The use of telehealth in sepsis care: a scoping and systematic review and meta-analysis

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Tele-ED increases pooled survival of sepsis patients, especially in settings with high sepsis mortality.

BACKGROUND AND METHODS

Objectives: Sepsis is associated with significant mortality. Telehealth may improve the quality of sepsis care, but the use and impact of telehealth applications for sepsis remain unclear. We aim to describe the telehealth interventions that have been used for sepsis and to summarize the reported effect of telehealth on sepsis outcomes.

Data sources: We identified articles reporting telehealth use for sepsis using an English-language search of PubMed, CINAHL Plus (EBSCO), Academic Search Ultimate (EBSCO), APA PsycINFO (EBSCO), Public Health (ProQuest), and Web of Science databases with no restrictions on publication date. Included studies met the following criteria: 1) use of telehealth as an intervention, 2) sepsis was diagnosed and/or treated using telehealth, 3) Surveillance for the presence of sepsis was included if it was paired with telehealth, 4) the paper was original comparative effectiveness research with a control group.

Results: A total of 15 studies were included, involving 188,418 patients with sepsis. Thirteen studies used observational study designs, and the most common telehealth applications were provider-to-provider telehealth consultation and intensive care unit telehealth. Clinical and methodological heterogeneity was high but did not prevent pooling. Telehealth use was associated with higher survival (adjusted odds ratio [aOR] 1.81, 95% CI 1.12-2.93; I2 =83%), but was not associated with significantly improved 3-hour sepsis bundle adherence (aOR 1.63, 95% CI 0.61-4.40, I2 =73%) or antibiotic timeliness (aOR 1.50, 95% CI, 0.75-2.98, I2 =67%). Telehealth was most strongly associated with improved survival in settings with low control group survival (meta-regression β 0.18 lower log-odds survival per 10% increase in control group survival, 95 % CI -0.12 to -0.24).

Conclusions: Telehealth has been used in diverse applications for sepsis care, and pooled survival was higher in cases where telehealth was used. Additional interventional trials and cost-based analyses would clarify the causal role of telehealth in improving sepsis outcomes.

