Controle - COVID

November 1, 2022

1 Modelo 3

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\begin{aligned}
\frac{dS}{dt} &= -\frac{\beta(t)(1-\psi(t))}{N} S I_T - \tau(t) S \\
\frac{dE}{dt} &= \frac{\beta(t)(1-\psi(t)) S I_T}{N} - \kappa E \\
\frac{dV}{dt} &= \tau(t) S - \phi V \\
\frac{dS_V}{dt} &= \phi(1-\epsilon) V - \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N} \\
\frac{dE_V}{dt} &= \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N} - \kappa_V E_V \\
\frac{dI_A}{dt} &= (1-p)\kappa E - \gamma_A I_A \\
\frac{dI_S}{dt} &= p\kappa E - \gamma_S I_S \\
\frac{dI_{VA}}{dt} &= (1-p_V)\,\kappa_V E_V - \gamma_{VA} I_{VA} \\
\frac{dI_{VS}}{dt} &= p_V \kappa_V E_V - \gamma_{VS} I_{VS} \\
\frac{dH}{dt} &= h\xi\gamma_S I_S + (1-\mu_U+\omega_U\mu_U)\,\gamma_U U - \gamma_H H \\
\frac{dU}{dt} &= h(1-\xi)\gamma_S I_S + \omega_H\gamma_H H - \gamma_U U \\
\frac{dU_V}{dt} &= h_V(1-\xi_V)\gamma_{VS} I_{VS} + \omega_H \gamma_{VH} H_V - \gamma_U U_V \\
\frac{dH_V}{dt} &= h_V \xi_V \gamma_{VS} I_{VS} + (1-\mu_{VU}+\omega_U\mu_{VU})\,\gamma_{VU} U_V - \gamma_{VH} H_V \\
\frac{dR}{dt} &= \gamma_A I_A + (1-h)\gamma_S I_S + (1-\mu_H)\,(1-\omega_H)\,\gamma_H H \\
\frac{dR_V}{dt} &= \gamma_{VA} I_{VA} + (1-h_V)\gamma_{V_S} I_{V_S} + (1-\mu_{VH})\,(1-\omega_H)\,(\gamma_{VH} H_V) + \phi\epsilon V \\
\frac{dD}{dt} &= (1-\omega_H)\,(\mu_H\gamma_H H + \mu_{VH}\gamma_{VH} H_V) + (1-\omega_U)\,(\mu_U\gamma_U U + \mu_{VU}\gamma_{VU} U_V)
\end{aligned}
$$

$$\mathrm{I}_T = I_S + \delta I_A + \delta_{VA} I_{VA} + \delta_{VS} I_{VS}$$

Versao do modelo 3 com compartimentos que envovle vacina em vermelho

$$\frac{dS}{dt} = -\frac{\beta(t)}{N} S I_T - \tau(t) S$$
$$\frac{dE}{dt} = \frac{\beta(t) S I_T}{N} - \kappa E$$
$$\frac{dV}{dt} = \tau(t) S - \phi V$$
$$\frac{dS_V}{dt} = \phi(1-\epsilon) V - \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N}$$
$$\frac{dE_V}{dt} = \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N} - \kappa_V E_V$$
$$\frac{dI_A}{dt} = (1-p)\kappa E - \gamma_A I_A$$
$$\frac{dI_S}{dt} = p\kappa E - \gamma_S I_S$$
$$\frac{dI_{VA}}{dt} = (1-p_V)\,\kappa_V E_V - \gamma_{VA} I_{VA}$$
$$\frac{dI_{VS}}{dt} = p_V \kappa_V E_V - \gamma_{VS} I_{VS}$$
$$\frac{dH}{dt} = h\xi\gamma_S I_S + (1-\mu_U+\omega_U\mu_U)\,\gamma_U U - \gamma_H H$$
$$\frac{dU}{dt} = h(1-\xi)\gamma_S I_S + \omega_H \gamma_H H - \gamma_U U$$
$$\frac{dU_V}{dt} = h_V(1-\xi_V)\gamma_{VS} I_{VS} + \omega_H \gamma_{VH} H_V - \gamma_U U_V$$
$$\frac{dH_V}{dt} = h_V \xi_V \gamma_{VS} I_{VS} + (1-\mu_{VU}+\omega_U \mu_{VU})\,\gamma_{VU} U_V - \gamma_{VH} H_V$$
$$\frac{dR}{dt} = \gamma_A I_A + (1-h)\gamma_S I_S + (1-\mu_H)\,(1-\omega_H)\,\gamma_H H$$
$$\frac{dR_V}{dt} = \gamma_{VA} I_{VA} + (1-h_V)\gamma_{V_S} I_{V_S} + (1-\mu_{VH})\,(1-\omega_H)\,(\gamma_{VH} H_V) + \phi\epsilon V$$
$$\frac{dD}{dt} = (1-\omega_H)\,(\mu_H\gamma_H H + \mu_{VH}\gamma_{VH} H_V) + (1-\omega_U)\,(\mu_U\gamma_U U + \mu_{VU}\gamma_{VU} U_V)$$

