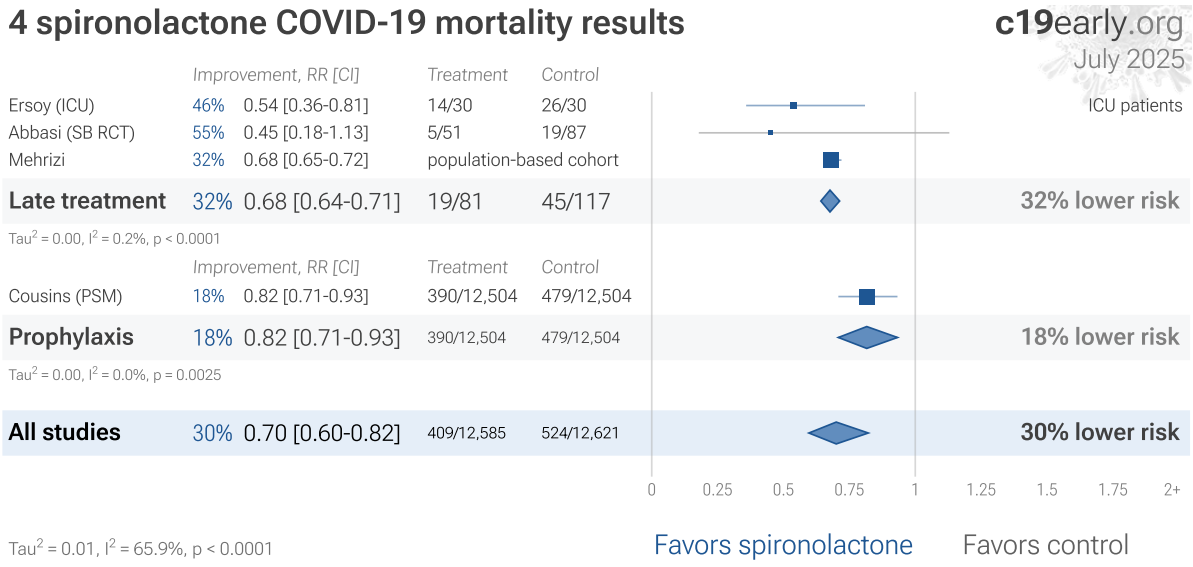


Figure 6. Random effects meta-analysis for mortality results.

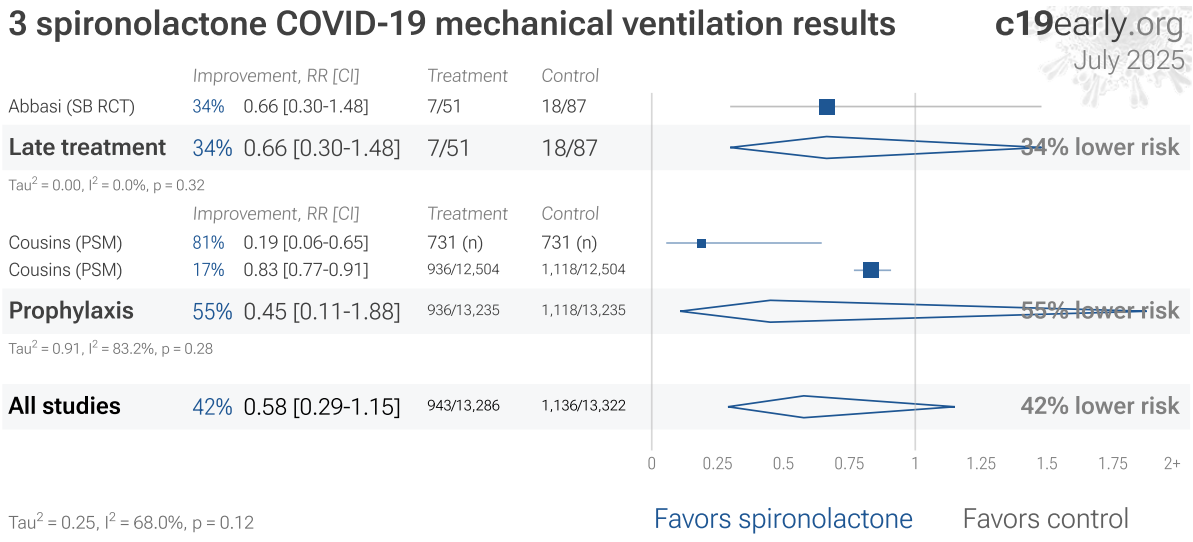


Figure 7. Random effects meta-analysis for ventilation.

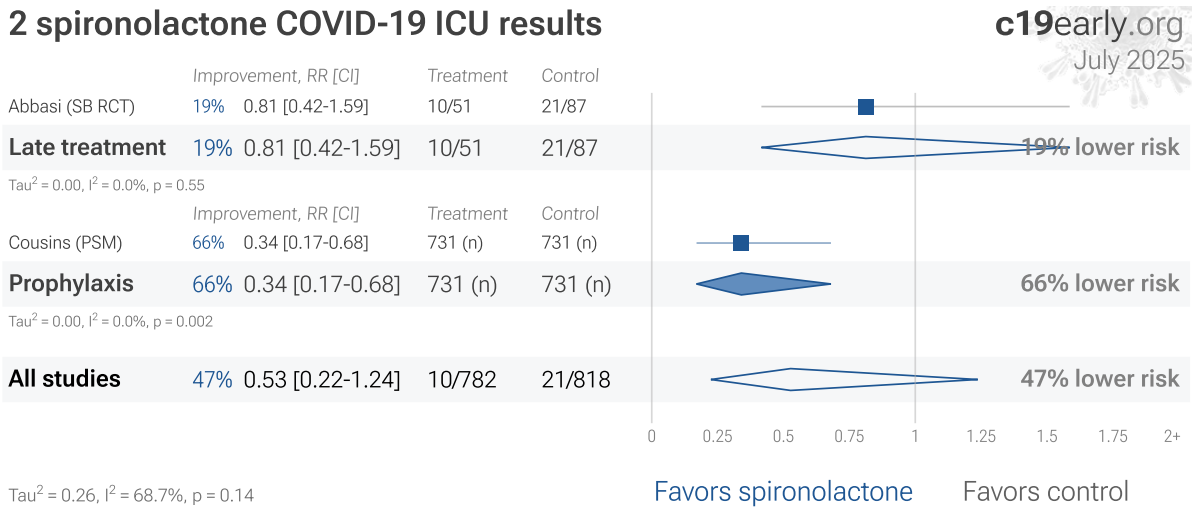


Figure 8. Random effects meta-analysis for ICU admission.

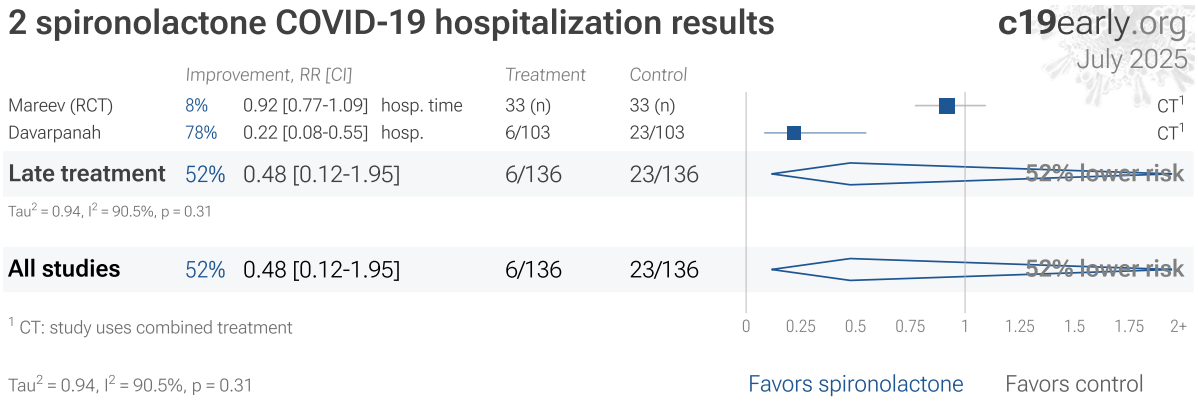


Figure 9. Random effects meta-analysis for hospitalization.

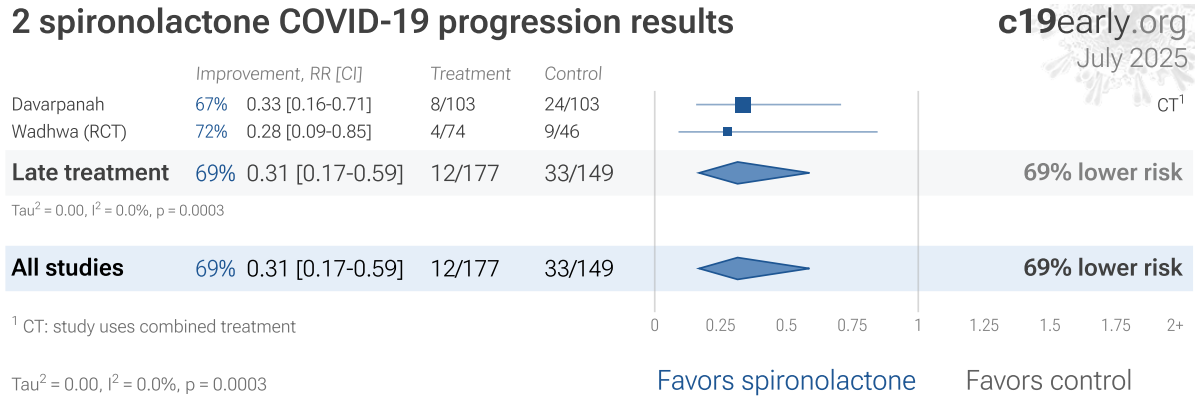


Figure 10. Random effects meta-analysis for progression.

