Practical considerations for estimating the effective reproductive number, R_t

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Practical considerations for measuring the effective reproductive number, Rt

Katelyn M Gostic, Lauren McGough, Edward Baskerville, Sam Abbott, Keya Joshi, Christine Tedijanto, Rebecca Kahn, Rene Niehus, James A Hay, Pablo M. De Salazar, Joel Hellewell, Sophie Meakin, James Munday, Nikos Bosse, Katharine Sherratt, Robin M Thompson, Laura F White, Jana Huisman, Jérémie Scire, Sebastian Bonhoeffer, Tanj Stadler, Jacco Wallinga, Sebastian Funk, Marc Lipsitch, Sarah Cobey

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Outline

Choose wisely: Accuracy of common methods

Two definitions of R_t

Challenges when working with imperfect data

Back-calculating times of infection
Specifying the generation interval
Accounting for uncertainty

Why estimate R_t?

Is the epidemic growing, shrinking or holding steady?

Assess policy effects

➡ Instantaneous reproductive number

Why estimate R_t?

Is the epidemic growing, shrinking or holding steady?

Assess policy effects

➡ Instantaneous reproductive number

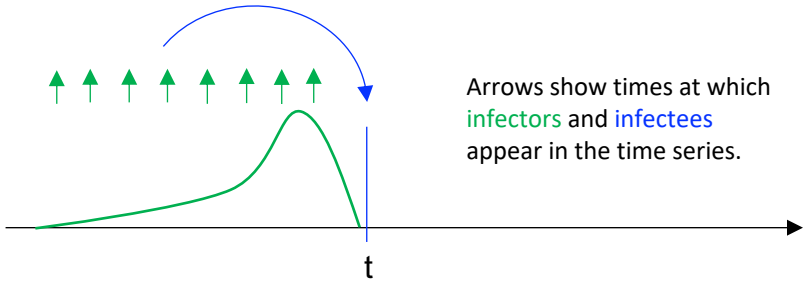
On average, how many new infections will a single individual cause?

Analyze transmission chains.

➡ Case reproductive number

Instantaneous reproductive number

Methods of Cori et al. and Bettencourt & Ribeiro



Arrows show times at which infectors and infectees appear in the time series.

New infections at time *t*

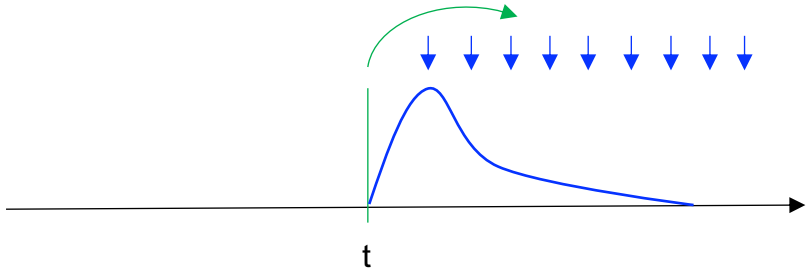
$$R_t^{inst} = \frac{I_t}{\sum_{s=1}^{t} I_{t-s} w(s)}$$

Number and current infectiousness of individuals infected in the previous generation

Cori et al. *American Journal of Epidemiology.* 2013.