$$\mathrm{I}_T = I_S + \delta I_A + \delta_{VA} I_{VA} + \delta_{VS} I_{VS}$$

2 Modelo 2

$$
\begin{aligned}
\frac{dS}{dt} &= -\frac{\beta(t)(1-\psi(t))}{N}SI_T - \tau(t)S. \\
\frac{dE}{dt} &= \frac{\beta(t)(1-\psi(t))SI_T}{N} - \kappa E \\
\frac{dV}{dt} &= \tau(t)S - \gamma_S S_V - \gamma_R R_V \\
\frac{dS_V}{dt} &= \tau(t)(1-\epsilon)S + \gamma_V S_V - \frac{\beta_V(t)(1-\psi(t))S_V I_T}{N} \\
\frac{dE_V}{dt} &= \frac{\beta_V(t)(1-\psi(t))S_V I_T}{N} - \kappa_V E_V \\
\frac{dI_A}{dt} &= (1-p)\kappa E - \gamma_A I_A \\
\frac{dI_S}{dt} &= p\kappa E - \gamma_S I_S \\
\frac{dI_{VA}}{dt} &= (1-p_V)\,\kappa_V E_V - \gamma_{VA} I_{VA} \\
\frac{dI_{VS}}{dt} &= p_V \kappa_V E_V - \gamma_{VS} I_{VS} \\
\frac{dH}{dt} &= h\xi\gamma_S I_S + (1-\mu_U+\omega_U\mu_U)\,\gamma_U U - \gamma_H H \\
\frac{dU}{dt} &= h(1-\xi)\gamma_S I_S + \omega_H\gamma_H H - \gamma_U U \\
\frac{dU_V}{dt} &= h_V(1-\xi_V)\gamma_{VS} I_{VS} + \omega_H \gamma_{VH} H_V - \gamma_U U_V \\
\frac{dH_V}{dt} &= h_V \xi_V \gamma_{VS} I_{VS} + (1-\mu_{VU}+\omega_U\mu_{VU})\,\gamma_{VU} U_V - \gamma_{VH} H_V \\
\frac{dR}{dt} &= \gamma_A I_A + (1-h)\gamma_S I_S + (1-\mu_H)\,(1-\omega_H)\,\gamma_H H \\
\frac{dR_V}{dt} &= \gamma_R V + \gamma_{VA} I_{VA} + (1-h_V)\gamma_{V_S} I_{V_S} + (1-\mu_{VH})\,(1-\omega_H)\,(\gamma_{VH} H_V) + \tau(t)\epsilon S \\
\frac{dD}{dt} &= (1-\omega_H)\,(\mu_H\gamma_H H + \mu_{VH}\gamma_{VH} H_V) + (1-\omega_U)\,(\mu_U\gamma_U U + \mu_{VU}\gamma_{VU} U_V)
\end{aligned}
$$