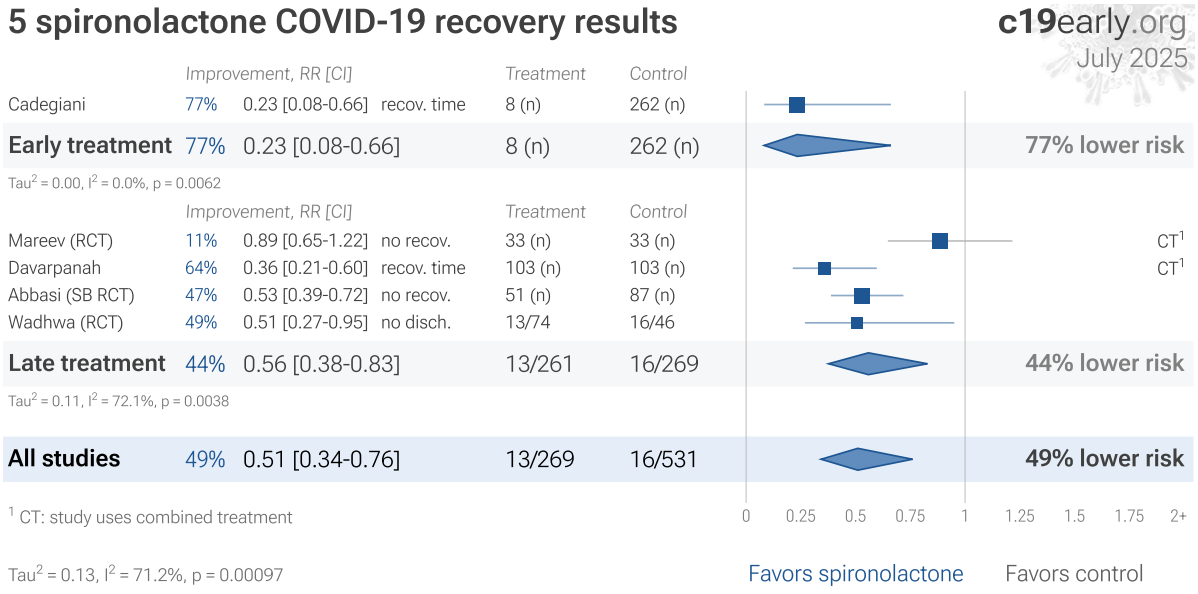


Figure 11. Random effects meta-analysis for recovery.

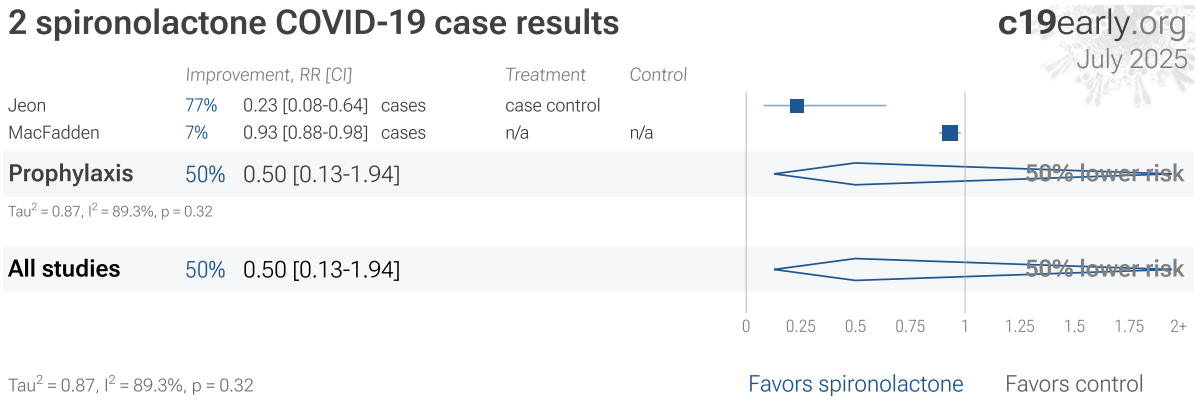


Figure 12. Random effects meta-analysis for cases.

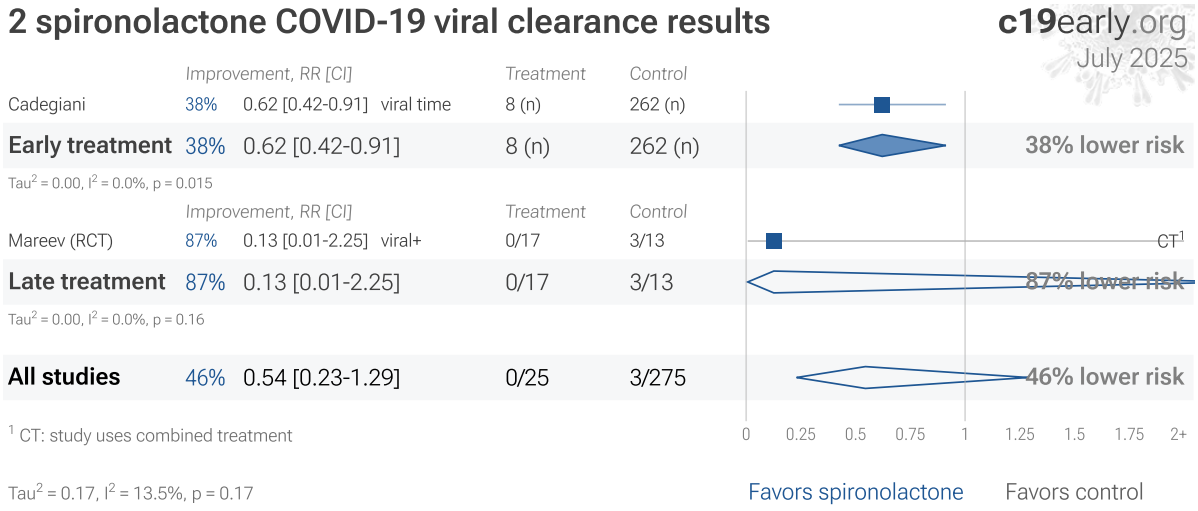


Figure 13. Random effects meta-analysis for viral clearance.

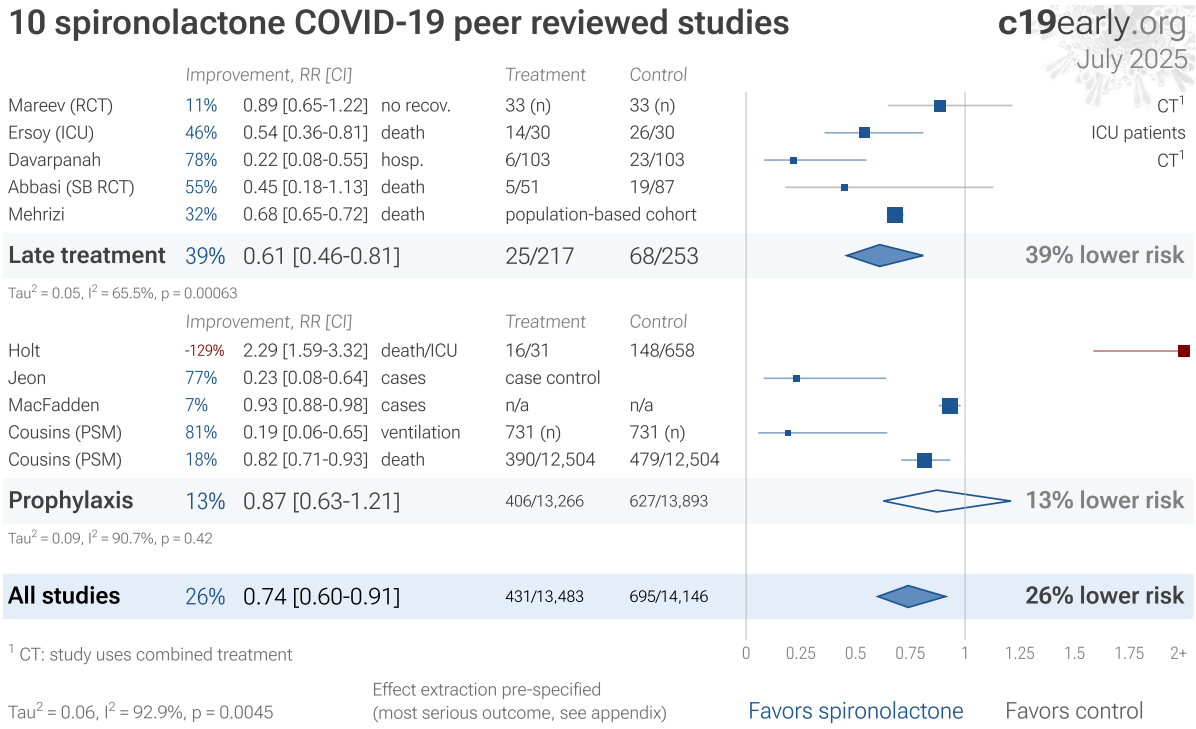


Figure 14. **Random effects meta-analysis for peer reviewed studies.** Effect extraction is pre-specified, using the most serious outcome reported, see the appendix for details. Analysis validating pooled outcomes for COVID-19 can be found below. *Zeraatkar et al.* analyze 356 COVID-19 trials, finding no significant evidence that preprint results are inconsistent with peer-reviewed studies. They also show extremely long peer-review delays, with a median of 6 months to journal publication. A six month delay was equivalent to around 1.5 million deaths during the first two years of the pandemic. Authors recommend using preprint evidence, with appropriate checks for potential falsified data, which provides higher certainty much earlier. *Davidson et al.* also showed no important difference between meta analysis results of preprints and peer-reviewed publications for COVID-19, based on 37 meta analyses including 114 trials.

Randomized Controlled Trials (RCTs)

Figure 15 shows a comparison of results for RCTs and observational studies. Random effects meta analysis of RCTs shows 44% improvement, compared to 30% for other studies. Figure 16 and 17 show forest plots for random effects meta-analysis of all Randomized Controlled Trials and RCT mortality results. RCT results are included in Table 1 and Table 2.

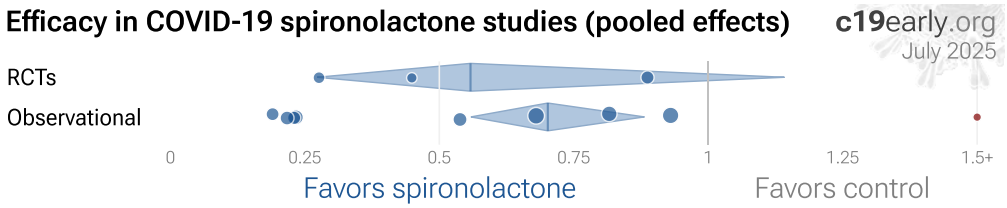


Figure 15. **Results for RCTs and observational studies.**

RCTs have many potential biases

RCTs help to make study groups more similar and can provide a higher level of evidence, however they are subject to many biases[32], and analysis of double-blind RCTs has identified extreme levels of bias[33]. For COVID-19, the overhead may delay treatment, dramatically compromising efficacy; they may encourage monotherapy for simplicity at the cost of efficacy which may rely on combined or synergistic effects; the participants that sign up may not reflect real world usage or the population that benefits most in terms of age, comorbidities, severity of illness, or other factors;

standard of care may be compromised and unable to evolve quickly based on emerging research for new diseases; errors may be made in randomization and medication delivery; and investigators may have hidden agendas or vested interests influencing design, operation, analysis, reporting, and the potential for fraud. All of these biases have been observed with COVID-19 RCTs. There is no guarantee that a specific RCT provides a higher level of evidence.