STUDY SELECTION

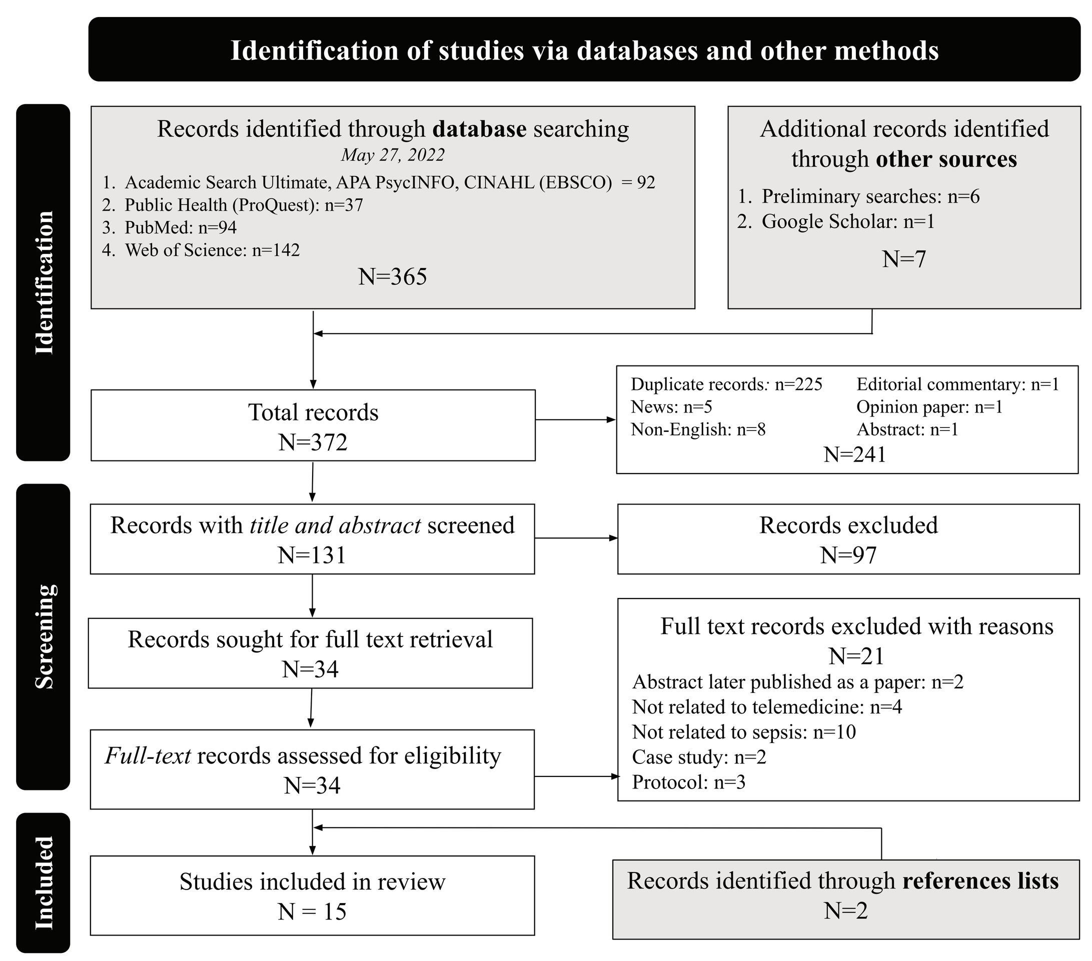


Figure 1. PRISMA study selection flow diagram. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

SYSTEMATIC REVIEW AND META-ANALYSIS

Author, Year	Patient Sample	Study Design	Type of Intervention	Mode of Telehealth	Setting of Telehealth Use	Telehealth Provider-Type
Agarwal et al., 2016	14	Cohort	Tele-ED consulting through a telehealth cart	Real-time video	ED	Physicians
Campbell et al., 2017	114	Cohort	Tele-ED Consulting	Real-time video	ED	Physicians
Davis et al., 2022	566	Before-After Cohort	Virtual sepsis surveillance + telehealth	Audio	Acute Care Units (excluding ICUs)	Physicians and Nurses
Deisz et al., 2019	196	Before-After Cohort	Tele-ICU Physician Daily Rounds	Real-time video	ICU	Physician
Forti et al., 2018	25,260	Before-After Cohort	Tele-ICU Intervention	Real-time video	ICU	Physicians and Nurses
Ilko et al., 2019	150,845	Cohort	Tele-ICU Intervention	Real-time video	ED and ICU	Physicians and Nurses
Machado et al., 2018	314	Cohort	Introduction of a telemedicine eICU cart	Real-time video	ED	Physician
Marx et al., 2022	748	Stepped-Wedge Cluster Randomized Trial	Telemedicine consultation inpatient-outpatient network	Real-time video	ICU	Physician
Mohr et al., 2021	655	Cohort	Tele-ED Consulting	Real-time video	ED	Physicians
Mohr et al., 2022	1,191	Cohort	Tele-ED Consulting	Real-time video	ED	Physicians
Powell et al., 2022	1,753	Cohort	In Situ Simulation Training on Telehealth	Real-time video	ED	Physicians and Nurses
Rincon et al., 2011	5,437	Cohort	Tele-ICU Intervention	Real-time video	ICU	Physicians and Nurses
Scott et al., 2020	NR	Before-After Cohort	Nursing Review of Automated Surveillance Output	Audio	ICU	Nurse
Steinman et al., 2015	633	Cohort	Tele-ICU & Tele-ED	Real-time video	ED and ICU	Physicians
Taylor et al. 2021	692	Pragmatic Randomized Trial	Post-discharge care of sepsis patients	Audio	Direct-to-consumer	Nurse

