An analysis of the Covid-19 fatalities Tamil Nadu: May 5- September 5, 2020

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Indian Scientists' Response to Covid-19

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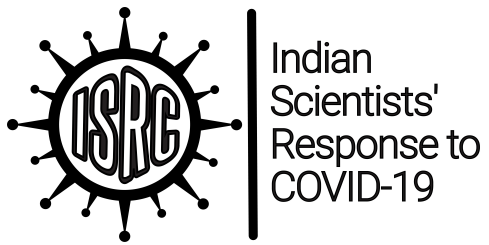
13th September 2020.



Outline

Motivation

Why analyse details of the deceased patients ?

- To provide input into minimising future deaths by quantitatively understanding the risk factors.
- To provide input into the management of critical medical facilities.
- To understand the progress of the epidemic:
  Only a small fraction of the actual infected patients are detected due to limited testing resources. However, it is likely that a larger fraction of the deaths are detected since it is likely that many of the critically ill patients would be admitted to hospitals.

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The Data

Data from the daily media bulletins of the Tamil Nadu Department of Health and Family Welfare

https://stopcorona.tn.gov.in/daily-bulletin/
https://covid19india.org (data curated from above)

In this report we focus on the detailed data on the deceased patients from 5th May, 2020 to 5th September, 2020:

- Dates of: report, admission to hospital, test, test result, death.
  Age, gender, district, comorbidities.
- District-wise time series of the confirmed, recovered and deceased patients.

In this report we analyse the data for all Tamil Nadu.
We will report on the district-wise analysis later.

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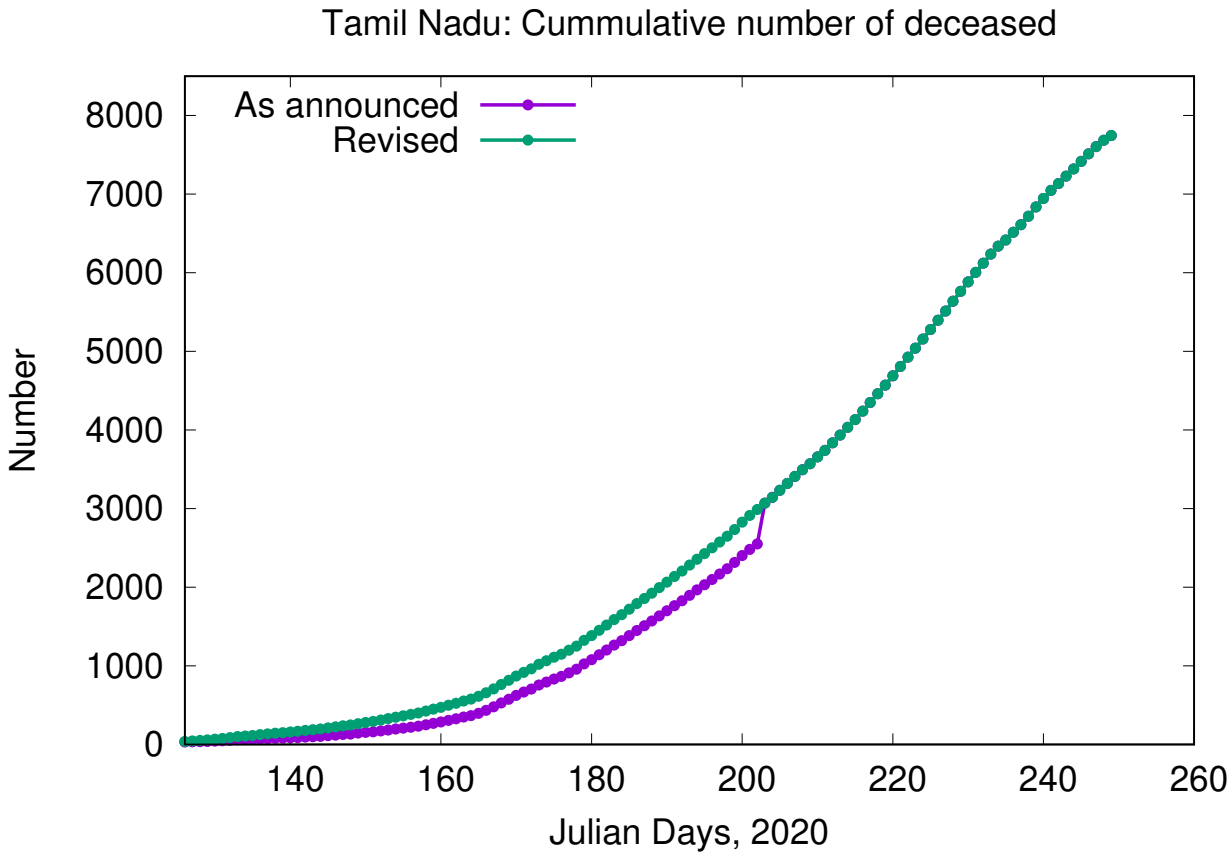
Outline

The revision



The number of deaths in Chennai was revised and 444 extra added on 22nd July, 2020. For some purposes, we have distributed this number uniformly during the period prior to 22/07/20. Click here for technical details.

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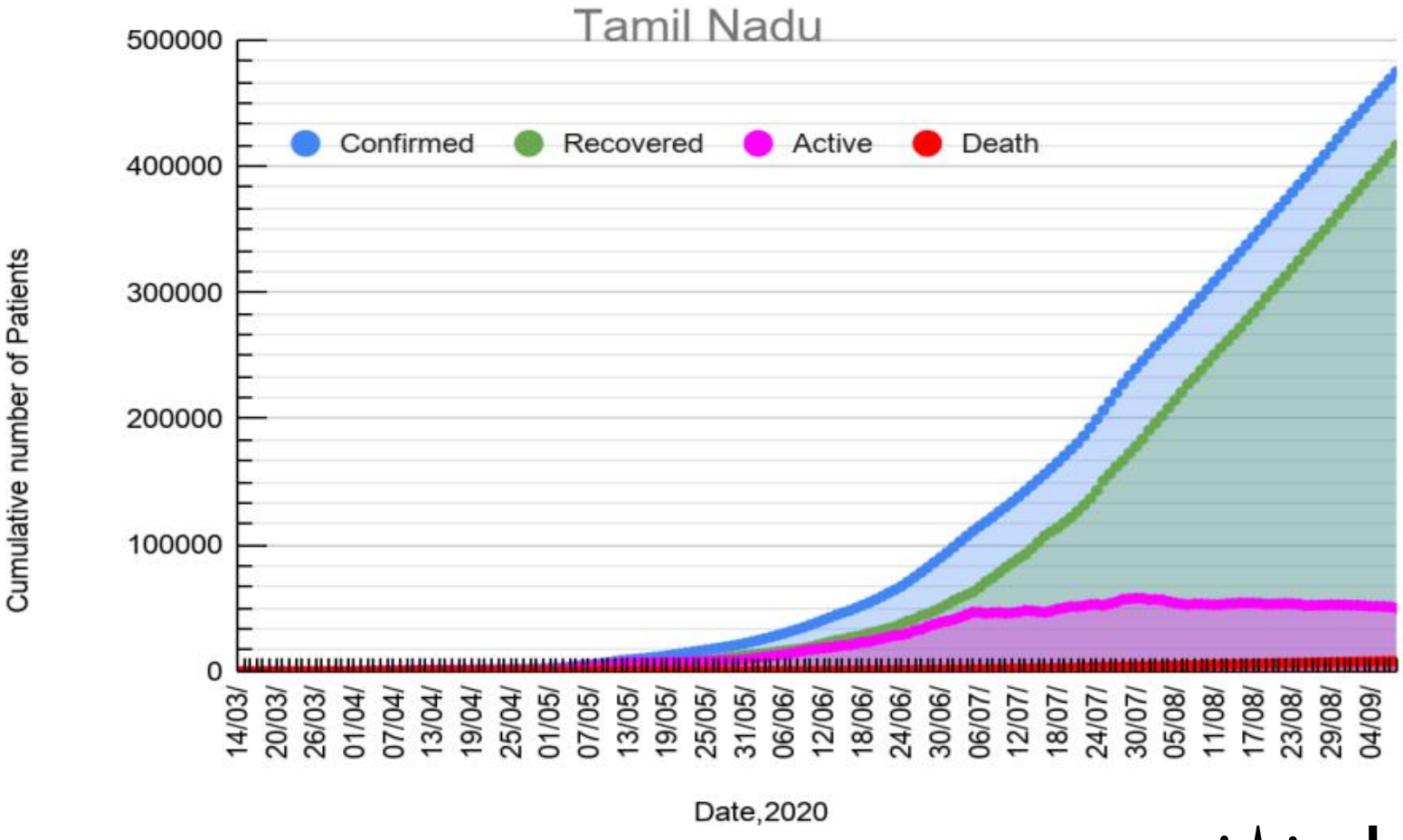
Confirmed, Recovered, Deceased and Active cases



