



HAL
open science

A two-stage seirs reinfection model with multiple endemic equilibria

Pierre-Alexandre Bliman, Marcel Fang

► **To cite this version:**

Pierre-Alexandre Bliman, Marcel Fang. A two-stage seirs reinfection model with multiple endemic equilibria. 15th Conference on Dynamical Systems Applied to Biology and Natural Sciences, DSABNS 2024, Feb 2024, Lisbonne, Portugal. hal-04526417

HAL Id: hal-04526417

<https://hal.science/hal-04526417v1>

Submitted on 29 Mar 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A TWO-STAGE SEIRS REINFECTION MODEL WITH MULTIPLE ENDEMIC EQUILIBRIA

Pierre-Alexandre Bliman^{1,2} and Marcel Fang^{*1,2}

¹Laboratoire Jacques-Louis Lions (Sorbonne Université, Paris, France)

²INRIA (Paris, France)

marcel.fang@inria.fr (*presenter)

pierre-alexandre.bliman@inria.fr

Since the introduction of SIR model by Kermack and McKendrick in 1927, compartmental models have been massively studied and successfully applied to various epidemic processes including characteristics such as quarantine, vaccination, variants, cross-immunity. Recently, a particular attention has been paid to reinfection models in epidemiology. To cite a few, threshold conditions for infection, reinfection and endemicity of various SIRS models are studied in [2], bifurcation analysis for a SIRS model presenting different contact rates for infection and reinfection in [4], and models counting reinfections in [3], [1]. Nevertheless, in most studies on reinfection, the infection and reinfection processes are assumed to behave essentially in the same way, which is quite limitative. With the aim of understanding the effects induced by differences between the stage of primo-infection and further reinfections, we introduce here an 8-dimensional two-stage SEIRS reinfection model in which the parameters characteristic of the disease dynamics are different for the primo-infection and for the following reinfections. The value of the basic reproduction number \mathcal{R}_0 of the model around the (unique) disease-free equilibrium is first derived, and the existence of up to two and three endemic equilibria, respectively in the cases $\mathcal{R}_0 \leq 1$ and $\mathcal{R}_0 > 1$, is theoretically established under appropriate conditions on the system parameters. Finally, numerical testing and simulations are achieved, which in particular exhibit bistability in the cases when multiple endemic equilibria arise.

References

- [1] Fang, M., Bliman P-A. (2022). Modelling, Analysis, Observability and Identifiability of Epidemic Dynamics with Reinfections, *20th European Control Conference*.
- [2] Gomes, M.G.M., White, L.J., Medley, G.F.(2004). Infection, reinfection, and vaccination under suboptimal immune protection: epidemiological perspectives, *Journal of Theoretical Biology* 228(4):539-549.
- [3] Katriel, G. (2010). Epidemics with partial immunity to reinfection, *Mathematical Biosciences* 228(2):153-159.
- [4] Pagliara, R., Dey, B., Leonard, N.E., Bistability and Resurgent Epidemics in Reinfection Models. (2018). *IEEE Control Systems Letters*.