OR [95% CI] following telemedicine implementation								
Author, Year	Survival	Interhosital Transfer	Antibiotic timeliness	3-hr Bundle Adherence	6-hr Bundle Adherence	Complete bundle adherence	3-hr lactate measurement	6-hr lactate measurement
Cohort Studies								
Campbell et al., 2017	1.83 [0.36, 9.25]	7.79 [2.89, 21.05]	2.65 [0.99, 7.09]				1.18 [0.29, 4.86]	
Ilko et al., 2019		0.69 [0.54, 0.88] †						
Mohr et al., 2021		7.14 [3.48, 14.66] *	4.01 [1.16, 13.87]	3.05 [1.42, 6.57]		17.27 [6.64, 44.90]	7.85 [2.64, 23.34]	
Mohr et al., 2022	1.96 [0.49, 7.89]	77.57 [51.55, 116.73] *	0.86 [0.42, 1.77]	0.59 [0.29, 1.22]	0.67 [0.08, 5.82]	0.45 [0.02, 11.60]	1.30 (0.55 - 3.06)	0.94 [0.15, 5.80]
Machado et al., 2018	0.81 [0.46, 1.41]	0.57 [0.12, 2.72] *	1.85 [1.02, 3.38]					9.97 [1.32, 75.24]
Powell et al., 2022	1.04 [0.56, 1.93] *	11.17 [6.54, 19.06] *	0.93 [0.52, 1.66] *				2.47 [0.34, 18.09] *	
Steinman et al., 2015	3.59 [2.33, 5.55] *							
Before-After Studies								
Davis et al., 2022	1.60 [1.08, 2.37]							
Deisz et al., 2019	2.86 [1.04, 7.83]		3.31 [0.13, 86.07] *	1.37 [0.25, 7.39] *	20.00 [2.24, 178.92] *			23.89 [1.26, 453.00] *
Fortis et al., 2018	1.04 [0.91, 1.19]	RR 0.70 [0.46-1.07]						
Randomized Studies								
Marx et al., 2022	1.29 [0.70, 2.41]	2.903 [2.01, 4.19].	6.82 [1.27, 56.61]	3.33 [0.86, 12.92] *	14.245 [3.12, 85.424]	7.739 [2.38, 28.03]		
Taylor et al. 2021	1.61 [0.85, 3.02]							

Table 1. Characteristics of included studies. Tele-ICU and Tele-ED are the use of telehealth to diagnose/treat sepsis patients from an off-site telehealth center in ICUs and EDs, respectively.

Table 2. aOR of study outcomes following telehealth. * refers to unadjusted results.