Conflicts of interest for COVID-19 RCTs

RCTs are expensive and many RCTs are funded by pharmaceutical companies or interests closely aligned with pharmaceutical companies. For COVID-19, this creates an incentive to show efficacy for patented commercial products, and an incentive to show a lack of efficacy for inexpensive treatments. The bias is expected to be significant, for example *Als-Nielsen et al.* analyzed 370 RCTs from Cochrane reviews, showing that trials funded by for-profit organizations were 5 times more likely to recommend the experimental drug compared with those funded by nonprofit organizations. For COVID-19, some major philanthropic organizations are largely funded by investments with extreme conflicts of interest for and against specific COVID-19 interventions.

RCTs for novel acute diseases requiring rapid treatment

High quality RCTs for novel acute diseases are more challenging, with increased ethical issues due to the urgency of treatment, increased risk due to enrollment delays, and more difficult design with a rapidly evolving evidence base. For COVID-19, the most common site of initial infection is the upper respiratory tract. Immediate treatment is likely to be most successful and may prevent or slow progression to other parts of the body. For a non-prophylaxis RCT, it makes sense to provide treatment in advance and instruct patients to use it immediately on symptoms, just as some governments have done by providing medication kits in advance. Unfortunately, no RCTs have been done in this way. Every treatment RCT to date involves delayed treatment. Among the 172 treatments we have analyzed, 67% of RCTs involve very late treatment 5+ days after onset. No non-prophylaxis COVID-19 RCTs match the potential real-world use of early treatments. They may more accurately represent results for treatments that require visiting a medical facility, e.g., those requiring intravenous administration.

Observational studies have been shown to be reliable

Evidence shows that observational studies can also provide reliable results. *Concato et al.* found that well-designed observational studies do not systematically overestimate the magnitude of the effects of treatment compared to RCTs. *Anglemyer et al.* analyzed reviews comparing RCTs to observational studies and found little evidence for significant differences in effect estimates. We performed a similar analysis across the 172 treatments we cover, showing no significant difference in the results of RCTs compared to observational studies, RR 0.98 [0.92-1.05][38]. Similar results are found for all low-cost treatments, RR 1.00 [0.91-1.09]. High-cost treatments show a non-significant trend towards RCTs showing greater efficacy, RR 0.92 [0.84-1.02]. Details can be found in the supplementary data. *Lee et al.* showed that only 14% of the guidelines of the Infectious Diseases Society of America were based on RCTs. Evaluation of studies relies on an understanding of the study and potential biases. Limitations in an RCT can outweigh the benefits, for example excessive dosages, excessive treatment delays, or remote survey bias may have a greater effect on results. Ethical issues may also prevent running RCTs for known effective treatments. For more on issues with RCTs see[40,41].

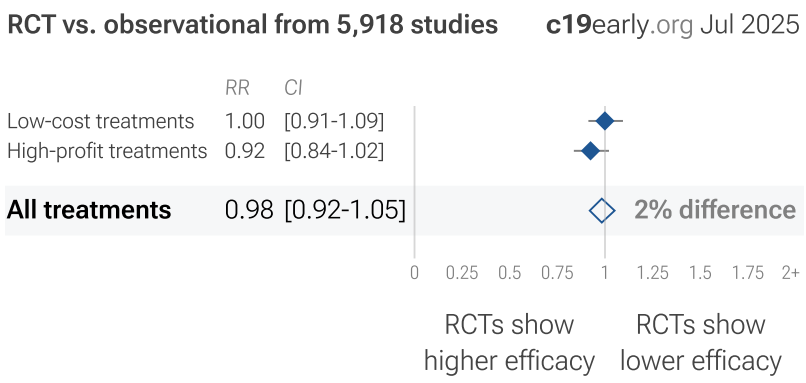


Figure 18. **For COVID-19, observational study results do not systematically differ from RCTs, RR 0.98 [0.92-1.05] across 172 treatments[35].**

Using all studies identifies efficacy 8+ months faster (9+ months for low-cost treatments)

Currently, 55 of the treatments we analyze show statistically significant efficacy or harm, defined as ≥10% decreased risk or >0% increased risk from ≥3 studies. Of these, 58% have been confirmed in RCTs, with a mean delay of 7.7 months (64% with 8.9 months delay for low-cost treatments). The remaining treatments either have no RCTs, or the

point estimate is consistent.

Summary

We need to evaluate each trial on its own merits. RCTs for a given medication and disease may be more reliable, however they may also be less reliable. For off-patent medications, very high conflict of interest trials may be more likely to be RCTs, and more likely to be large trials that dominate meta analyses.

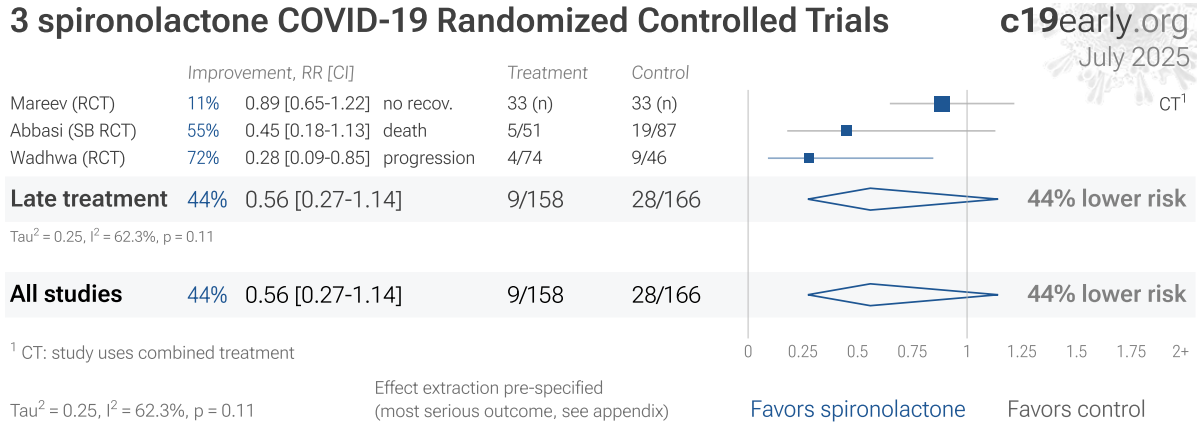


Figure 16. **Random effects meta-analysis for all Randomized Controlled Trials.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome reported. For details see the appendix.

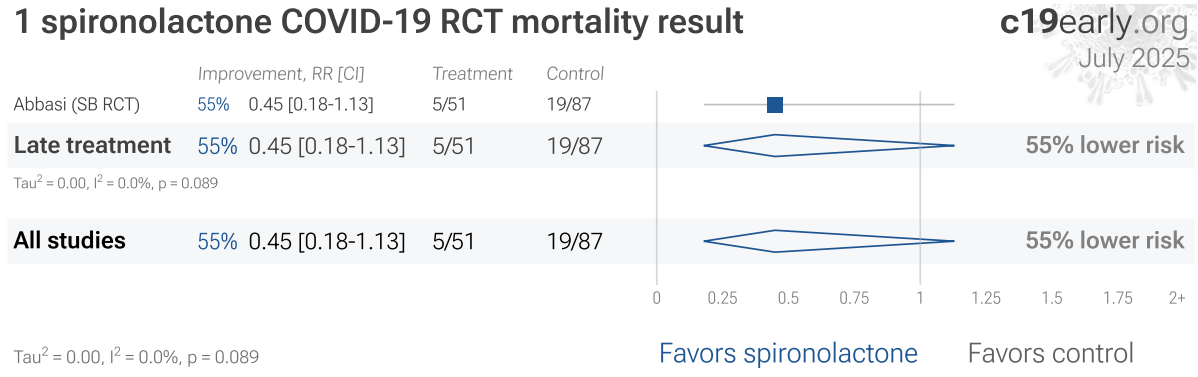


Figure 17. **Random effects meta-analysis for RCT mortality results.**

Exclusions

To avoid bias in the selection of studies, we analyze all non-retracted studies. Here we show the results after excluding studies with major issues likely to alter results, non-standard studies, and studies where very minimal detail is currently available. Our bias evaluation is based on analysis of each study and identifying when there is a significant chance that limitations will substantially change the outcome of the study. We believe this can be more valuable than checklist-based approaches such as Cochrane GRADE, which can be easily influenced by potential bias, may ignore or underemphasize serious issues not captured in the checklists, and may overemphasize issues unlikely to alter outcomes in specific cases (for example certain specifics of randomization with a very large effect size and well-matched baseline characteristics).

The studies excluded are as below. Figure 19 shows a forest plot for random effects meta-analysis of all studies after exclusions.

Cadegiani, significant unadjusted differences between groups.

Holt, unadjusted results with no group details.

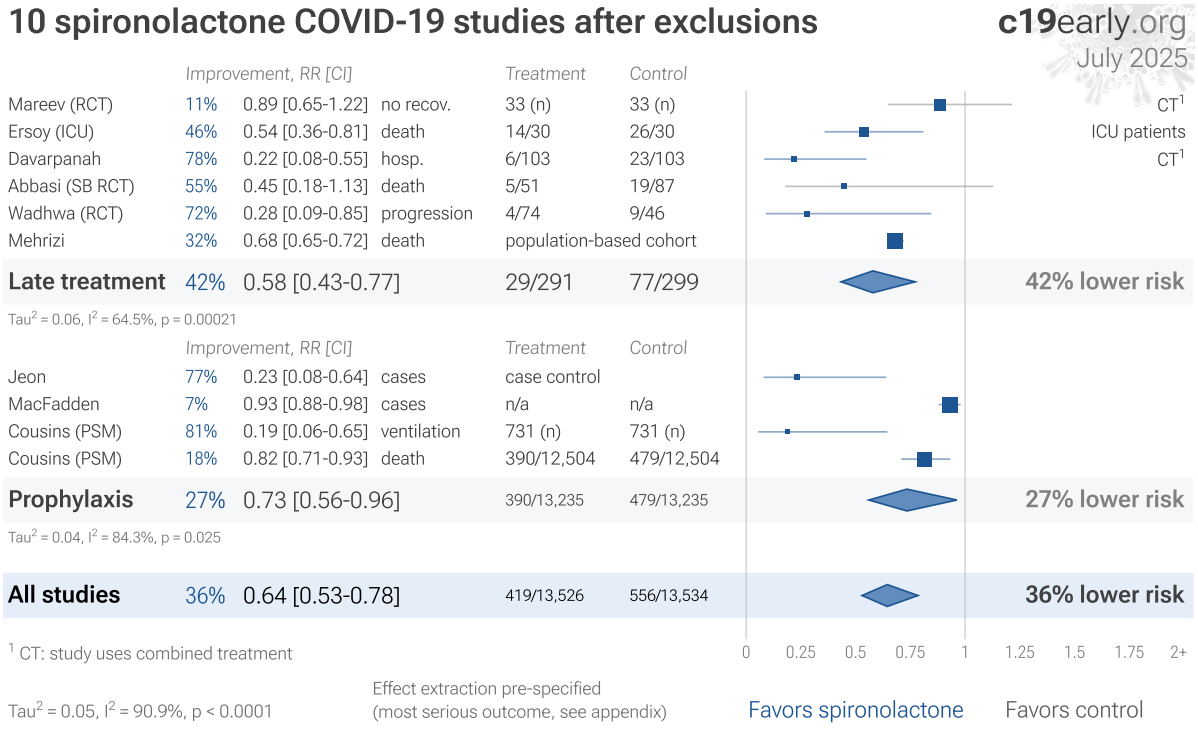


***Figure 19.* Random effects meta-analysis for all studies after exclusions.** This plot shows pooled effects, see the specific outcome analyses for individual outcomes. Analysis validating pooled outcomes for COVID-19 can be found below. Effect extraction is pre-specified, using the most serious outcome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