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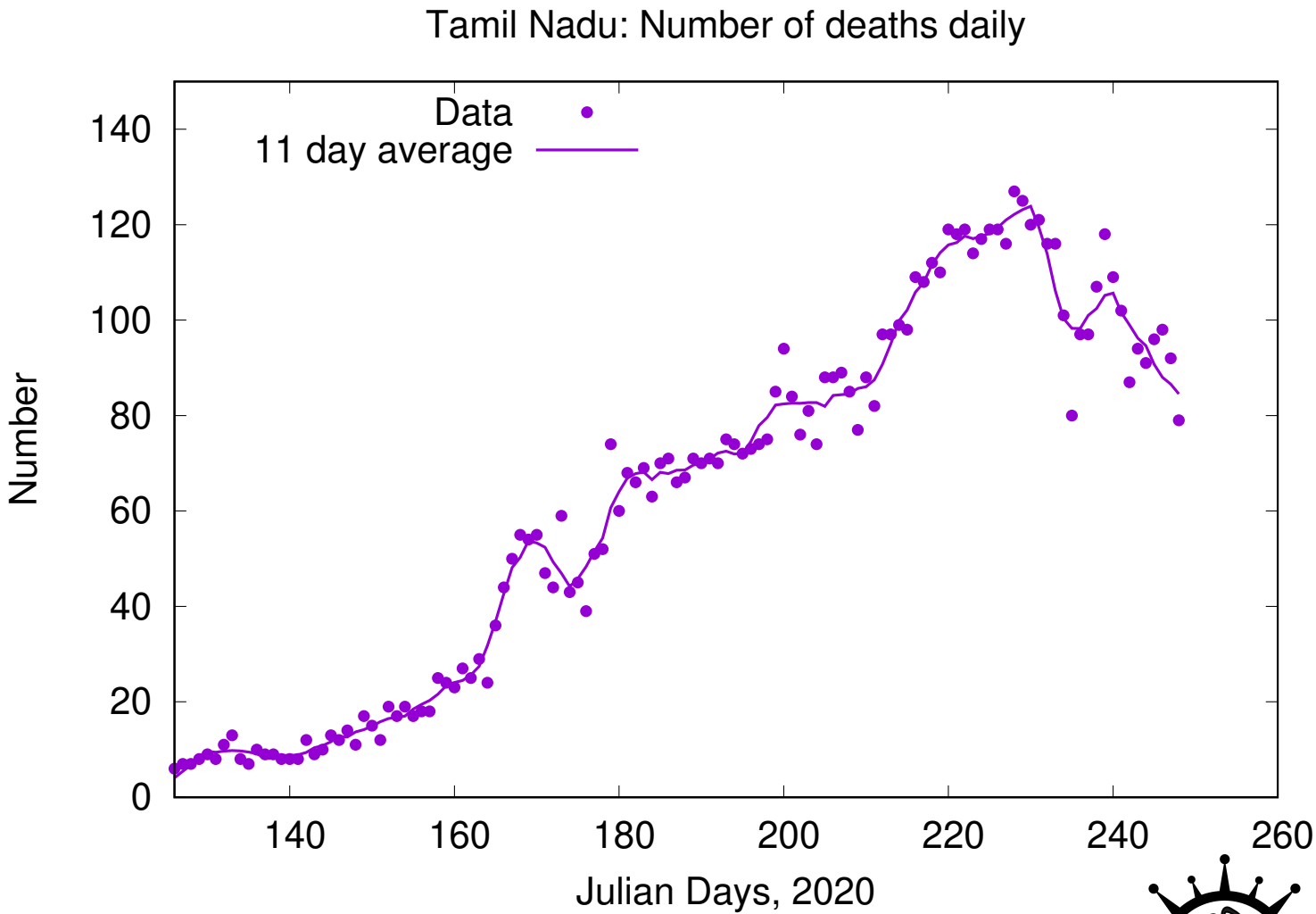
Number of daily deaths



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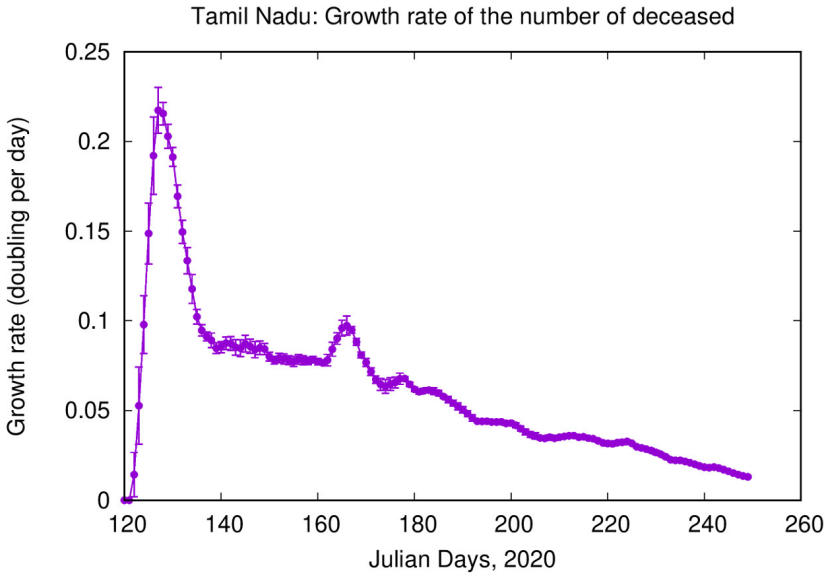
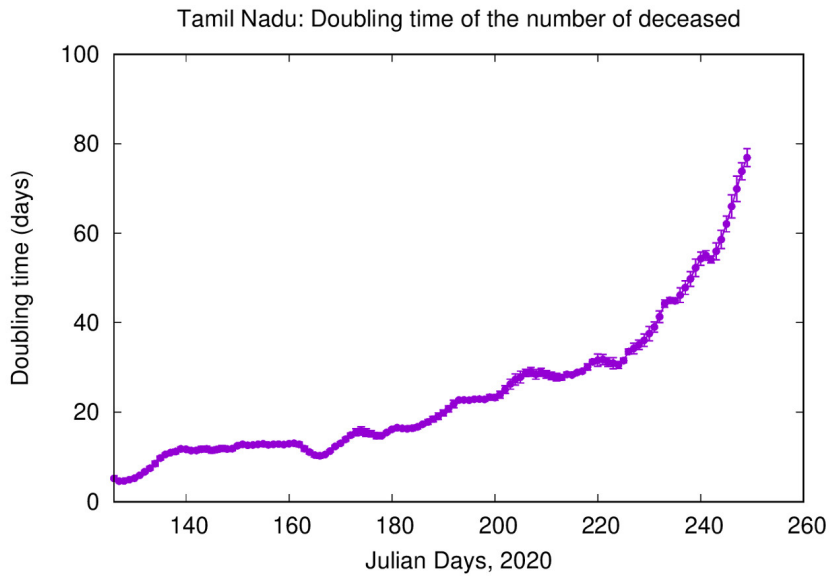
Doubling times and growth rates of the deceased cases





The doubling time is the time taken for the cases to double. The growth rate is the inverse of the doubling time.

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Discussion of results

- 7,748 of the patients who had tested positive for Covid-19 had died till 5th September 2020.
- The number of daily deaths rose till the middle of August. It has decreased after that (Click here for graph).
- The number of active cases has been roughly constant from the middle of July. (Click here for graph)
- The growth rate of the number of deaths has been steadily decreasing from early May onwards (Click here for graph)