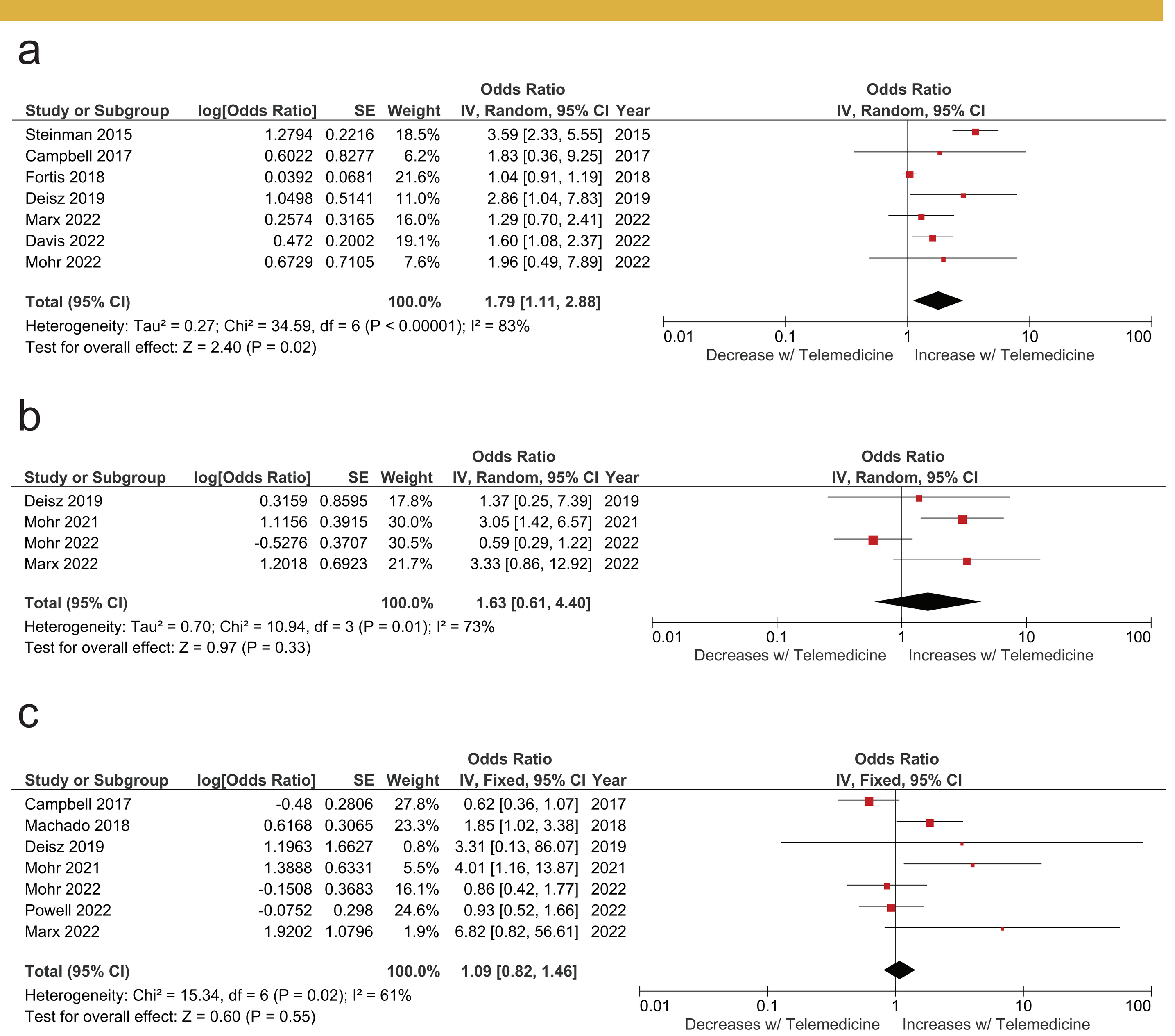


Figure 2. Meta-analyses of telehealth implementation effects. Effect on **a)** patient survival, **b)** 3-hr bundle adherence, and **c)** antibiotic timliness. Statistical analyses were performed using RevMan 5 (Cochrane). Patient outcomes were pooled if values from at least 4 studies were available. Adjusted odds ratio (aOR) and 95% confidence intervals were abstracted from studies. Pooled mean difference with 95% confidence interval (CI) was calculated by the inverse variance approach and presented in a forest plot for continuous variables. For categorical variables, pooled risk ratio (RR) with 95% CI was calculated by the Mantel-Haenszel method and presented in a forest plot. A random-effect model was used regardless of heterogeneity level. Statistical significance was set at p<0.05 (two tailed), and statistical heterogeneity was screened using I^2.