Case reproductive number

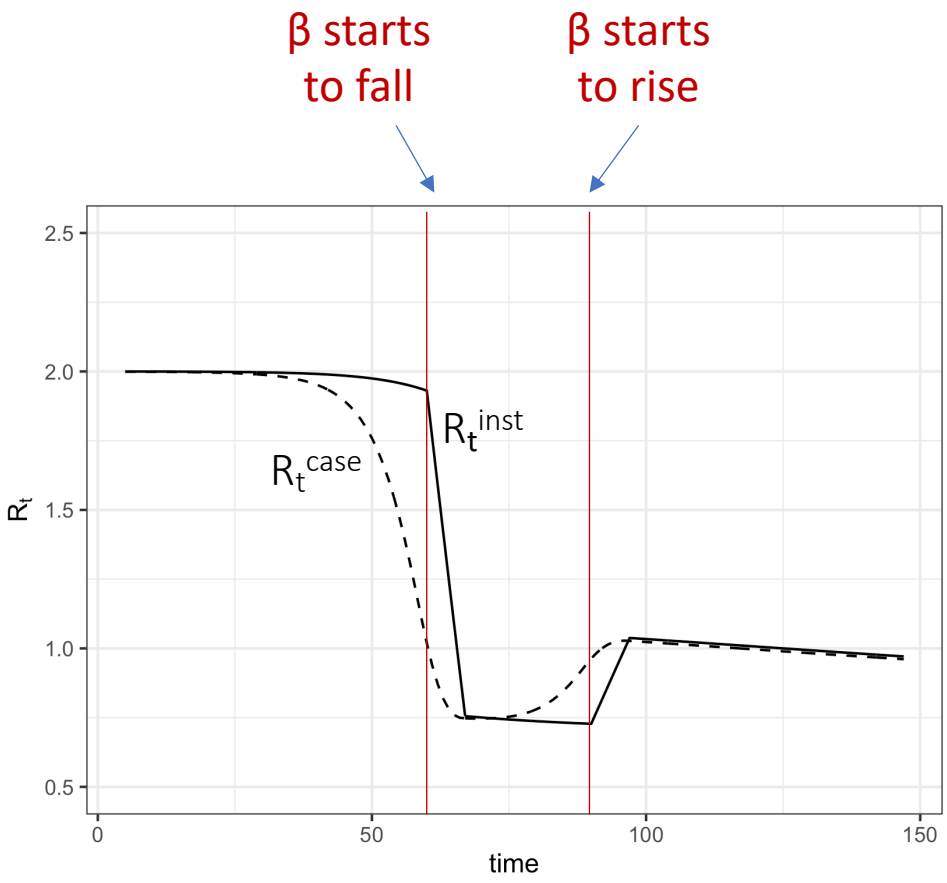
Method of Wallinga & Teunis



$$R_t^{case} = \sum_{u \geq t} R_u^{inst} w(u-t)$$

Wallinga & Lipsitch. *Proc. Roy. Soc. B.* 2006.

Synthetic data from an SEIR model in which the transmission rate falls, then rises.