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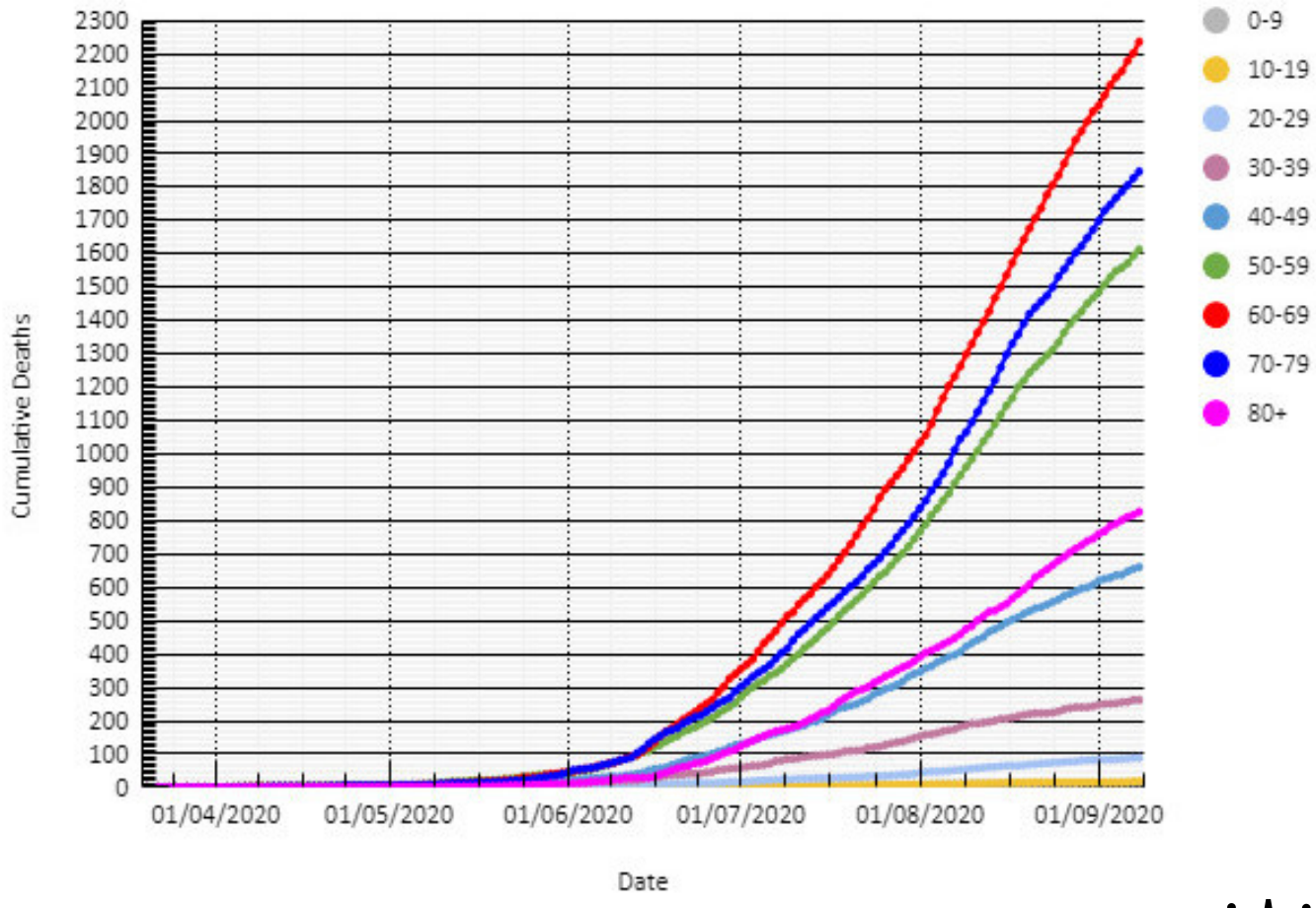
Outline

Motivation

To understand risk factors that correlate with death:

- Age and gender.
- Pre-existing Diabetes mellitus.
- Hypertension
- Ischemic heart disease.
- Renal disease.
- Pregnancy.
- Cancer.
- Immunocompromised conditions such as rheumatoid arthritis, SLE etc
- Endocrine diseases such as hypothyroidism.

Age distribution of the deceased patients



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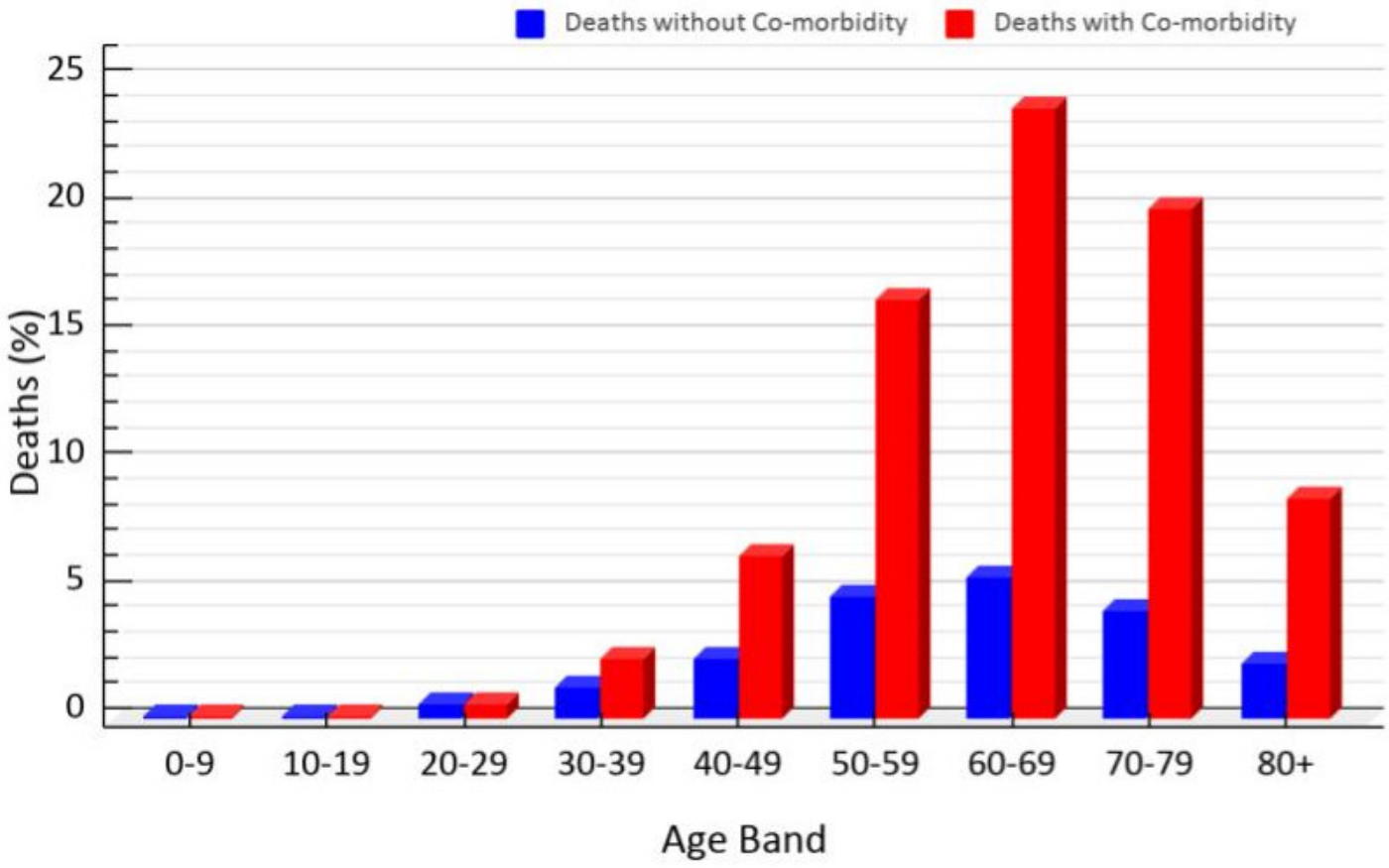
Deceased patients with/without comorbidities



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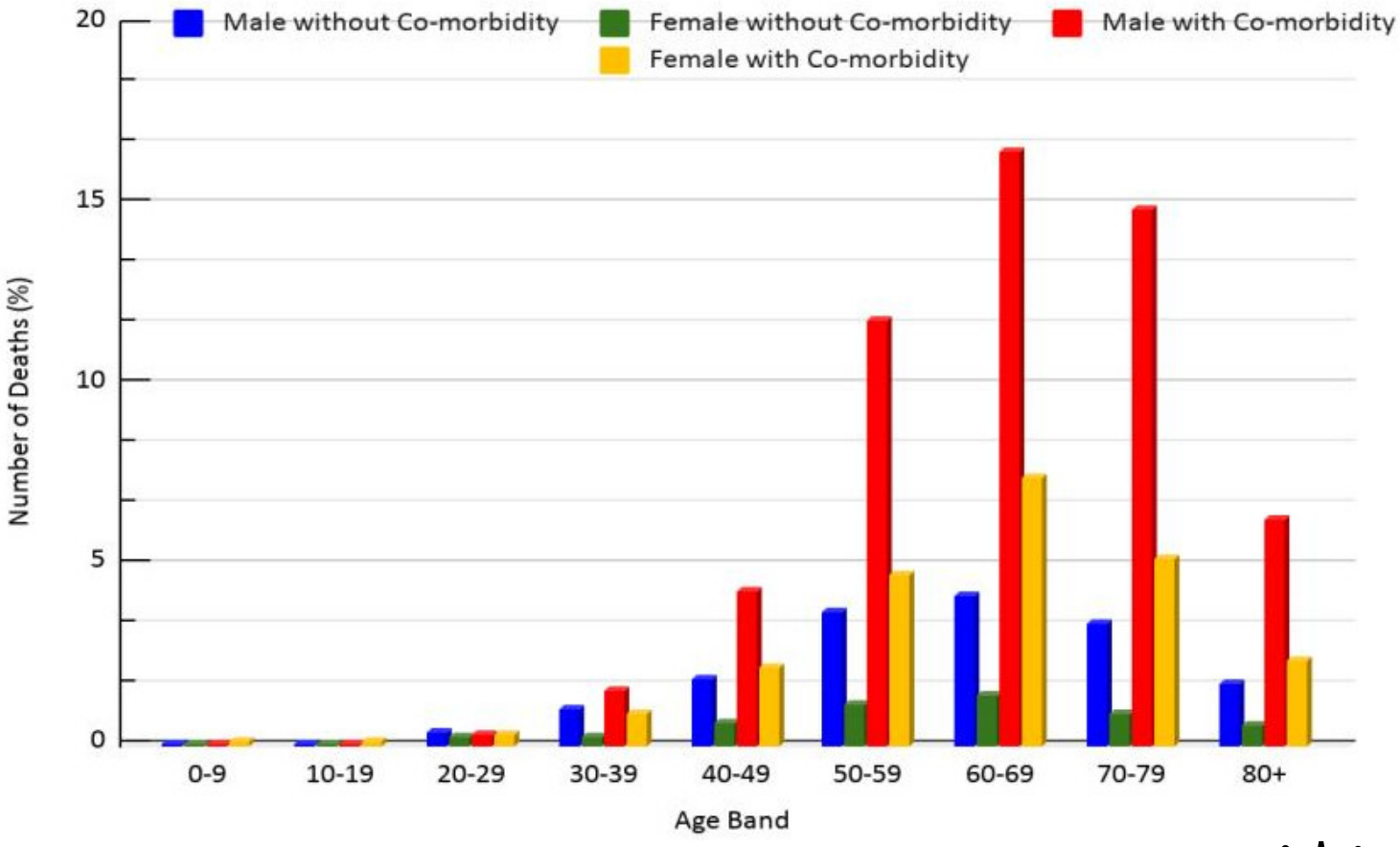
Deceased patients with/without comorbidities by gender