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[44,45]. 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[46]
<24 hours	-33 hours symptoms[47]
24-48 hours	-13 hours symptoms[47]
Inpatients	-2.5 hours to improvement[48]

***Table 3.* Studies of baloxavir marboxil for influenza show that early treatment is more effective.**

Figure 20 shows a mixed-effects meta-regression of efficacy as a function of treatment delay in COVID-19 spironolactone studies, with group estimates for different stages when a specific value is not provided. For comparison, Figure 21 shows a meta-regression for all studies providing specific values across 172 treatments. Efficacy declines rapidly with treatment delay. Early treatment is critical for COVID-19.

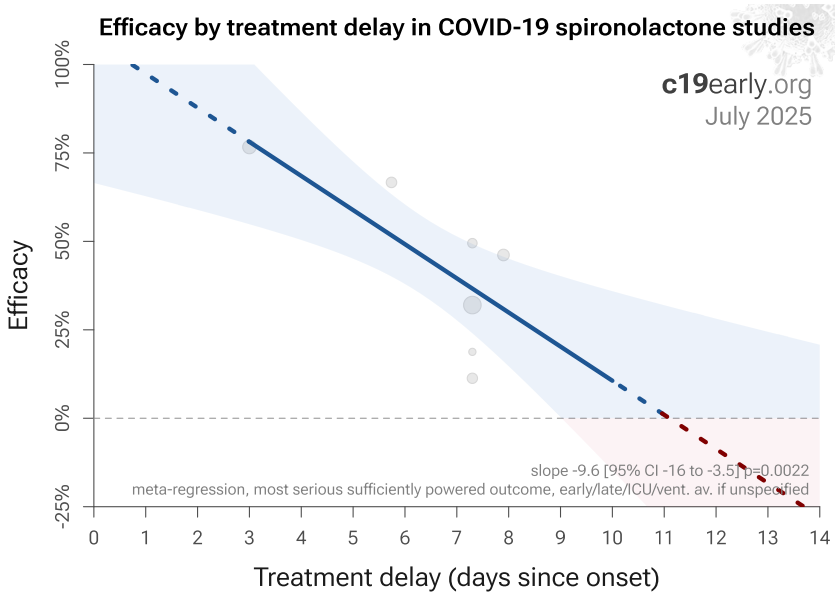


Figure 20. **Early treatment is more effective.** Meta-regression showing efficacy as a function of treatment delay in COVID-19 spironolactone studies.

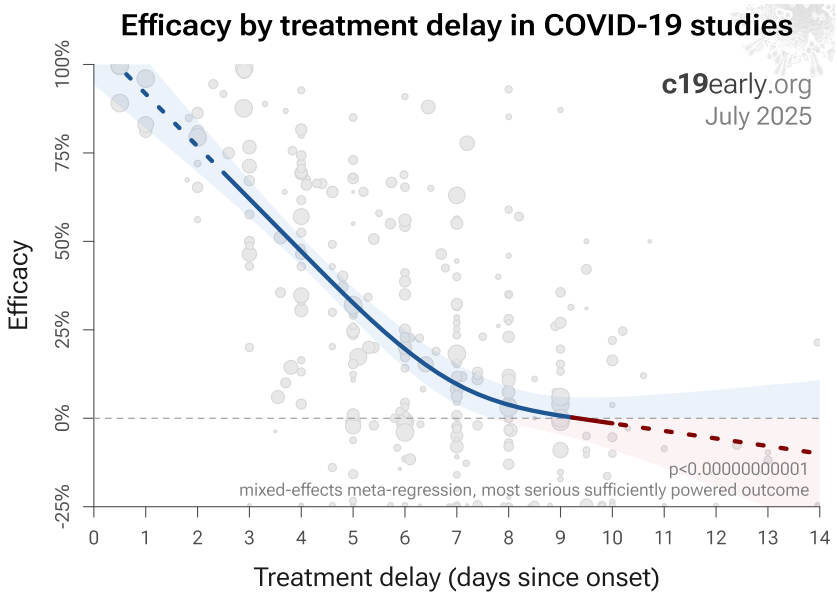


Figure 21. **Early treatment is more effective.** Meta-regression showing efficacy as a function of treatment delay in COVID-19 studies from 172 treatments.

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.*

SARS-CoV-2 variants

Efficacy may depend critically on the distribution of SARS-CoV-2 variants encountered by patients. Risk varies significantly across variants [50], for example the Gamma variant shows significantly different characteristics [51-54]. 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 [55,56].

Treatment regimen

Effectiveness may depend strongly on the dosage and treatment regimen.

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.

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 [59-75], therefore efficacy may depend strongly on combined treatments.

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

Pooled effects are no longer required to show efficacy as of March 2023

This section validates the use of pooled effects for COVID-19, which enables earlier detection of efficacy, however pooled effects are no longer required for spironolactone as of March 2023. Efficacy is now known based on specific outcomes. Efficacy based on specific outcomes was delayed by 12.7 months compared to using pooled outcomes.

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. Pooling the results of studies reporting different outcomes allows us to use more of the available information. Logically we should, and do, use additional information when evaluating treatments—for example dose-response and treatment delay-response relationships provide additional evidence of efficacy that is considered when reviewing the evidence for a treatment.

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.

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 and safer collection of evidence.

Validating pooled outcome analysis for COVID-19

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.

Analysis of the the association between different outcomes across studies from all 172 treatments we cover confirms the validity of pooled outcome analysis for COVID-19. Figure 22 shows that lower hospitalization is very strongly associated with lower mortality ($p < 0.000000000001$). Similarly, Figure 23 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 24 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 $p = 0.000000082$ to $p = 0.0000000033$.

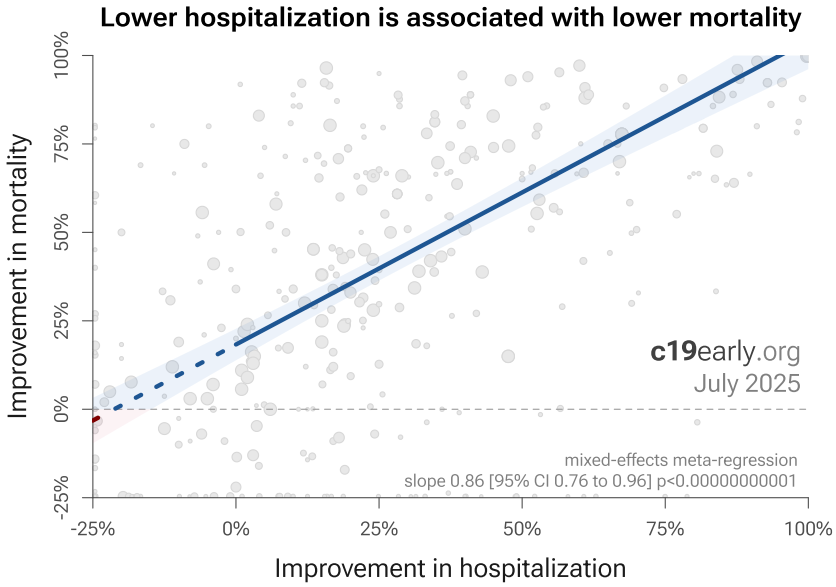


Figure 22. **Lower hospitalization is associated with lower mortality, supporting pooled outcome analysis.**

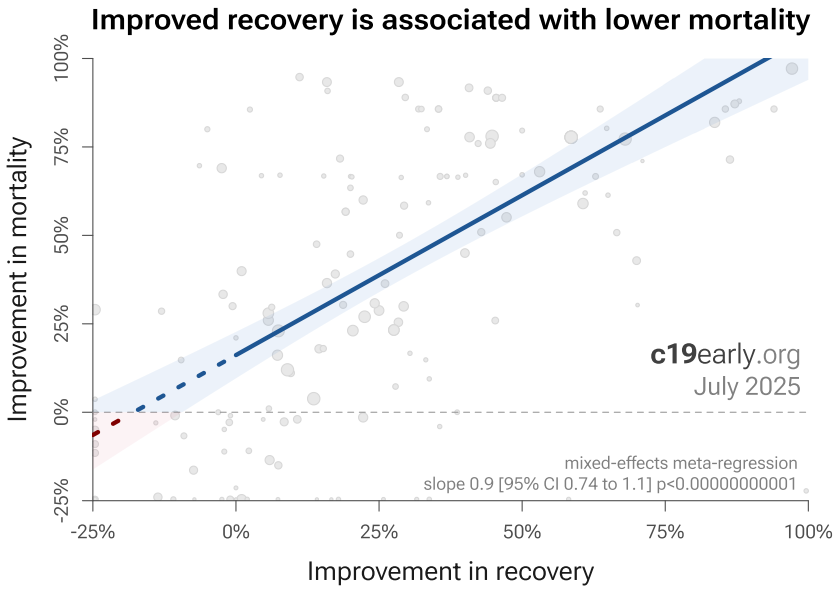


Figure 23. Improved recovery is associated with lower mortality, supporting pooled outcome analysis.