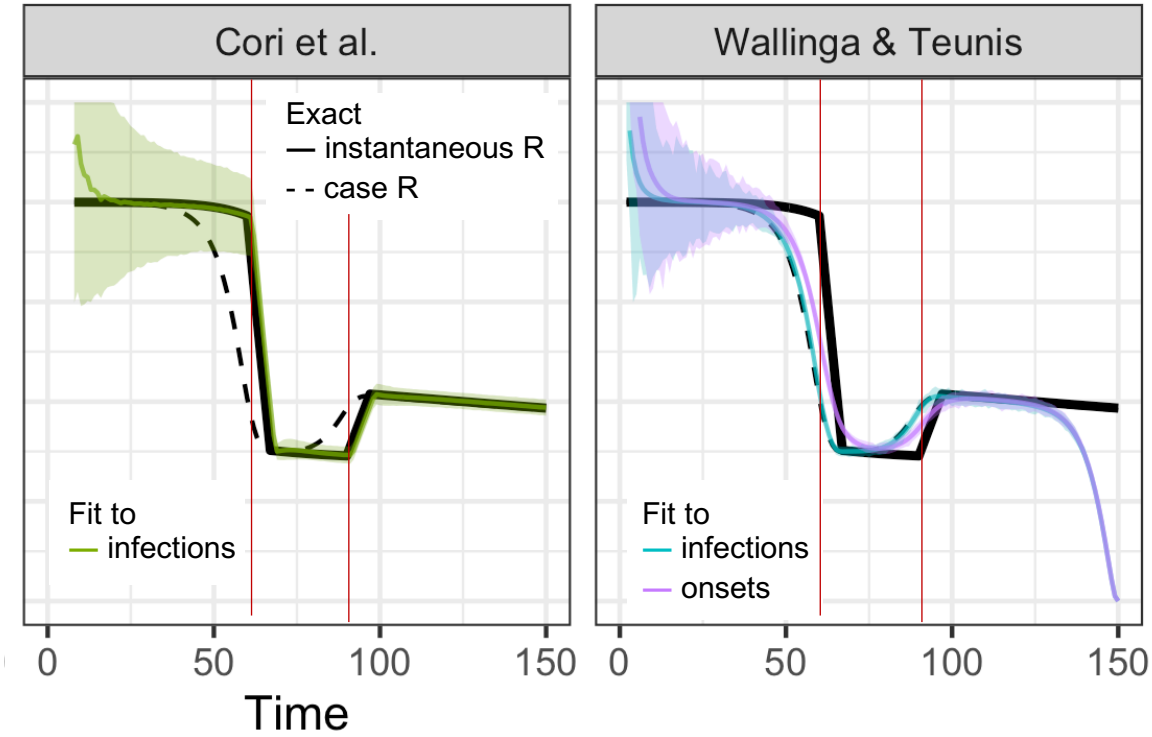


Estimate instantaneous R

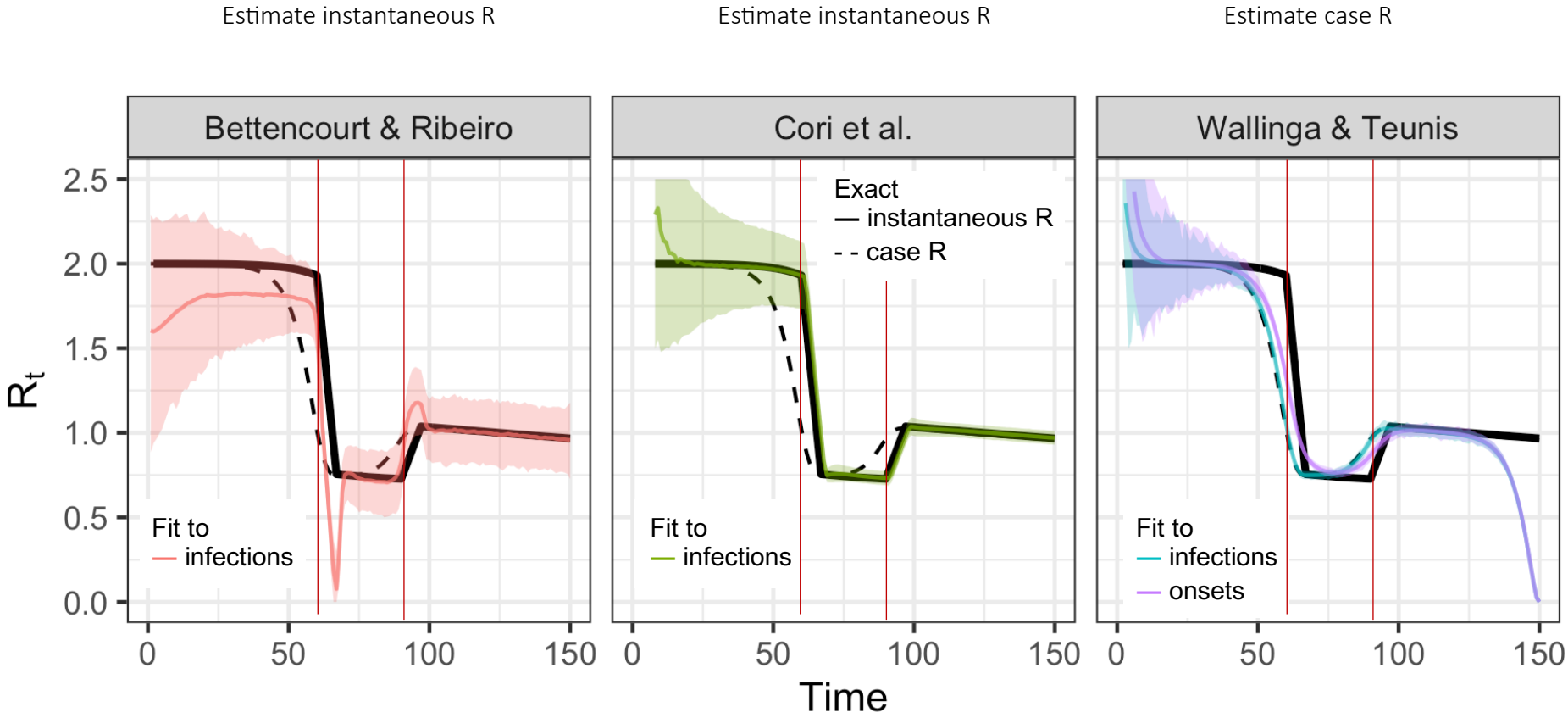
Cori et al. *American Journal of Epidemiology.* 2013.

Estimate instantaneous R

Estimate case R



Wallinga & Teunis. *American Journal of Epidemiology*. 2004.



Bettencourt & Ribeiro. *PLOS One*. 2008.