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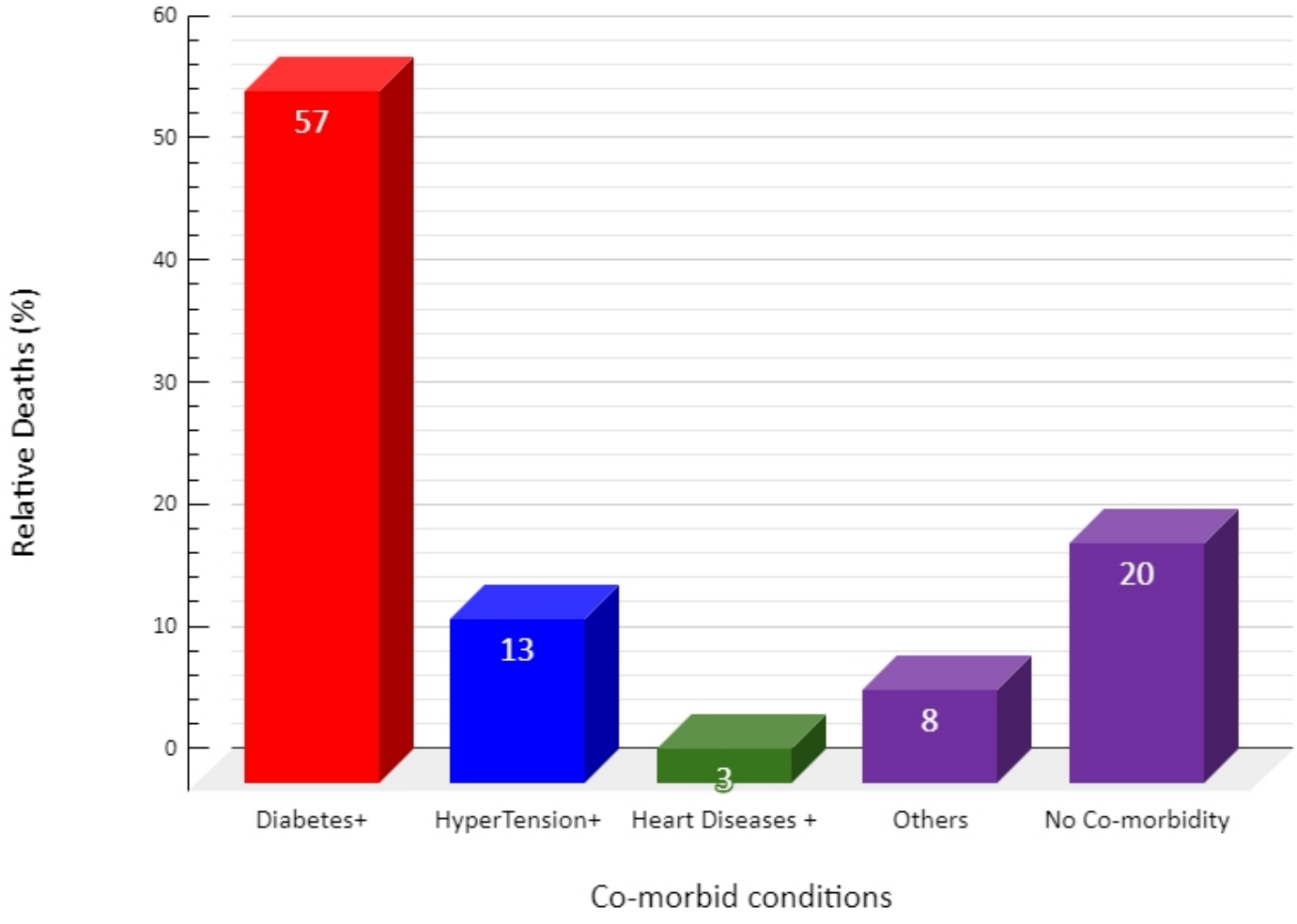
The distribution of comorbidities



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The prevalence of the comorbidities in Tamil Nadu

Comorbidity	Crude Prevalence in population	Prevalence in Covid-19 deceased
Diabetes	11.8%	56%
Hypertension	28%	45%
Heart diseases	2-5%	17%

The prevalence in covid-19 deceased given in the table are absolute. Namely the percentage of the comorbidity with or without other comorbidities.

Click here for the sources
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Discussion of results

- Diabetes is the most common risk factor associated with mortality. While its prevalence in the population is about 12%, its prevalence in the deceased is about 56%. (Click here for table)
- Systemic hypertension is another significant risk factor. Its prevalence in the covid-19 deceased is also quite large (45%).
- The comorbidities increases the probability of death for both genders in all age groups, particularly among the elderly. (Click here for chart)
- A significant fraction of the deceased, around 20%, were previously healthy. (Click here for chart)

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Outline

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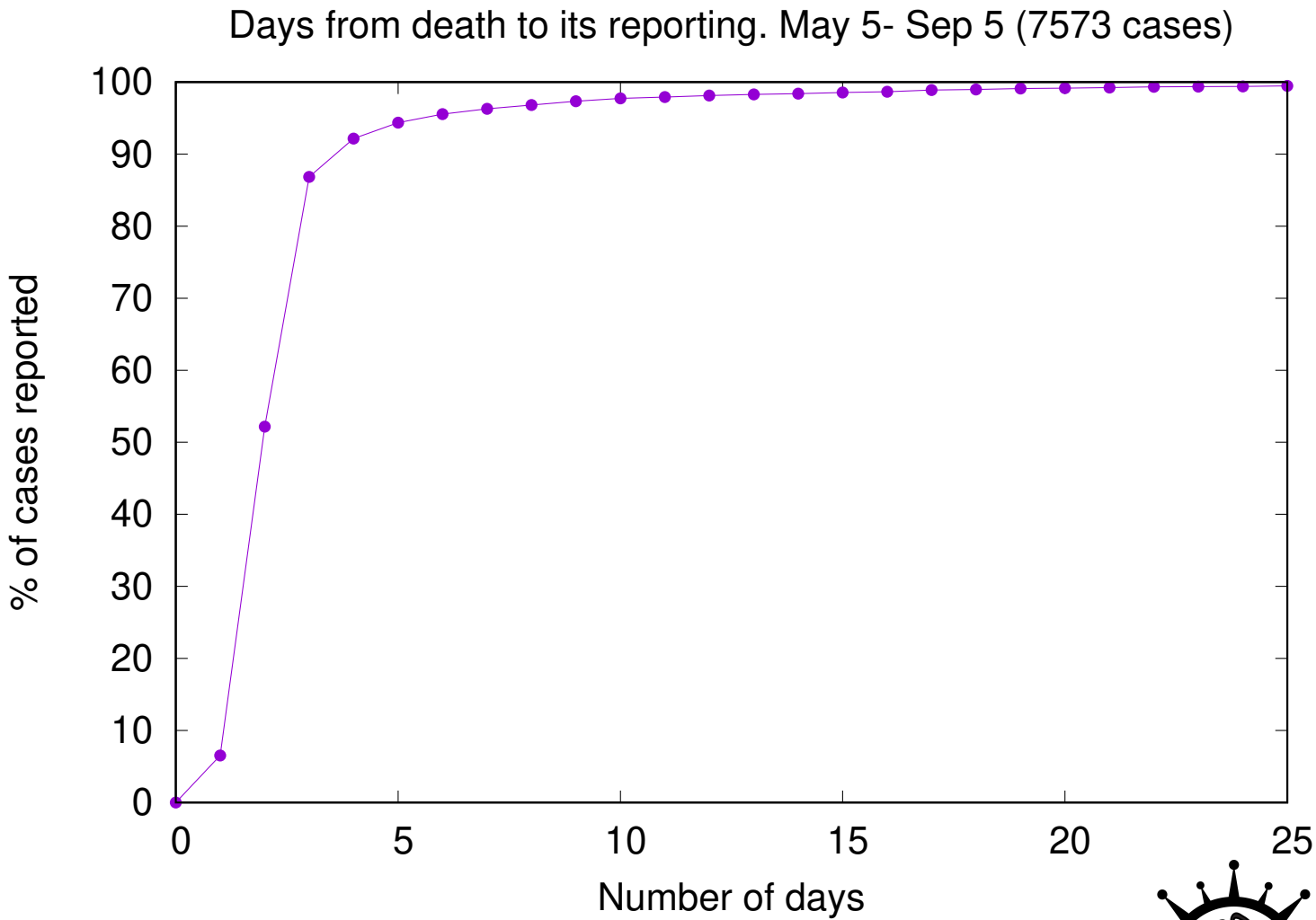
Death to reporting times