$$
\mathrm{I}_T = I_S + \delta I_A + \delta_{VA} I_{VA} + \delta_{VS} I_{VS}
$$

3 Parameters - using data until september 2020 before vaccination in Bahia

Variable	Description	Interval	value	condition
N	population	-	14,873,064 (fixed)	
β	transmission rate of non-vaccinated individuals	β_1 $[0, 2]$	0.96 (estimated)	
β_V	transmission rate of vaccinated individuals.	$\beta_{V1}[0, 1]$	0.48 (estimated)	$\beta_V = 0.5\beta$
τ	vaccination rate.		1/10000 (unit??)	average rate
δ	mild symptoms infectivity factor for non-vaccinated cases	$[0, 0.75]$	0.31 (estimated)	$(\delta < 1)$
δ_{VA}	mild symptoms infectivity factor for vaccinated cases	$[0, 0.75]$	0.31 (fixed)	$\delta \geq \delta_{VA}$
δ_{VS}	reduced infectivity factor due to vaccination	$[0, 0.75]$	0.31 (fixed)	$\delta_{VS} > \delta_{VA}$
ϕ	inverse time for immunity	$[0.05, 0.1]$	0.07 (fixed)	average time for immunity
ϵ	vaccine efficacy	[0.5, 0.9]	0.7 (fixed)	average efficacy
κ	inverse of exposed period for non vaccinated susceptible	[1/6, 1/3]	1/4 (fixed)	
κ_V	inverse of exposed period for vaccinated susceptible.	[1/5, 1/2]	1/3 (fixed)	$\kappa_V > \kappa$
p	proportion of non-vaccinated latent to symptomatic cases.	[0.13,0.5]	0.2 (fixed)	
p_v	proportion of vaccinated latent to symptomatic cases.	[0.065,0.25]	0.1 (fixed)	$p_V < p$
γ_A	mean infected period for non vaccinated assymptomatic cases.	[1/3.7, 1/3.24]	1/3.5 (fixed)	
γ_S	mean infected period for non vaccinated symptomatic cases.	[1/5,1/3]	1/4 (fixed)	
γ_{VA}	mean infected period for vaccinated assymptomatic cases.	[1/3.7 1/3.24]	1/3.5 (fixed)	$\gamma_{VA} \geq \gamma_A$
γ_{VS}	mean infected period for vaccinated symptomatic cases.	[1/5,1/3]	1/4 (fixed)	$\gamma_{VS} \geq \gamma_S$
h	proportion of hospitalized symptomatic non-vaccinated cases.	[0.05,0.25]	0.06 (estimated)	
h_V	proportion of hospitalized symptomatic vaccinated cases.	[0,0.05]	0.012 (fixed)	$h >> h_V$
$(1-\xi)$	proportion of symptomatic non-vaccinated cases who need ICU.	[0.01, 0.5]	0.47 (fixed)	
$(1-\xi_V)$	proportion of vaccinated cases who needs ICU	[0,0.1]	0.1 (fixed)	$\xi_V >> \xi$
γ_H	mean (clinical) hospitalization period for non-vaccinated cases.	[1/12,1/4]	0.18 (fixed)	
γ_{VH}	mean (clinical) hospitalization period for vaccinated cases.	[1/6,1/2]	0.36 (fixed)	$\gamma_{VH} > \gamma_H$
γ_U	inverse of mean ICU bed for non-vaccinated cases.	[1/12, 1/3]	0.13 (fixed)	
γ_{VU}	inverse of mean ICU bed for vaccinated cases.	[1/6, 1/2]	0.26 (fixed)	$\gamma_{VU} > \gamma_U$
ω_H	proportion of hospitalized cases that goes to ICU.	[0.1,0.3]	0.14 (fixed)	
ω_U	proportion of ICU cases that goes back to hospitalization	[0.1, 0.3]	0.29 (fixed)	
μ_H	death rate of non-vaccinated hospitalized cases.	[0.1,0.2]	0.15 (fixed)	
μ_U	death rate of ICU non-vaccinated hospitalized cases.	[0.4, 0.5]	0.4 (fixed)	
μ_{VH}	death rate of vaccinated (clinical) hospitalized cases.	[0.02, 0.04]	0.03 (fixed)	$\mu_{VH} \approx \mu_H/5$
μ_{VU}	death rate of vaccinated ICU hospitalized cases.	[0.08, 0.1]	0.08 (fixed)	$\mu_{VU} \approx \mu_U/5$

4 Modelo 1

$$
\begin{aligned}
\frac{dS}{dt} &= -\frac{\beta(t)(1-\psi(t))}{N} S I_T - \tau(t) S. \\
\frac{dE}{dt} &= \frac{\beta(t)(1-\psi(t)) S I_T}{N} - \kappa E \\
\frac{dS_V}{dt} &= \tau(t) S - \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N} - \phi\epsilon S_V \\
\frac{dE_V}{dt} &= \frac{\beta_V(t)(1-\psi(t)) S_V I_T}{N} - \kappa_V E_V \\
\frac{dI_A}{dt} &= (1-p)\kappa E - \gamma_A I_A \\
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\frac{dU}{dt} &= h(1-\xi)\gamma_S I_S + \omega_H \gamma_H H - \gamma_U U \\
\frac{dU_V}{dt} &= h_V(1-\xi_V)\gamma_{VS} I_{VS} + \omega_H \gamma_{VH} H_V - \gamma_U U_V \\
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\frac{dR}{dt} &= \gamma_A I_A + (1-h)\gamma_S I_S + (1-\mu_H)\,(1-\omega_H)\,\gamma_H H \\
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\frac{dD}{dt} &= (1-\omega_H)\,(\mu_H \gamma_H H + \mu_{VH}\gamma_{VH} H_V) + (1-\omega_U)\,(\mu_U \gamma_U U + \mu_{VU}\gamma_{VU} U_V)
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ϕ	inverse time for immunity	$[0.05, 0.1]$	0.07 (fixed)	average time for immunity
t_0	average time for vaccine effect	$[12, 18]$	15 (fixed)	
ϵ	vaccine efficacy	$[0.5, 0.9]$	0.7 (fixed)	
κ	inverse of exposed period for non vaccinated susceptible	[1/6, 1/3]	1/4 (fixed)	
κ_V	inverse of exposed period for vaccinated susceptible.	[1/5, 1/2]	1/3 (fixed)	$\kappa_V > \kappa$
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