META-REGRESSION, SUBGROUP ANALYSES, SCOPING REVIEW, AND BIAS

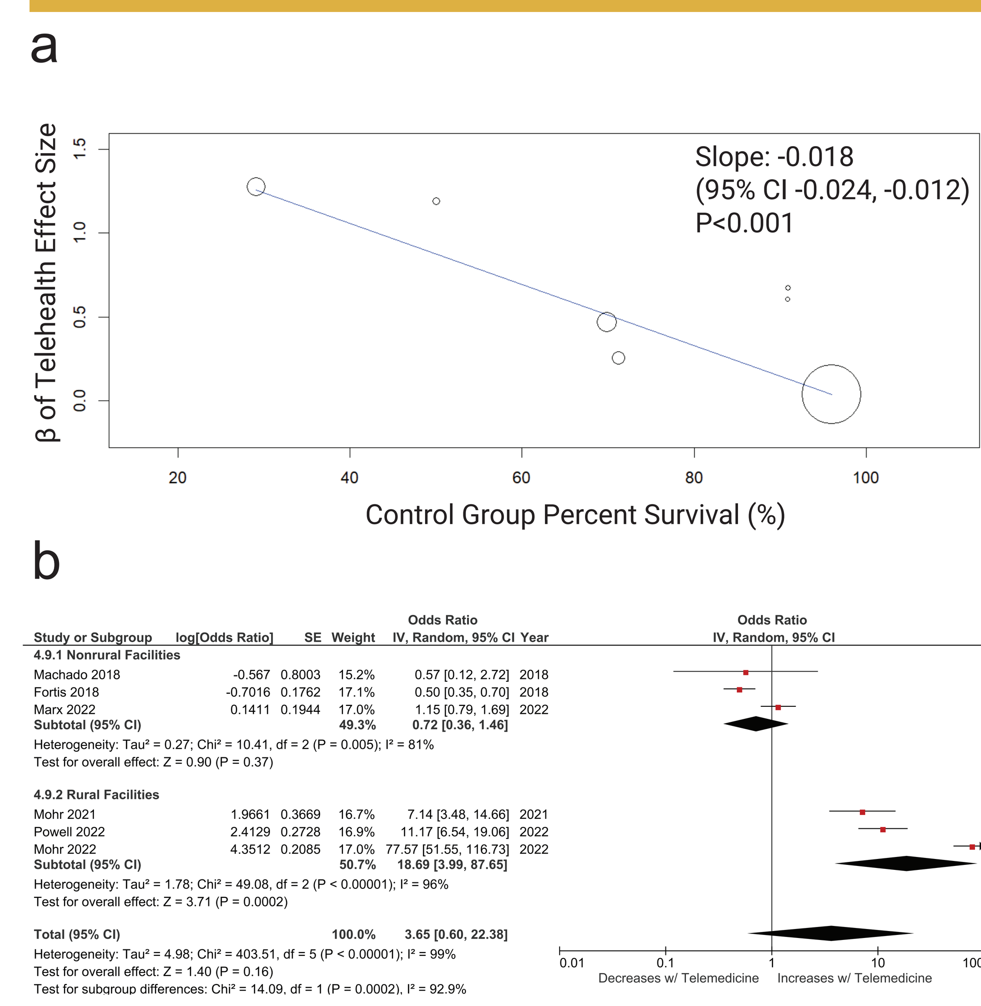


Figure 3. Meta-regression and subgroup analysis. a) Meta-regression with the horizontal axis reporting control group survival (%), and the vertical axis reporting β, the adjusted effect size of telehealth on survival. The size of each point is proportional to the sample size. **b)** Subgroup meta-analyses of interhospital transfer rates between studies conducted in nonrural and rural facilities. The statistical methods from Figure 2 were used here.