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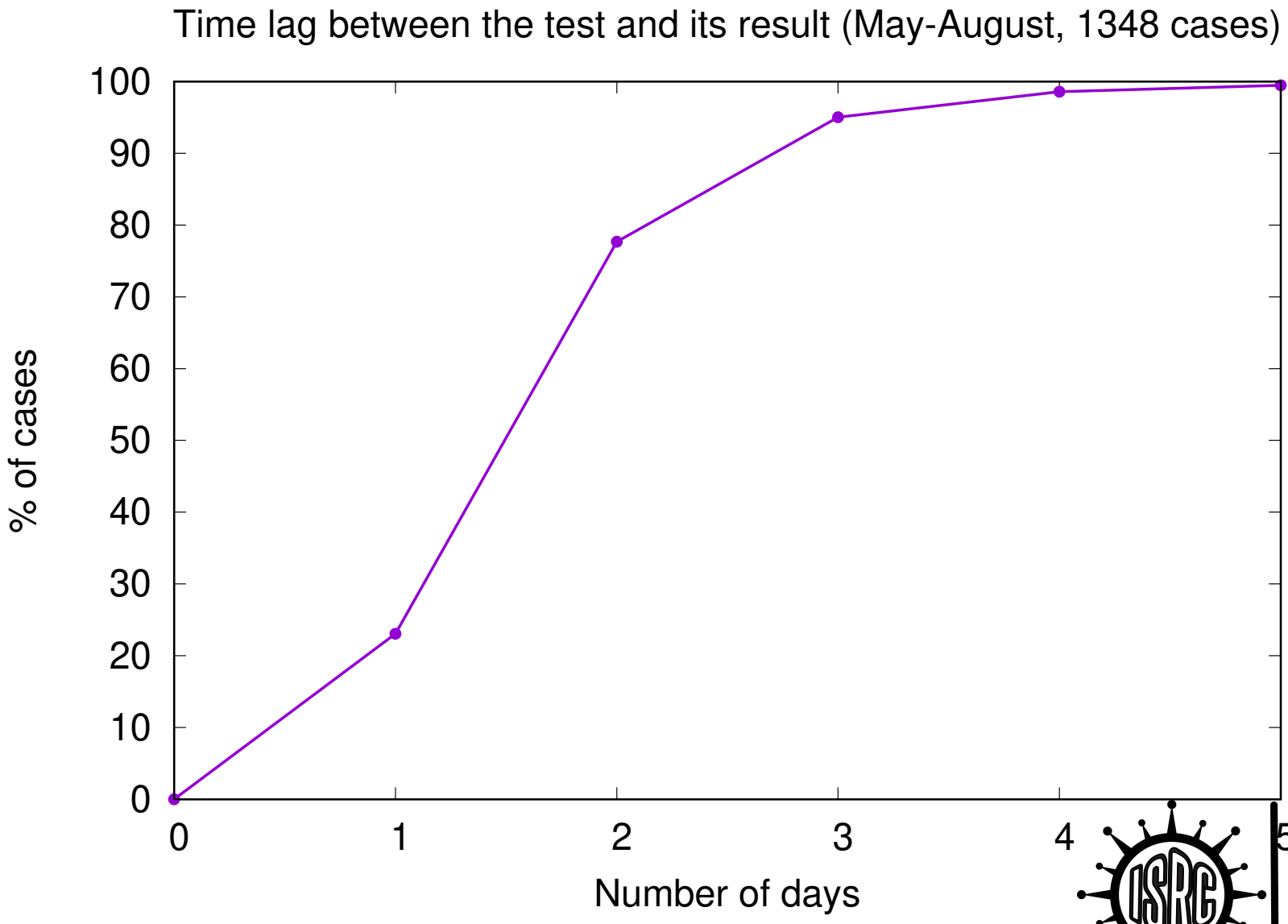
Test to result times



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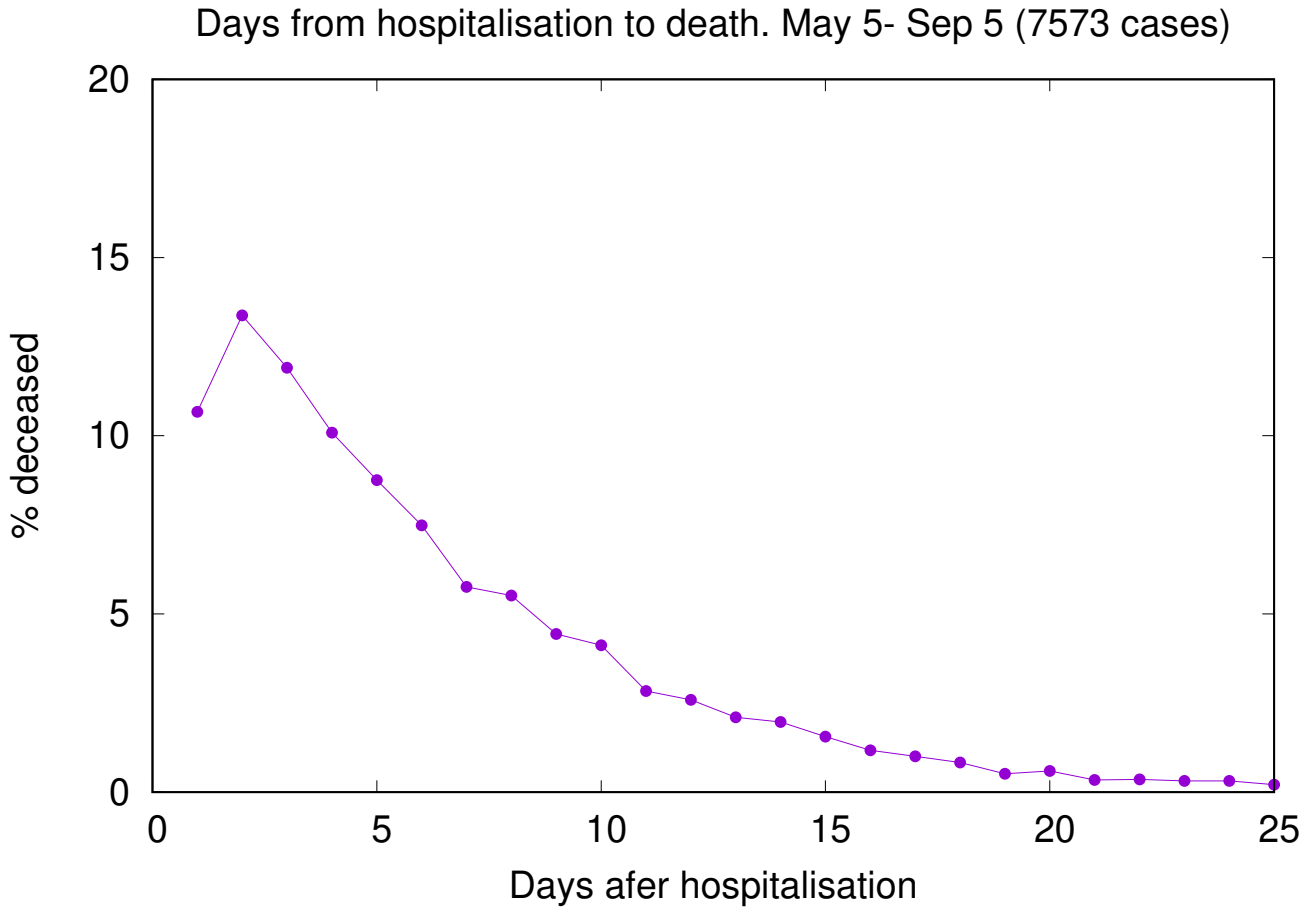
Hospitalisation to death times