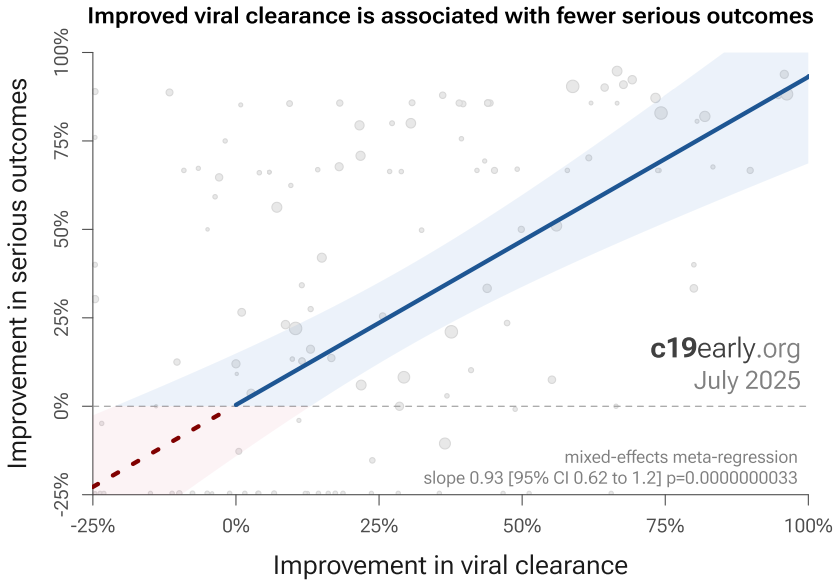


Figure 22. Improved viral clearance is associated with fewer serious outcomes, supporting pooled outcome analysis.

Pooled outcomes identify efficacy 5 months faster (7 months for RCTs)

Currently, 55 of the treatments we analyze show statistically significant efficacy or harm, defined as ≥10% decreased risk or >0% increased risk from ≥3 studies. 88% of these have been confirmed with one or more specific outcomes, with a mean delay of 4.9 months. When restricting to RCTs only, 57% of treatments showing statistically significant efficacy/harm with pooled effects have been confirmed with one or more specific outcomes, with a mean delay of 7.3 months. Figure 25 shows when treatments were found effective during the pandemic. Pooled outcomes often resulted in earlier detection of efficacy.

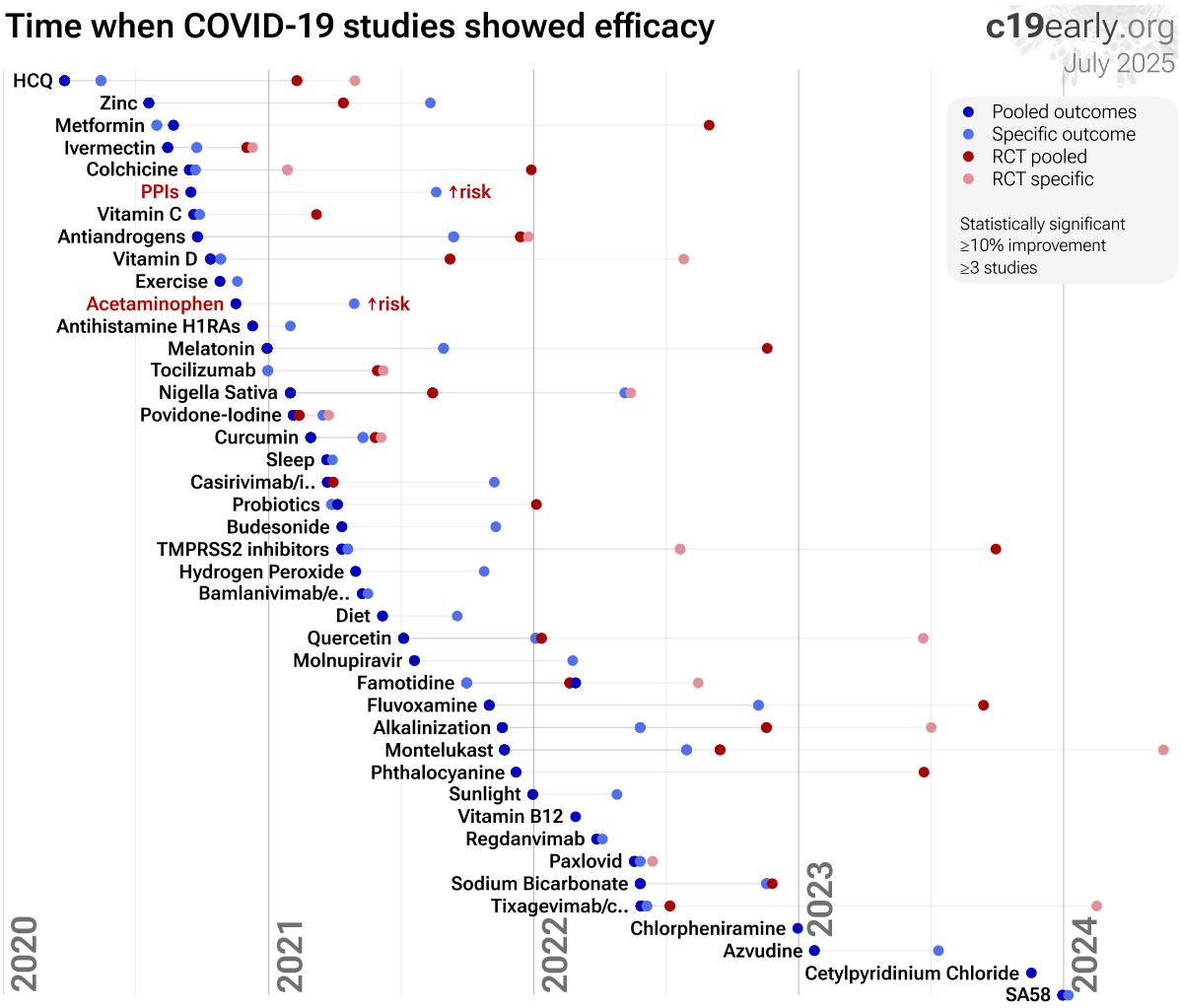


Figure 25. **The time when studies showed that treatments were effective, defined as statistically significant improvement of ≥10% from ≥3 studies.** Pooled results typically show efficacy earlier than specific outcome results. Results from all studies often shows efficacy much earlier than when restricting 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, however evidence suggests that there may be a negative bias for inexpensive treatments for COVID-19. Both negative and positive results are very important for COVID-19, media in many countries prioritizes negative results for inexpensive treatments (inverting the typical incentive for scientists that

value media recognition), and there are many reports of difficulty publishing positive results[77-80]. For spironolactone, there is currently not enough data to evaluate publication bias with high confidence.

One method to evaluate bias is to compare prospective vs. retrospective studies. Prospective studies are more likely to be published regardless of the result, while retrospective studies are more likely to exhibit bias. For example, researchers may perform preliminary analysis with minimal effort and the results may influence their decision to continue. Retrospective studies also provide more opportunities for the specifics of data extraction and adjustments to influence results.

Figure 26 shows a scatter plot of results for prospective and retrospective studies. 86% of retrospective studies report a statistically significant positive effect for one or more outcomes, compared to 100% of prospective studies, consistent with a bias toward publishing negative results. The median effect size for retrospective studies is 32% improvement, compared to 72% for prospective studies, suggesting a potential bias towards publishing results showing lower efficacy.

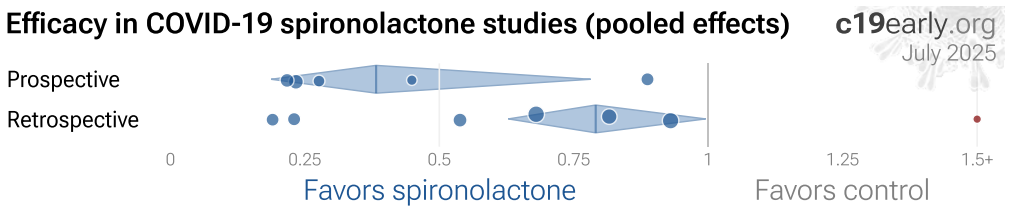


Figure 26. **Prospective vs. retrospective studies. The diamonds show the results of random effects meta-analysis.**

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 27 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 $p < 0.05$[81-88]. 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.

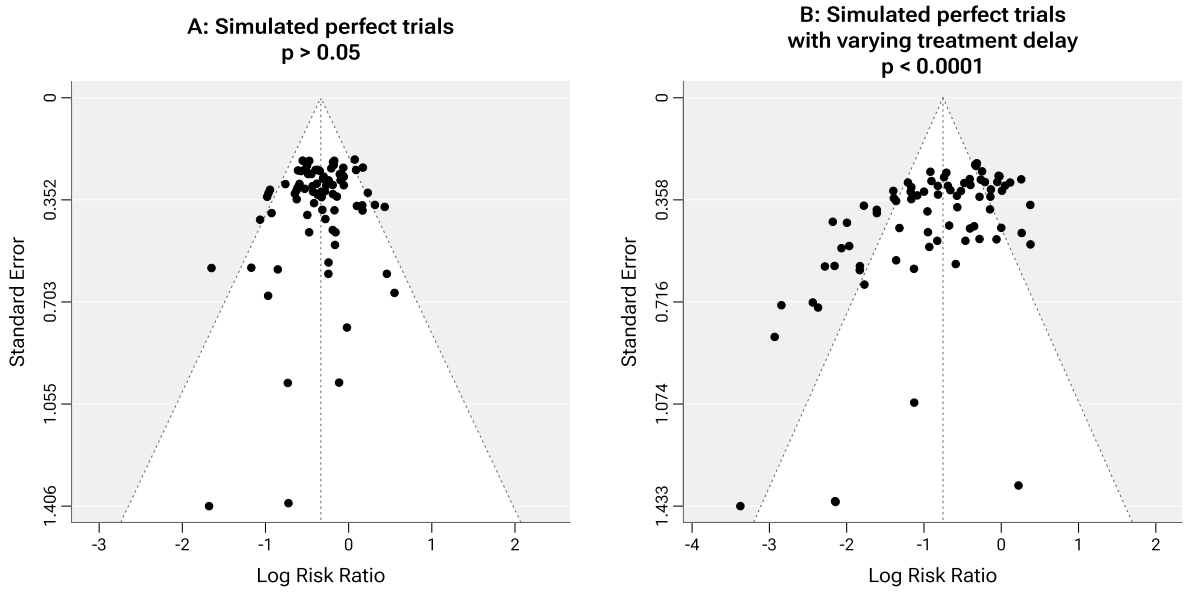


Figure 27. **Example funnel plot analysis for simulated perfect trials.**

Conflicts of interest

Pharmaceutical drug trials often have conflicts of interest whereby sponsors or trial staff have a financial interest in the outcome being positive. Spironolactone for COVID-19 lacks this because it is off-patent, has multiple manufacturers, and is very low cost. In contrast, most COVID-19 spironolactone trials have been run by physicians on the front lines with the primary goal of finding the best methods to save human lives and minimize the collateral damage caused by COVID-19. While pharmaceutical companies are careful to run trials under optimal conditions (for example, restricting patients to those most likely to benefit, only including patients that can be treated soon after onset when necessary, and ensuring accurate dosing), not all spironolactone trials represent the optimal conditions for efficacy.