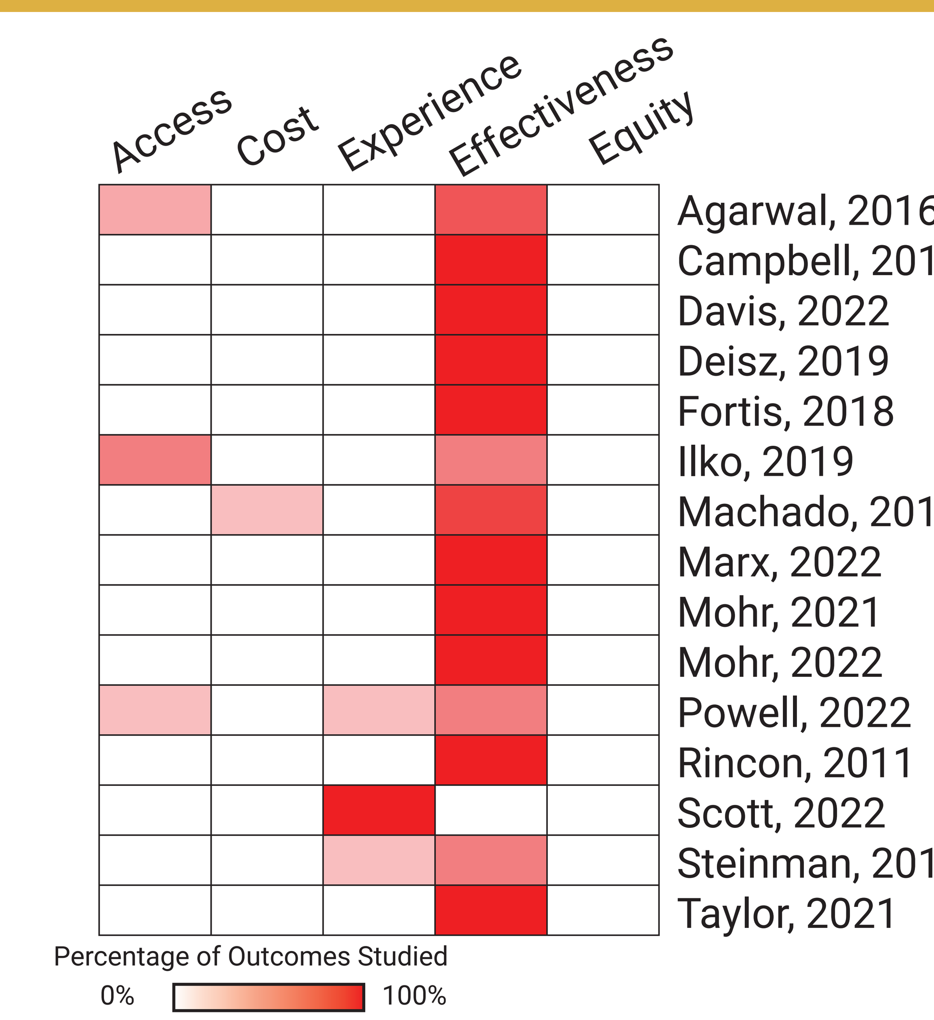


Figure 4. Telehealth outcome domain heatmap. A heatmap classifying study outcomes reported according to the Rural Telehealth and Healthcare System Readiness Committee telehealth domains. The percentage of studied outcomes within a study (number of outcomes in each domain evaluated by the study/total number of outcomes evaluated by the study) is correlated to the redness of the cell.