The fraction of the deceased patients who died *exactly n* days after admission to a hospital.
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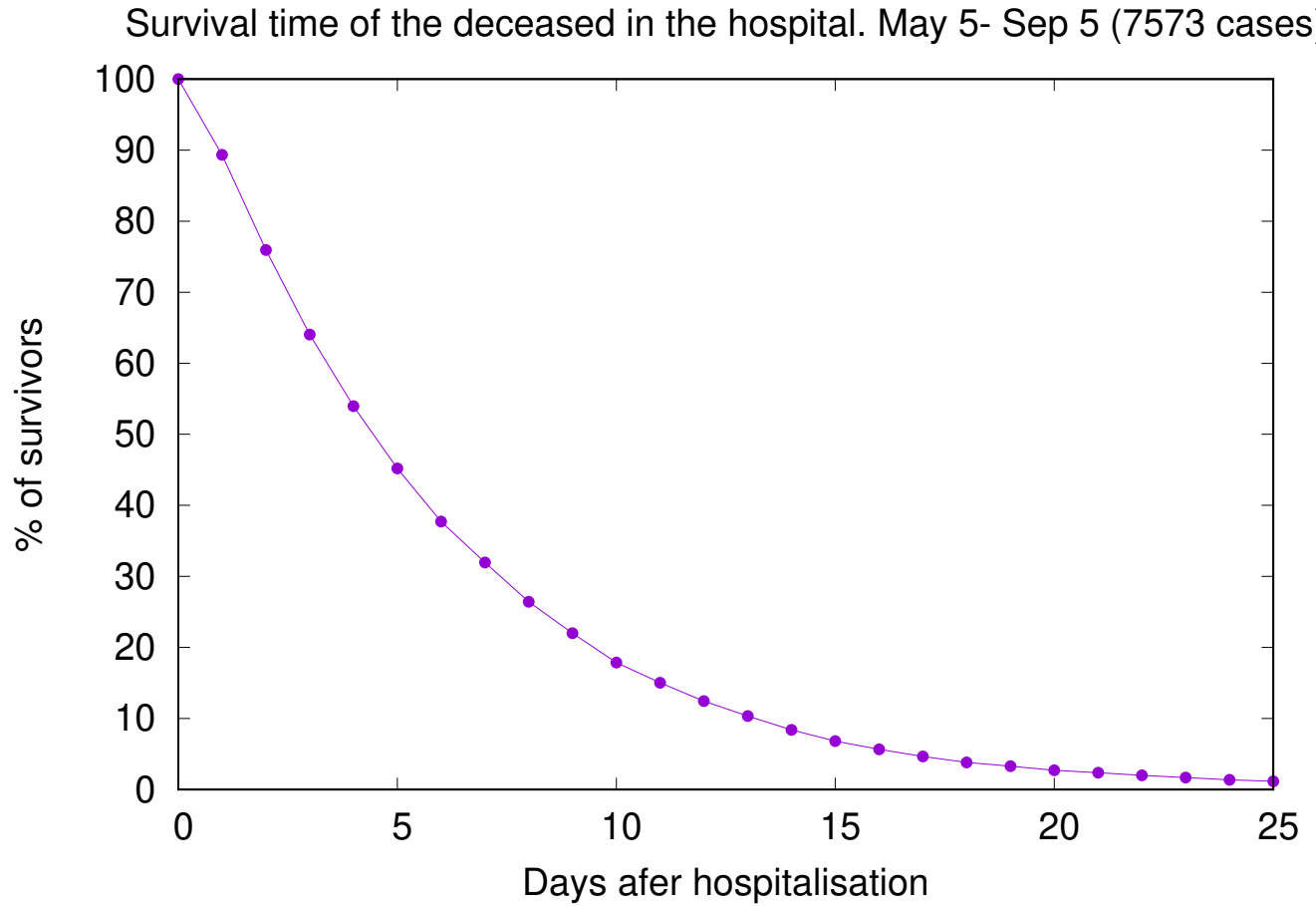
Hospital survival times



The fraction of the deceased patients who *survived* for *n* days after admission to a hospital.
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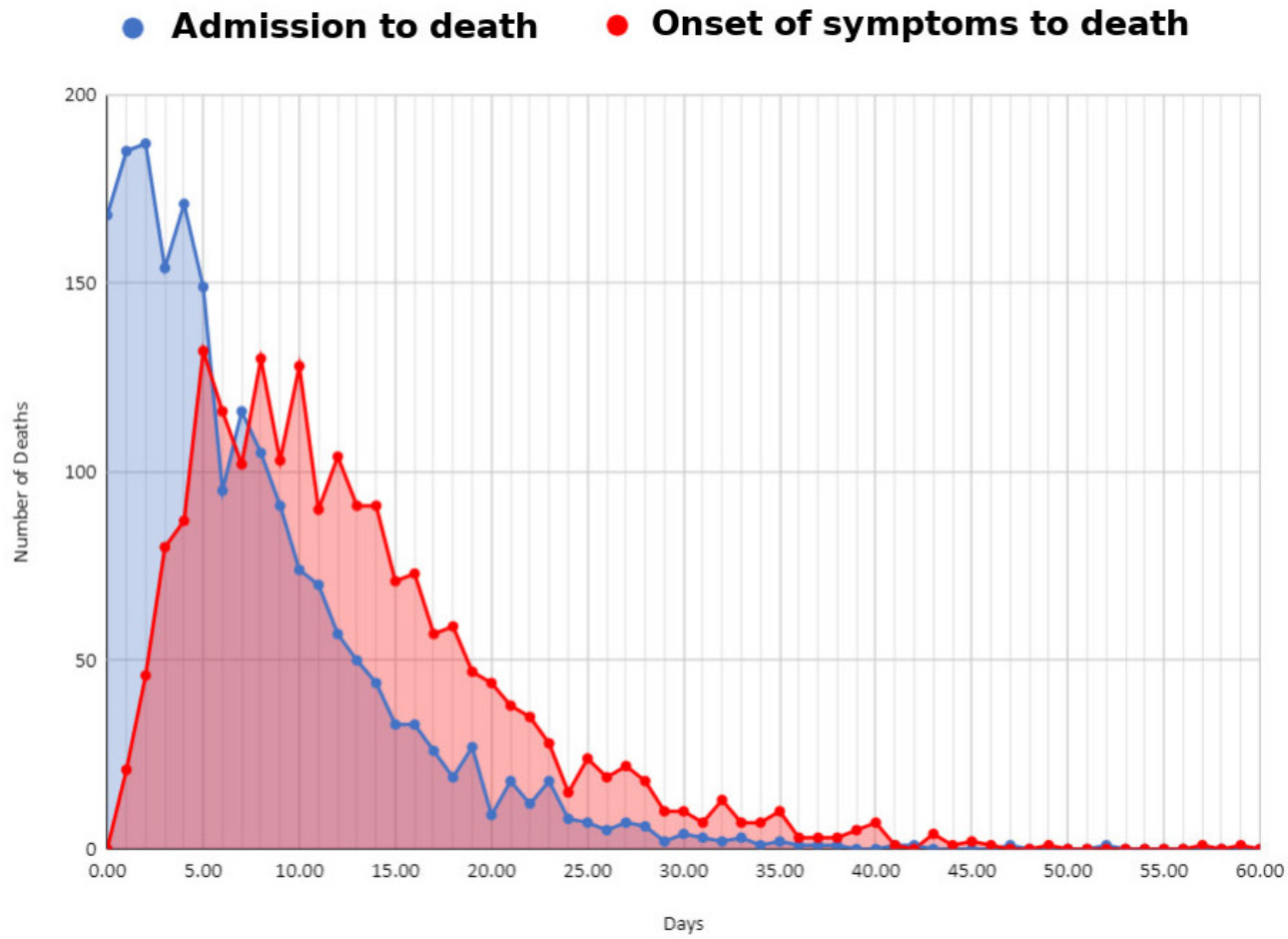
Days from onset of symptoms to death