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[59-75]. 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.

Notes

2 of 12 studies combine treatments. The results of spironolactone alone may differ. 1 of 3 RCTs use combined treatment.

Other studies

Additional preclinical or review papers suggesting potential benefits of spironolactone for COVID-19 include[99-109]. We have not reviewed these studies in detail.

Perspective

Results compared with other treatments

SARS-CoV-2 infection and replication involves a complex interplay of 100+ host and viral proteins and other factors[21-28], providing many therapeutic targets. Over 9,000 compounds have been predicted to reduce COVID-19 risk[29], either by directly minimizing infection or replication, by supporting immune system function, or by minimizing secondary complications. Figure 28 shows an overview of the results for spironolactone in the context of multiple COVID-19 treatments, and Figure 29 shows a plot of efficacy vs. cost for COVID-19 treatments.

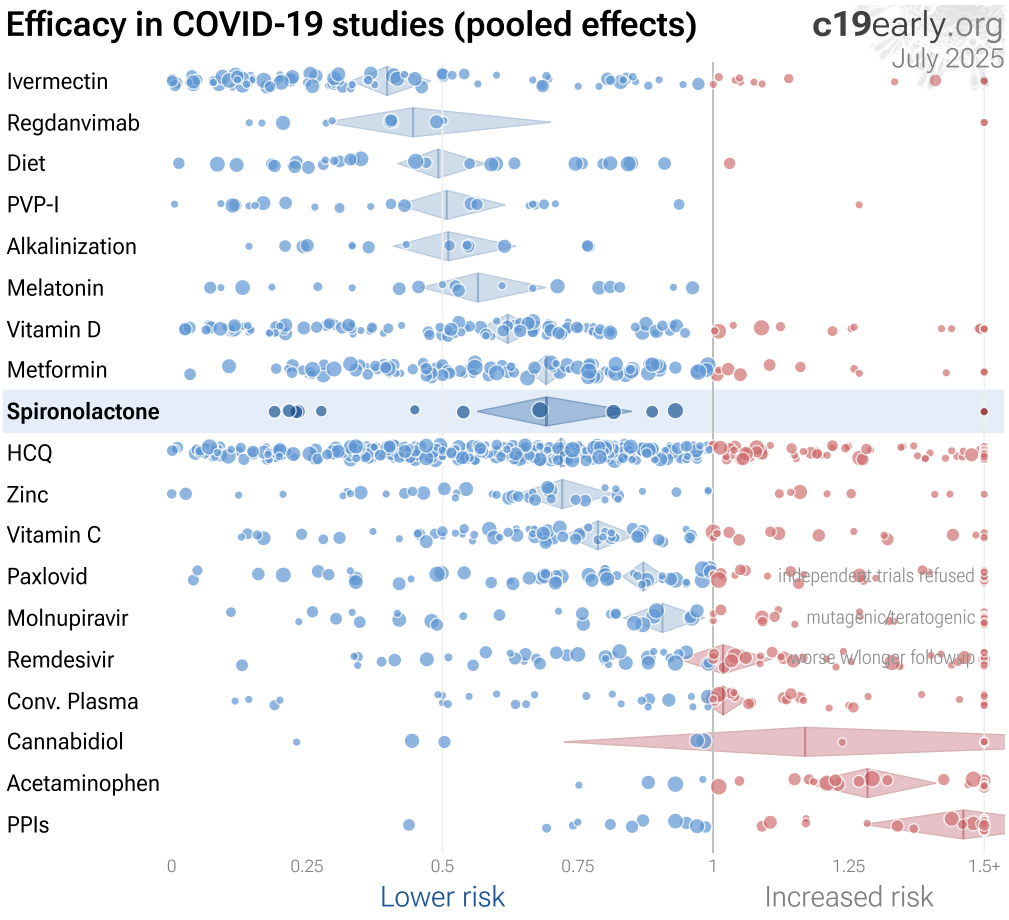


Figure 28. **Scatter plot showing results within the context of multiple COVID-19 treatments.** Diamonds shows the results of random effects meta-analysis. 0.6% of 9,000+ proposed treatments show efficacy [110].

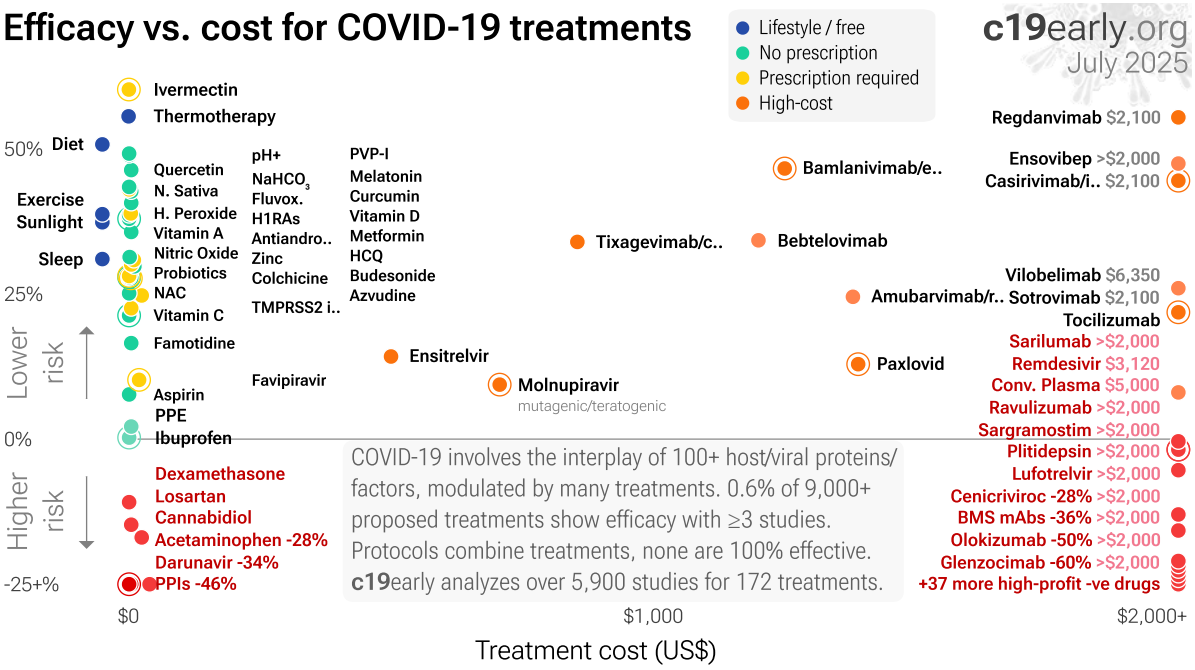


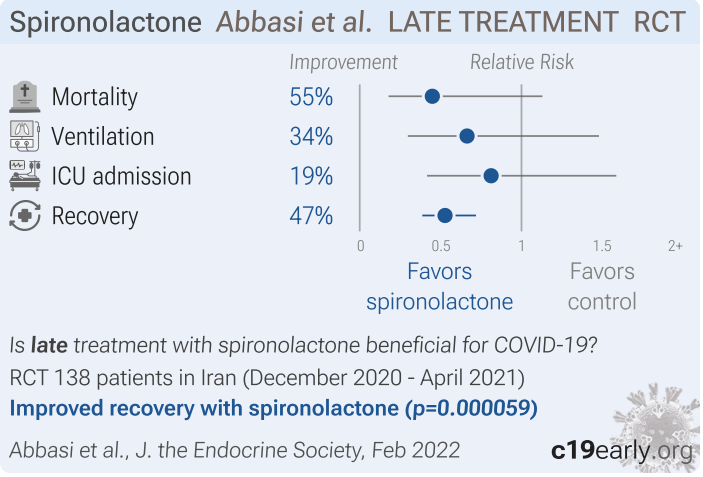
Figure 29. **Efficacy vs. cost for COVID-19 treatments.**

Conclusion

Studies to date show that spironolactone is an effective treatment for COVID-19. Significantly lower risk is seen for mortality, progression, and recovery. 11 studies from 10 independent teams in 8 countries show significant benefit. Meta analysis using the most serious outcome reported shows 31% [15-44%] lower risk. Results are similar for Randomized Controlled Trials, higher quality studies, and peer-reviewed studies. Early treatment is more effective than late treatment. Results are robust — in exclusion sensitivity analysis 4 of 12 studies must be excluded to avoid finding statistically significant efficacy in pooled analysis.

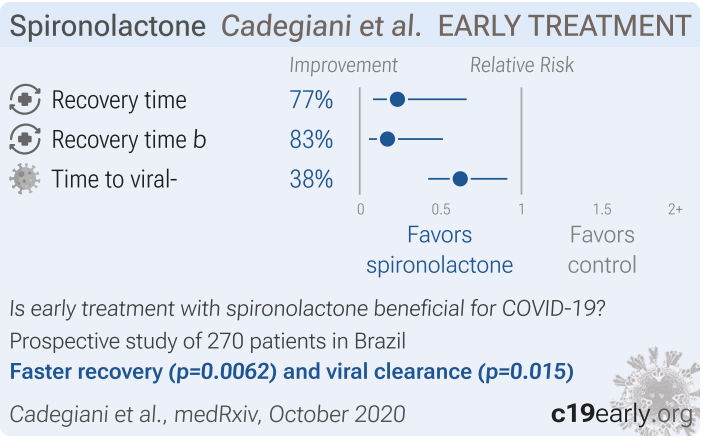
Study Notes

Abbasi



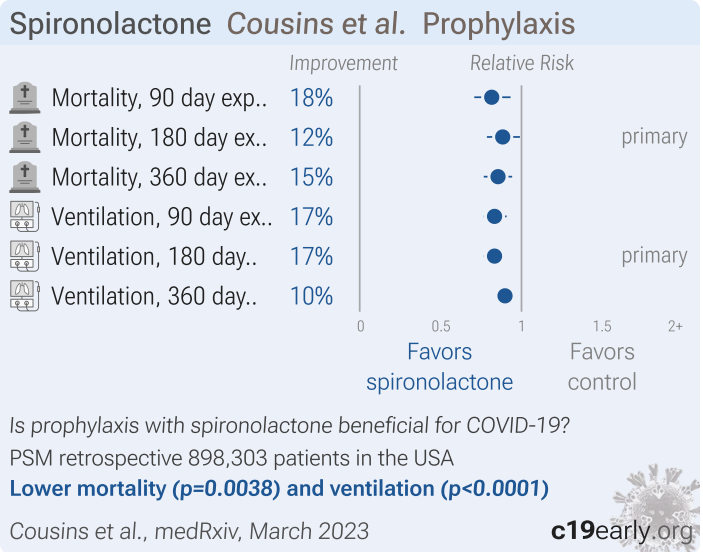
RCT including 51 spironolactone patients and 87 control patients in Iran, showing improved recovery with spironolactone, sitagliptin, and the combination of both.