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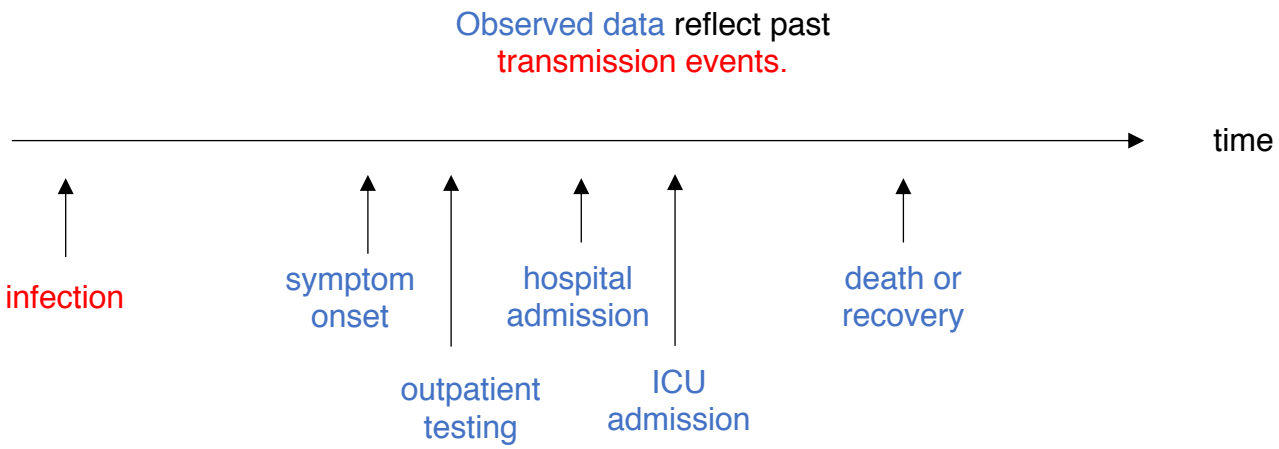
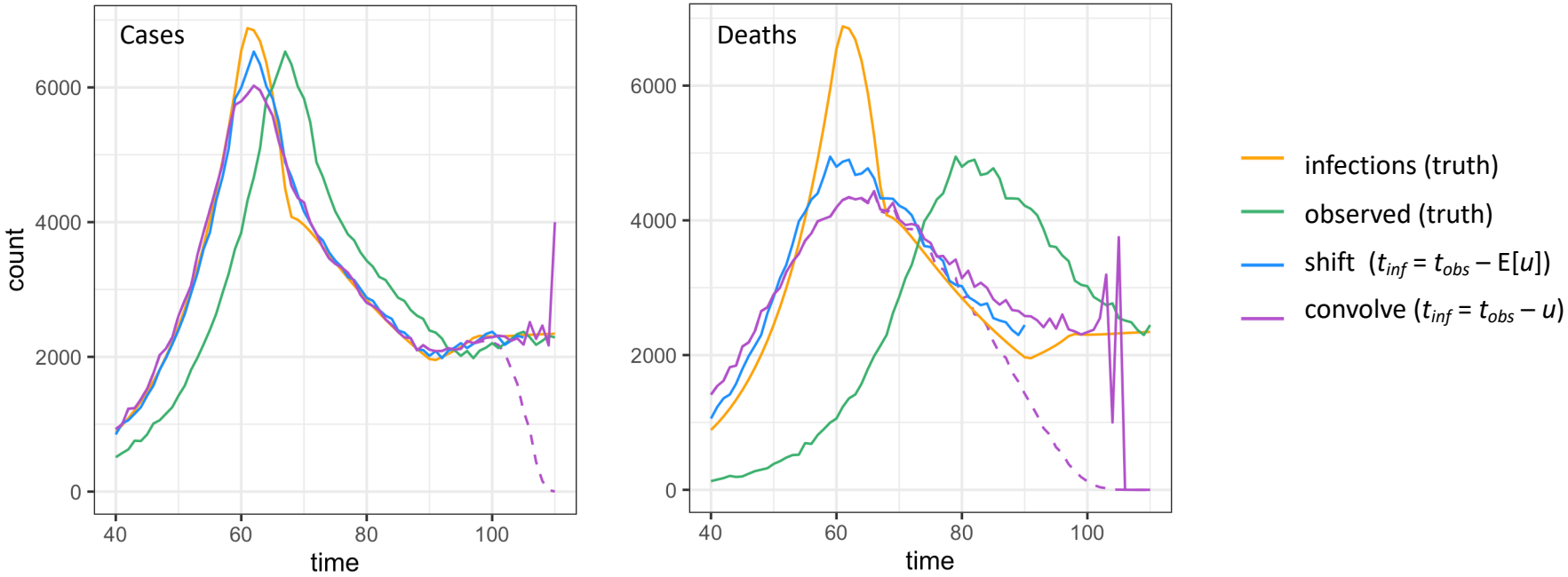
R_t measures transmission at time *t*. Lagged observations must be adjusted.