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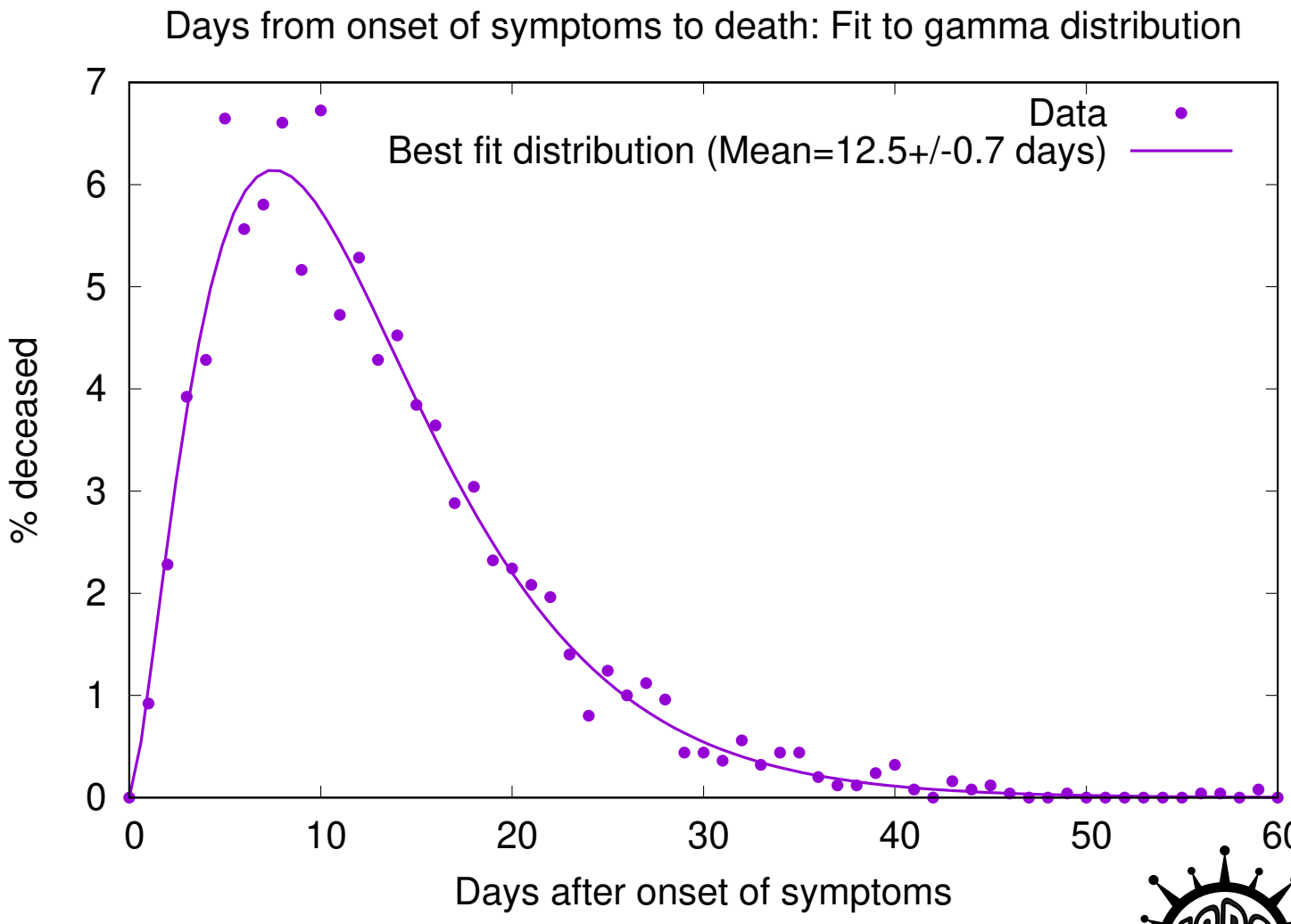
Fit to a Gamma distribution



Click here for technical details

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Discussion of results

- Around 92% of the deaths are reported within 4 days of their occurrence and about 99% within 14 days. (Click here for graph)
- Around 95% of the test results were reported within 4 days. (Click here for graph)
- Around 10% of the patients died within 24 hours of admission. Around 13% between the first and second day. After that the numbers fall day by day. (Click here for graph)
- Only around 50% of the deceased patients survived for more than 5 days after admission to hospital. (Click here for graph)

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Discussion of results (contd.)

- About 25% of the deceased patients died between 5-10 days of the onset of symptoms. (Click here for graph)
- This suggests that many of the patients were admitted to the hospital quite late. This may imply that some fraction may have died before admission.

Outline

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IFR and CFR

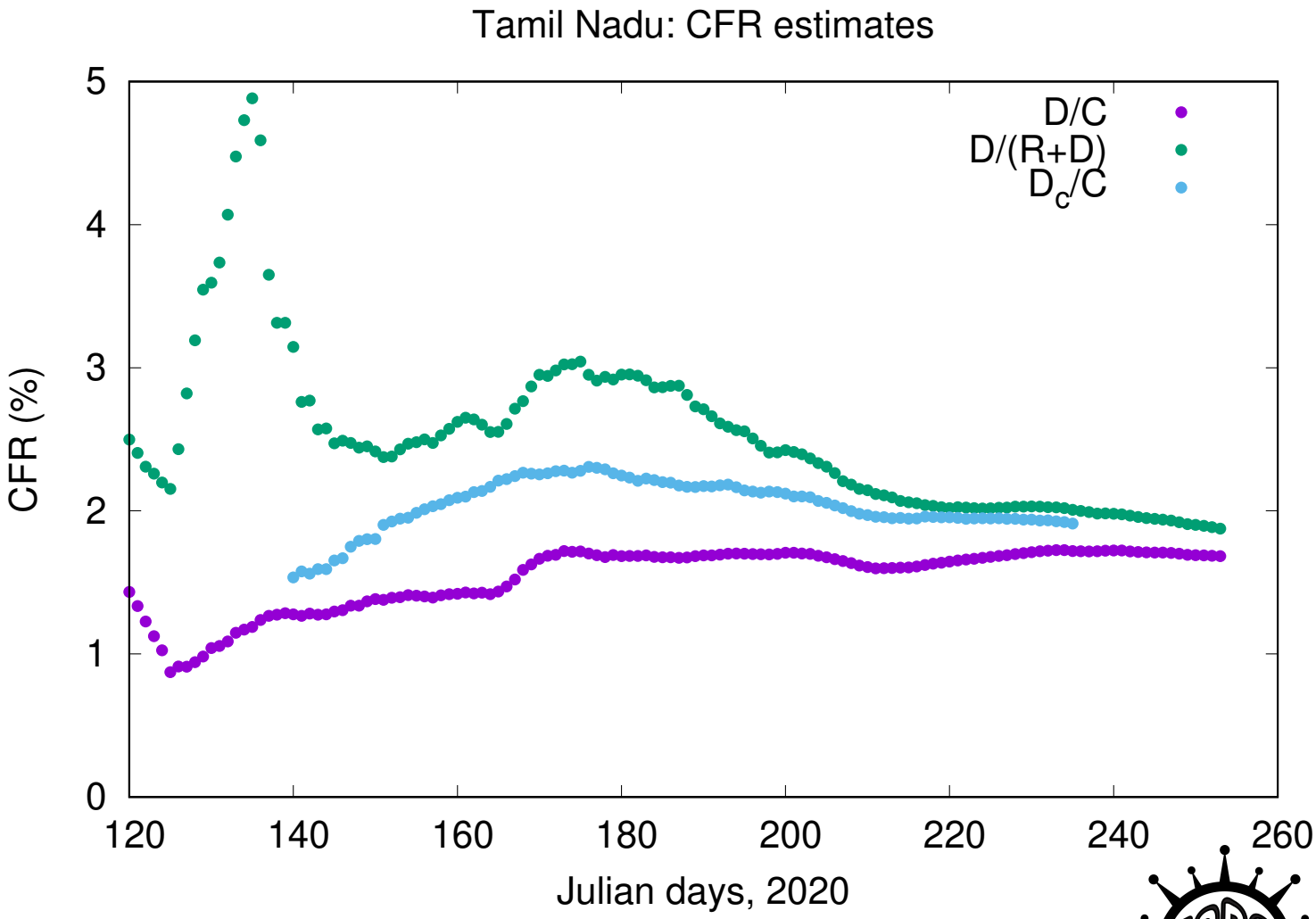
- The ratio of the number of deaths to the total number of actual cases, namely the probability that a person will die if she/he gets infected is called the Infection Fatality Ratio (*IFR*). It is difficult to to measure the *IFR* directly from the data since it is difficult to detect *all* the infected.
- The ratio of the number of deaths to the total number of confirmed cases, namely the probability that a detected case will die, is called the Case Fatality Ratio (*CFR*).

IFR and CFR

- The *CFR* is also difficult to estimate when there are a large number of active cases since their fate is unkown. There are several standard approximate ways to estimate the CFR from the time series of number of detections of the infected, their recoveries and their deaths.
- In addition to the above mentioned data, for Tamil Nadu, we also have data on time the infected who eventually died were detected. Using this data we introduce a more accurate way for the estimation of the CFR, D_c/C.

Click here for the technical details.