Cadegiani



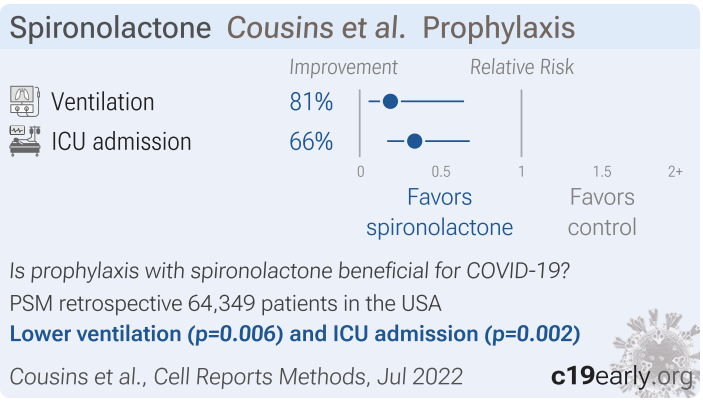
Prospective study of 270 female COVID-19 patients in Brazil, 75 with hyperandrogenism, of which 8 were on spironolactone. Results suggest that HA patients may be at increased risk, and that spironolactone use may reduce the risk compared to both other HA patients and non-HA patients. SOC included other treatments and there was no mortality or hospitalization.

Cousins



PSM retrospective 898,303 hospitalized COVID-19 patients in the USA, 16,324 on spironolactone, showing lower mortality and ventilation with spironolactone use.

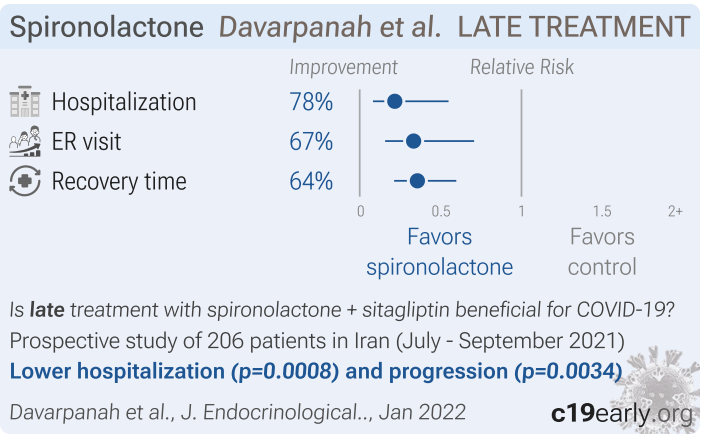
Cousins



PSM retrospective 64,349 COVID-19 patients in the USA, showing spironolactone associated with lower ICU admission.

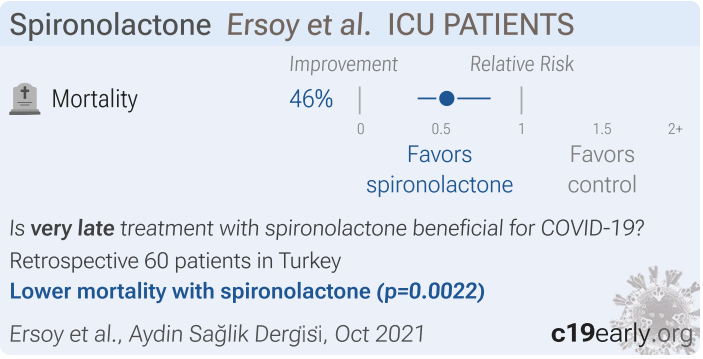
Authors also present In Vitro research showing dose-dependent inhibition in a human lung epithelial cell line.

Davarpanah



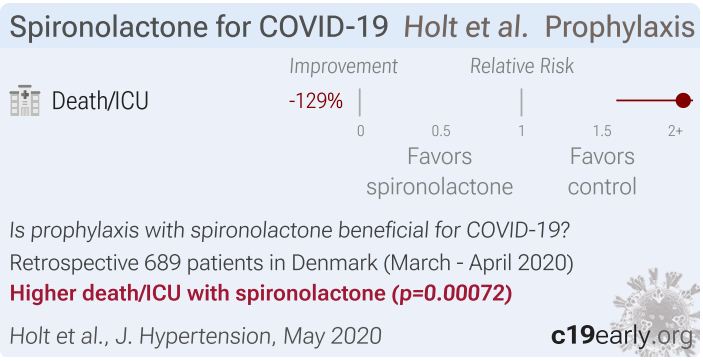
Prospective study of 206 outpatients in Iran, 103 treated with spironolactone and sitagliptin, showing lower hospitalization and faster recovery with treatment. spironolactone 100mg and sitagliptin 100mg daily.

Ersoy



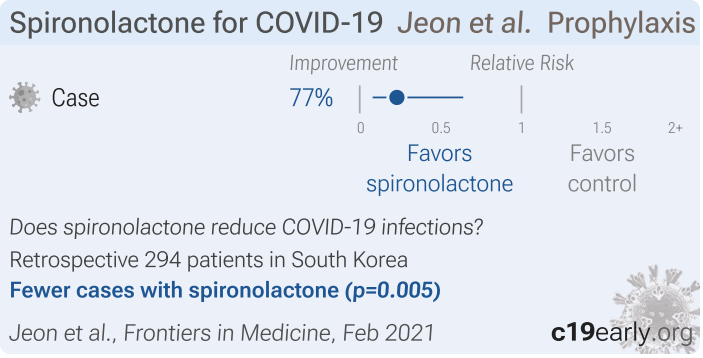
Retrospective 30 COVID-19 ARDS ICU patients and 30 control patients, showing lower mortality with treatment.

Holt



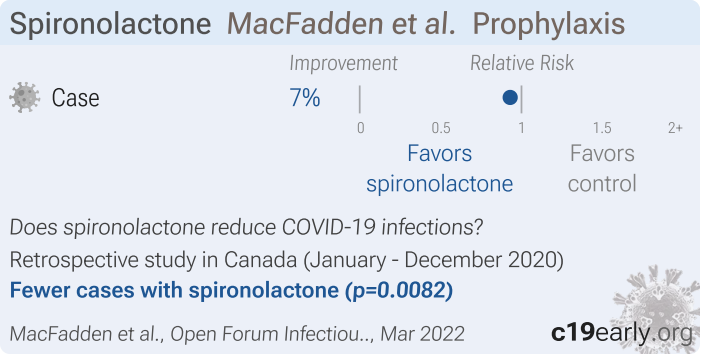
Retrospective 689 hospitalized COVID-19 patients in Denmark, showing higher risk of ICU/death with spironolactone use in unadjusted results subject to confounding by indication.

Jeon



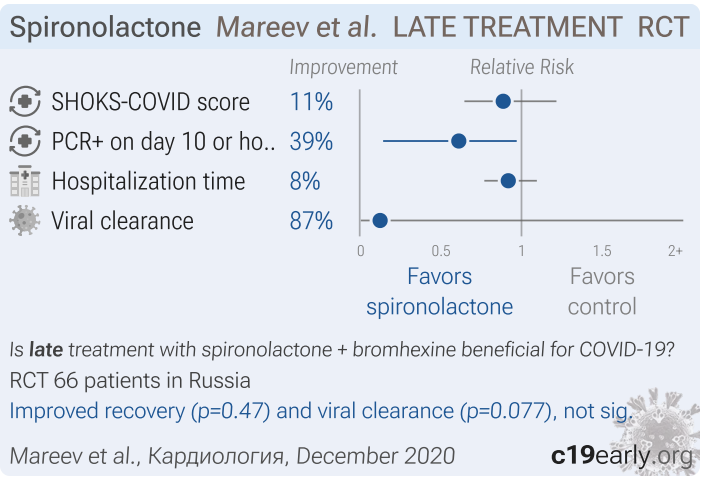
Retrospective 6,462 liver cirrhosis patients in South Korea, with 67 COVID+ cases, showing significantly lower cases with spironolactone treatment. Death and ICU results per group are not provided.

MacFadden



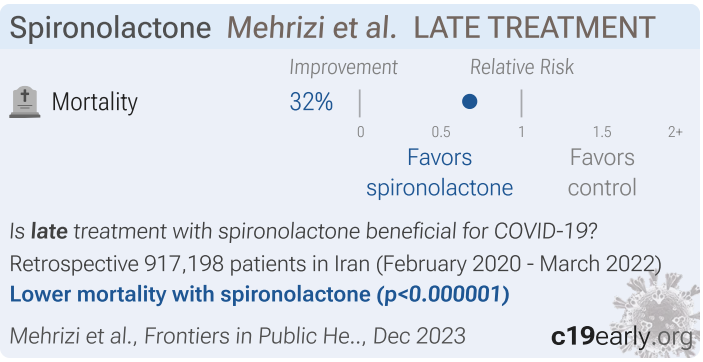
Retrospective 26,121 cases and 2,369,020 controls ≥65yo in Canada, showing lower cases with chronic use of spironolactone.

Mareev



Prospective 103 PCR+ patients in Russia, 33 treated with bromexhine+spironolactone, showing lower PCR+ at day 10 or hospitalization >10 days with treatment. Bromhexine 8mg 4 times daily, spironolactone 25-50 mg/day for 10 days.

Mehrizi

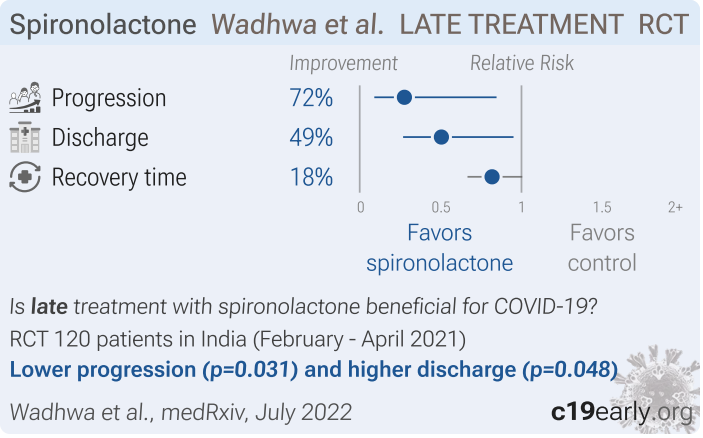


Retrospective study of 917,198 hospitalized COVID-19 cases covered by the Iran Health Insurance Organization over 26 months showing that antithrombotics, corticosteroids, and antivirals reduced mortality while diuretics, antibiotics, and antidiabetics increased it. Confounding makes some results very unreliable. For example, diuretics like furosemide are often used to treat fluid overload, which is more likely in ICU or advanced disease requiring aggressive fluid resuscitation. Hospitalization length has increased risk of significant confounding, for example longer hospitalization increases the chance of receiving a medication, and death may result in shorter hospitalization.