Simple methods do not accurately recover the latent infection curve



→ Longer and more variable delays pose a greater challenge

Better approaches

1. Infer times of infection from observations **using deconvolution methods adapted from signal and image processing**
2. Estimate R_t

Goldstein et al. *PNAS.* 2009.
Becker et al. *Stat. in Med. 1991*

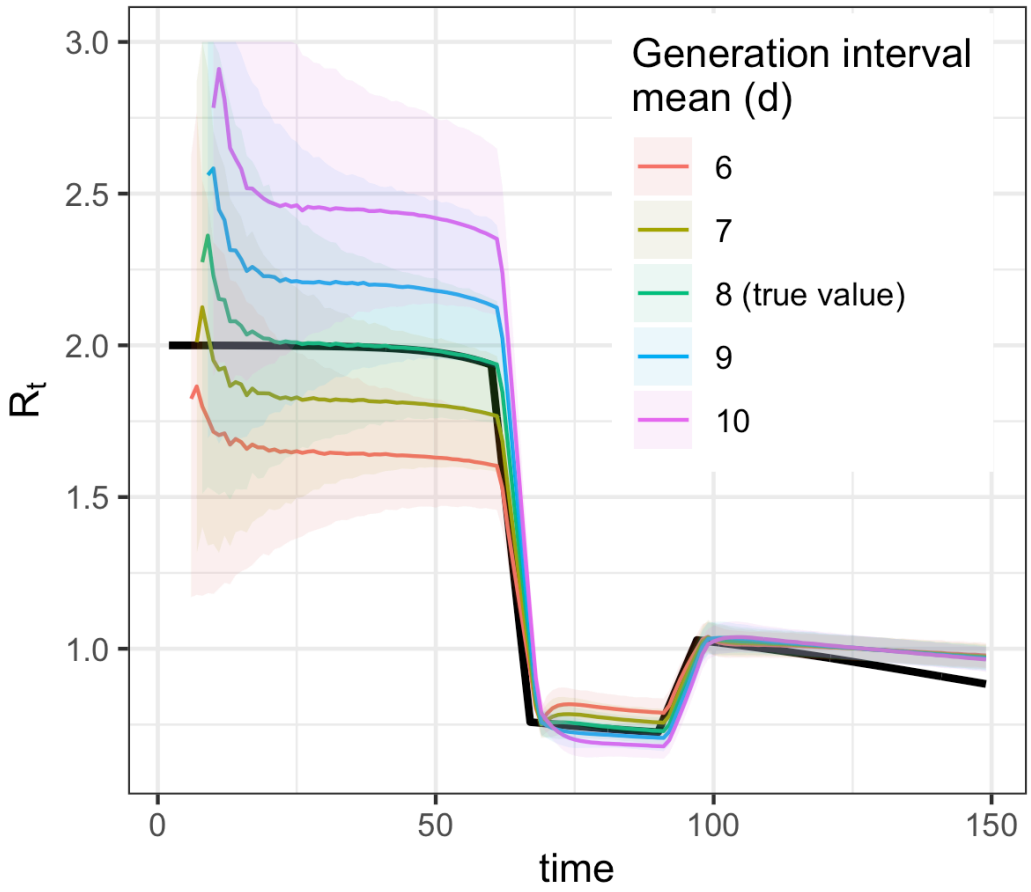
Treat times of infection as a latent state while estimating R_t

Imperfect observation

R_t estimation methods assume all infections are observed.

R_t estimates will remain accurate if the fraction of infections observed does not change over time. But even in this best-case scenario, **CIs will not include uncertainty from imperfect observation.**

Estimates will be biased if the fraction observed changes over time.



Caution when using serial interval estimates to parameterize the generation interval!

1. The serial interval can be negative, but the generation interval cannot.

Ganyani et al. *Eurosurveillance.* 2020

2. The observed serial interval tends to decrease as an epidemic progresses. The intrinsic generation interval does not.

Park et al. *medrxiv*. 2020.

Conclusions

Choose an appropriate estimation method.

Times of infection must be inferred from lagged observations.

Estimate the generation interval carefully.

Beware spurious precision and propagate all sources of uncertainty.

Thank you! Questions?

JSMF

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Comment on this paper

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