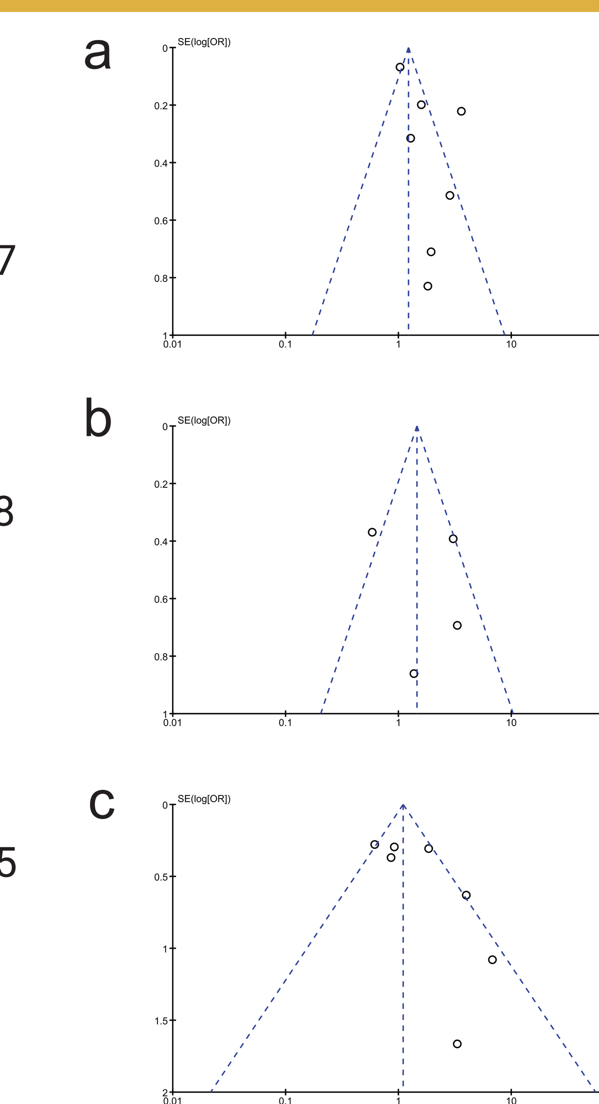
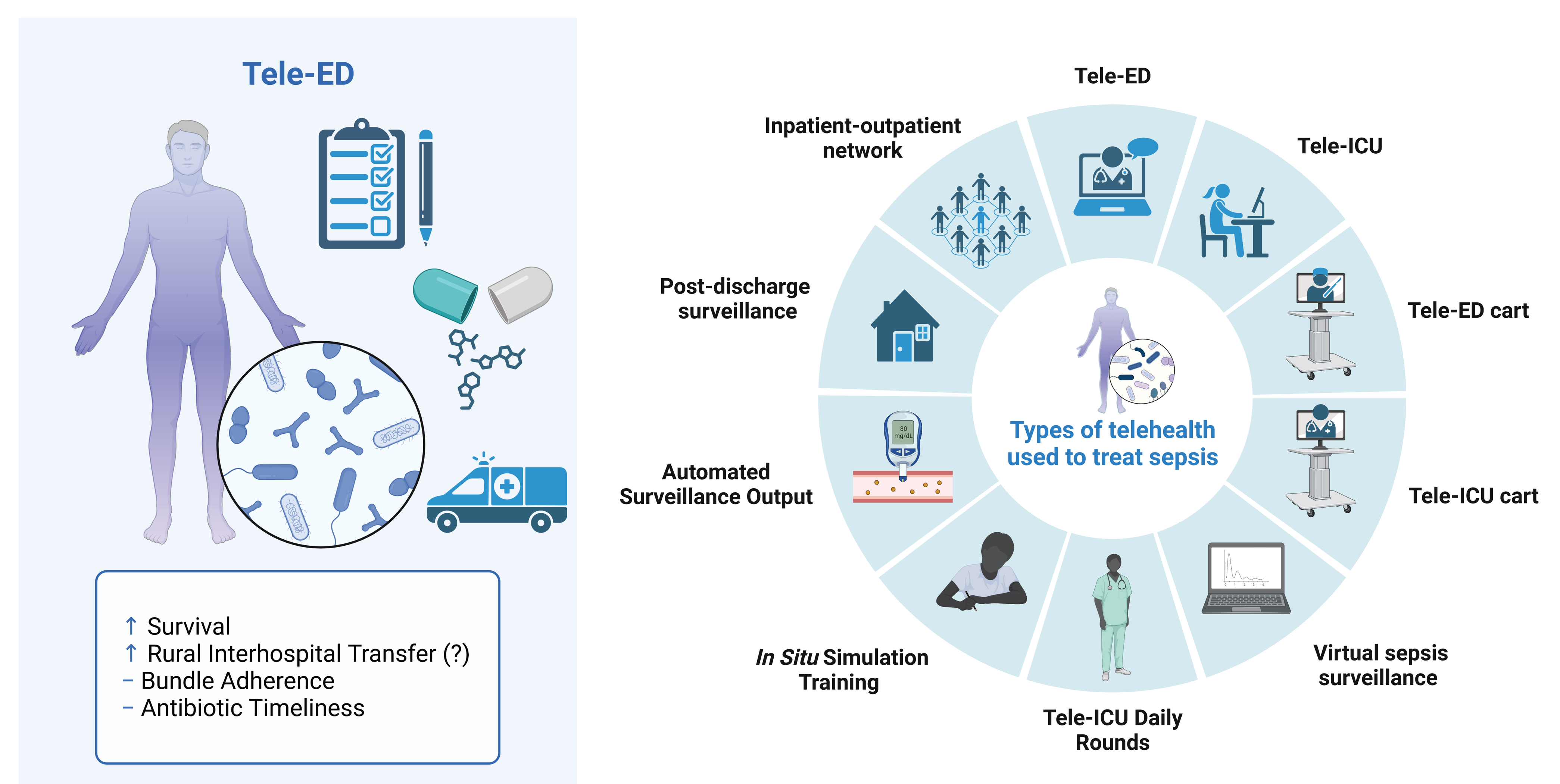


Figure 5. Funnel plots. Funnel plots of meta-analyses for **a)** patient survival, **b)** 3-hr bundle adherence, and **c)** antibiotic timeliness.

CONCLUSIONS



LIMITATIONS

- The number of published studies evaluating telehealth in sepsis care is limited and most are published by only a few research groups.
- High clinical and methodological heterogeneity amongst the included studies.
- Due to high variance in in the studies' findings, the certainty of our outcomes from the meta-analyses and regression are low.
- Our meta-analysis are subject to the limitations of the underlying observational study designs, which risk being confounded by indication.

FUTURE WORK

- There are very few studies that evaluate the potential of telehealth to address equity and access issues in sepsis treatment/outcomes.
- Few studies include long-term clinical or patient-centered outcomes.
- There is a need for more quasi-experimental and randomized studies to better elucidate the impact of telehealth in patient outcomes and better understand the heterogeneity of treatment effects.
- Robust large-sclae cost and cost-effectiveness studies have not been performed.

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