Mortality results may be more reliable.

Confounding by indication is likely to be significant for many medications. Authors adjustments have very limited severity information (admission type refers to ward vs. ER department on initial arrival). We can estimate the impact of confounding from typical usage patterns, the prescription frequency, and attenuation or increase of risk for ICU vs. all patients.

Wadhwa



RCT 120 hospitalized patients in India, 74 treated with spironolactone and dexamethasone, and 46 with dexamethasone, showing lower progression with treatment. Spironolactone 50mg once daily day 1, 25mg once daily until day 21.

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 spironolactone 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 spironolactone for COVID-19 that report a comparison with a control group are included in the main analysis. Sensitivity analysis is performed, excluding studies with major issues, epidemiological studies, and studies with minimal available information. Studies with major unexplained data issues, for example major outcome data that is impossible to be correct with no response from the authors, are excluded. 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 reported then they are both used in specific outcome analyses, while mortality is used for pooled analysis. If symptomatic results are reported at multiple times, we use 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 outcomes. 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. An IPD meta-analysis confirms that intermediate viral load reduction is more closely associated with hospitalization/death than later viral load reduction [111]. 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 *Zhang et al.* Reported confidence intervals and *p*-values are used when available, and adjusted values are used 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 [115]. 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 (3.13.5) with scipy (1.16.0), pythonmeta (1.26), numpy (2.3.1), statsmodels (0.14.4), and plotly (6.2.0).

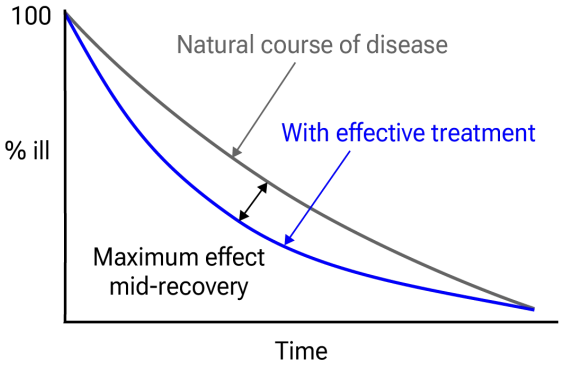


Figure 30. **Mid-recovery results can more accurately reflect efficacy when almost all patients recover.** *Mateja et al.* **confirm that intermediate viral load results more accurately reflect hospitalization/death.**

Forest plots are computed using PythonMeta [116] 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 0.8.2 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 [44,45].

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/spmeta.html.

Early 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.

Cadegiani, 10/6/2020, prospective, Brazil, preprint, 4 authors, average treatment delay 3.0 days, excluded in exclusion analyses: significant unadjusted differences between groups.	recovery time, 76.7% lower, relative time 0.23, $p = 0.006$, treatment 8, control 262, excluding anosmia.
	recovery time, 82.8% lower, relative time 0.17, $p = 0.002$, treatment 8, control 262, including anosmia.
	time to viral-, 37.9% lower, relative time 0.62, $p = 0.02$, treatment 8, control 262.

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.

Abbasi, 2/7/2022, Single Blind Randomized Controlled Trial, Iran, peer-reviewed, 11 authors, study period December 2020 - April 2021.	**risk of death, 55.1% lower, RR 0.45, $p = 0.10$**, treatment 5 of 51 (9.8%), control 19 of 87 (21.8%), NNT 8.3, day 5.
	risk of mechanical ventilation, 33.7% lower, RR 0.66, $p = 0.36$, treatment 7 of 51 (13.7%), control 18 of 87 (20.7%), NNT 14, day 5.
	risk of ICU admission, 18.8% lower, RR 0.81, $p = 0.67$, treatment 10 of 51 (19.6%), control 21 of 87 (24.1%), NNT 22, day 5.
	risk of no recovery, 47.3% lower, RR 0.53, $p < 0.001$, treatment mean 1.64 (±0.81) n=51, control mean 3.11 (±2.45) n=87, relative clinical score, day 5.
Davarpanah, 1/21/2022, prospective, Iran, peer-reviewed, 9 authors, study period July 2021 - September 2021, average treatment delay 5.74 days, this trial uses multiple treatments in the treatment arm (combined with sitagliptin) - results of individual treatments may vary.	**risk of hospitalization, 78.3% lower, RR 0.22, $p < 0.001$**, treatment 6 of 103 (5.8%), control 23 of 103 (22.3%), NNT 6.1, adjusted per study, odds ratio converted to relative risk, multivariable.
	ER visit, 66.7% lower, RR 0.33, $p = 0.003$, treatment 8 of 103 (7.8%), control 24 of 103 (23.3%), NNT 6.4.
	recovery time, 64.4% lower, relative time 0.36, $p < 0.001$, treatment 103, control 103.
Ersoy, 10/13/2021, retrospective, Turkey, peer-reviewed, 7 authors.	**risk of death, 46.2% lower, RR 0.54, $p = 0.002$**, treatment 14 of 30 (46.7%), control 26 of 30 (86.7%), NNT 2.5.
Mareev, 12/3/2020, Randomized Controlled Trial, Russia, peer-reviewed, 20 authors, this trial uses multiple treatments in the treatment arm (combined with bromhexine) - results of individual treatments may vary, trial NCT04424134 (history).	**relative SHOKS-COVID score, 11.3% better, RR 0.89, $p = 0.47$**, treatment mean 2.12 (±1.39) n=33, control mean 2.39 (±1.59) n=33.
	risk of PCR+ on day 10 or hospitalization >10 days, 38.8% lower, RR 0.61, $p = 0.02$, treatment 14 of 24 (58.3%), control 20 of 21 (95.2%), NNT 2.7, odds ratio converted to relative risk.
	hospitalization time, 8.2% lower, relative time 0.92, $p = 0.35$, treatment 33, control 33.
	risk of no viral clearance, 87.4% lower, RR 0.13, $p = 0.08$, treatment 0 of 17 (0.0%), control 3 of 13 (23.1%), NNT 4.3, relative risk is not 0 because of continuity correction due to zero events (with reciprocal of the contrasting arm), day 10.
Mehrizi, 12/18/2023, retrospective, Iran, peer-reviewed, 10 authors, study period 1 February, 2020 - 20 March, 2022.	**risk of death, 32.0% lower, OR 0.68, $p < 0.001$**, RR approximated with OR.
Wadhwa, 7/2/2022, Randomized Controlled Trial, placebo-controlled, India, preprint, 18 authors, study period 1 February, 2021 - 30 April, 2021, trial CTRI/2021/03/031721.	**risk of progression, 72.4% lower, RR 0.28, $p = 0.03$**, treatment 4 of 74 (5.4%), control 9 of 46 (19.6%), NNT 7.1, progression to WHO >4.
	risk of no hospital discharge, 49.5% lower, RR 0.51, $p = 0.048$, treatment 13 of 74 (17.6%), control 16 of 46 (34.8%), NNT 5.8.

	recovery time, 18.2% lower, relative time 0.82, $p = 0.06$, treatment 74, control 46.

Prophylaxis

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.

Cousins, 3/2/2023, retrospective, propensity score matching, USA, peer-reviewed, 2 authors.	**risk of death, 18.4% lower, RR 0.82, $p = 0.004$**, treatment 390 of 12,504 (3.1%), control 479 of 12,504 (3.8%), NNT 140, odds ratio converted to relative risk, 90 day exposure window, propensity score matching.
	risk of death, 11.6% lower, RR 0.88, $p = 0.04$, treatment 521 of 16,324 (3.2%), control 592 of 16,324 (3.6%), NNT 230, odds ratio converted to relative risk, 180 day exposure window, propensity score matching, primary outcome.
	risk of death, 14.5% lower, RR 0.85, $p = 0.003$, treatment 671 of 20,690 (3.2%), control 783 of 20,690 (3.8%), NNT 185, odds ratio converted to relative risk, 360 day exposure window, propensity score matching.
	risk of mechanical ventilation, 16.7% lower, RR 0.83, $p < 0.001$, treatment 936 of 12,504 (7.5%), control 1,118 of 12,504 (8.9%), NNT 69, odds ratio converted to relative risk, 90 day exposure window, propensity score matching.
	risk of mechanical ventilation, 16.7% lower, RR 0.83, $p < 0.001$, treatment 1,212 of 16,324 (7.4%), control 1,459 of 16,324 (8.9%), NNT 66, odds ratio converted to relative risk, 180 day exposure window, propensity score matching, primary outcome.
	risk of mechanical ventilation, 10.2% lower, RR 0.90, $p < 0.001$, treatment 1,524 of 20,690 (7.4%), control 1,701 of 20,690 (8.2%), NNT 117, odds ratio converted to relative risk, 360 day exposure window, propensity score matching.
Cousins (B), 7/6/2022, retrospective, propensity score matching, USA, peer-reviewed, 10 authors.	**risk of mechanical ventilation, 81.0% lower, OR 0.19, $p = 0.006$**, treatment 731, control 731, propensity score matching, RR approximated with OR.
	risk of ICU admission, 66.0% lower, OR 0.34, $p = 0.002$, treatment 731, control 731, propensity score matching, RR approximated with OR.
Holt, 5/7/2020, retrospective, Denmark, peer-reviewed, median age 70.0, 4 authors, study period 1 March, 2020 - 1 April, 2020, excluded in exclusion analyses: unadjusted results with no group details.	**risk of death/ICU, 129.5% higher, RR 2.29, $p < 0.001$**, treatment 16 of 31 (51.6%), control 148 of 658 (22.5%).
Jeon, 2/23/2021, retrospective, South Korea, peer-reviewed, 3 authors.	**risk of case, 77.0% lower, OR 0.23, $p = 0.005$**, treatment 6 of 49 (12.2%) cases, 89 of 245 (36.3%) controls, NNT 6.5, case control OR, model 2, within 3 months.
MacFadden, 3/29/2022, retrospective, Canada, peer-reviewed, 9 authors, study period 15 January, 2020 - 31 December, 2020.	**risk of case, 7.0% lower, OR 0.93, $p = 0.008$**, RR approximated with OR.

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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