CFR estimates using the three methods



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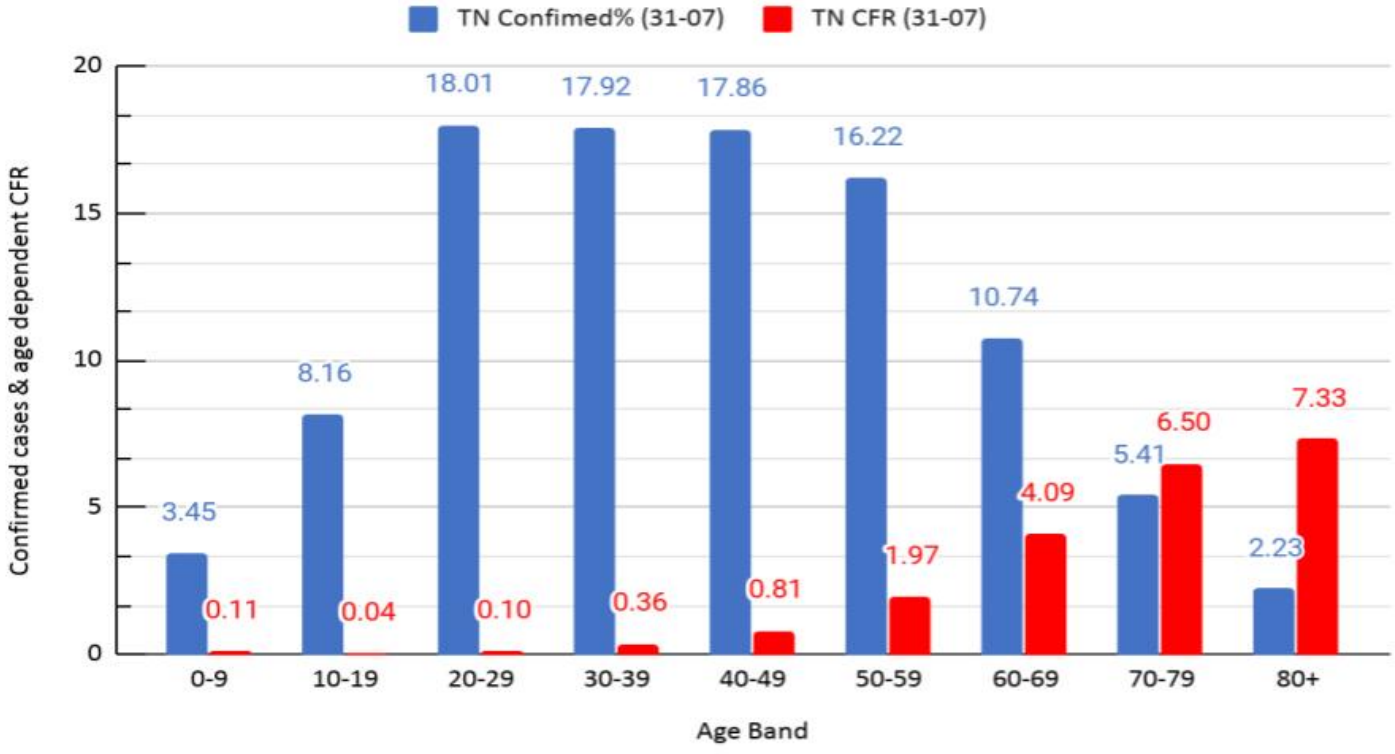
CFR: Age groups (on 31st July, 2020)



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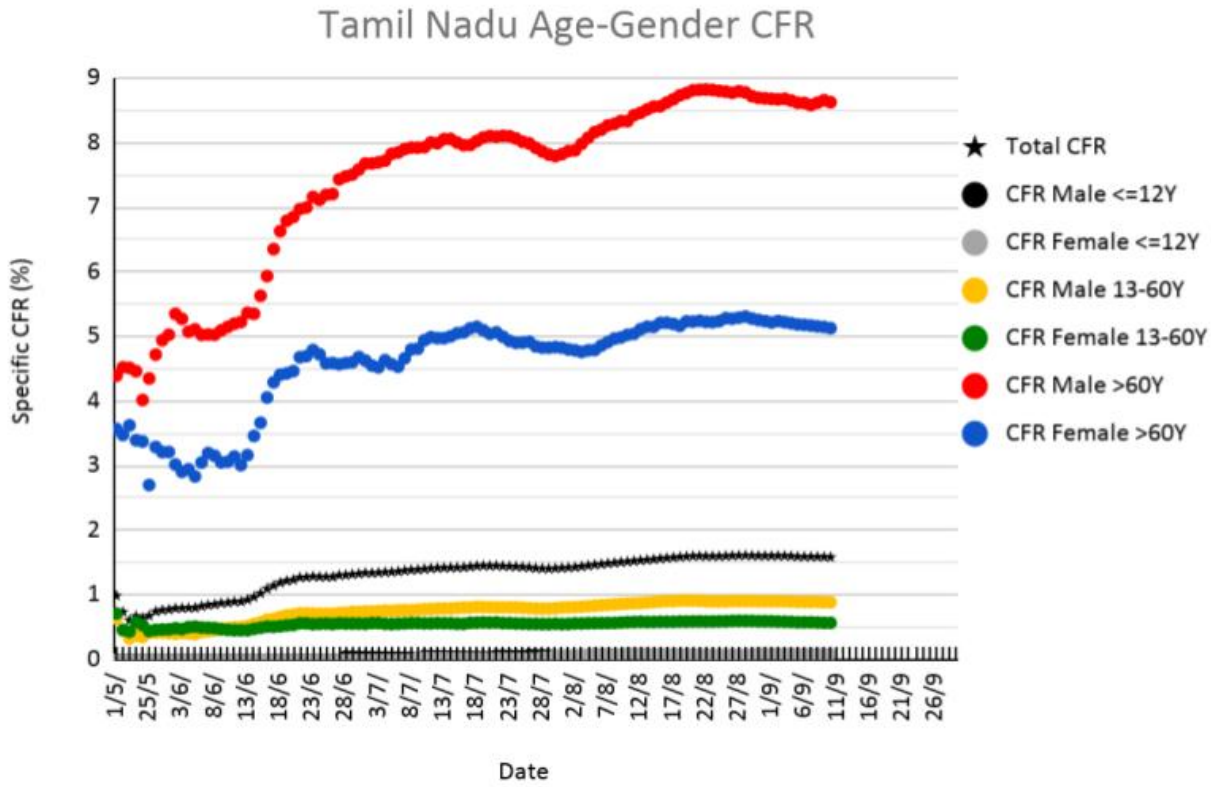
CFR: Gender



These estimates are D/C.

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Discussion of results

- Our estimate of the CFR, $(= D_c/C)$ is more stable than the other two (D/C and $D/(R+D)$), especially in the early stages. It lies between the other two. After the first week of July, it is much closer to $D/(R+D)$.
- The CFR rose to a little more than 2% in the middle of June. After that it has slowly but steadily decreased. On 5^{th} September, it was between 1.7% and 1.9%, probably closer to 1.9%. (Click here for graph)

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Discussion of results (contd.)

- The number of infections peak in the 20-50 age group, the typical age of the actively working population. However, the number of deaths peak in the 50-80 age group, indicating that the active section of the population are more suceptible to infection. However, the elderly are more likely to succumb to the infection. (Click here for graph)
- The CFR steadily increases with age. On 31st July, 2020, the age group (0-9 years) had a CFR of around 0.1% and it rose to around 7.3% for the 80+ age group. (Click here for graph)
- Females have a significantly lower CFR, around 1.5 times less, in all age groups. (Click here for graph)

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Outline

Take away points

- The mortality rate in Tamil Nadu is currently decreasing. From a peak of around 120 deaths per day in the middle of August, it is currently around 80 deaths per day.
- The average time from the onset of symptoms to death was around 12-13 days. However, a significant faction of the patients died within a few days of admission to the hospital. This indicates that a significant fraction of symptomatic patients are admitted late to the hospitals.
- This also suggests that a significant fraction may have died without being admitted to a hospital. The value of the fraction is uncertain. We are currently attempting to get a quantitative estimate of this fraction from the available data.

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Take away points (contd.)

- Age and gender are important prognostic factors for mortality. The risk increases with age. Women are at less risk than men across age groups.
- Associated disease, diabetes, hypertension, ischemic heart disease and renal disorders increase the risk of mortality.

Outline

Distributing the added deaths

On the recommendation of the Death Reconciliation Committee constitued by the Greater Chennai Corporation, 444 extra deaths were added on 22nd July, 2020. The detailed information about these deceased patients is not available to us.
For the purpose of estimating growth rates etc., we have distributed the deaths in the period prior to 22/07/20 as follows:

From 5th May (JD 126) to 29th May (JD 150)	:	Add 5 deaths daily
from 30th (JD 151) t0 21nd July (JD 203)	:	Add 6 deaths daily

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Estimating growth rates

We denote the cumulative number of deaths till time t by $D(t)$
The instantaneous doubling time, $t_d(t)$, and the instantaneous growth rate $\kappa(t)$ are defined by,

$$D(t) = D_0 2^{\frac{t}{t_d(t)}} = D_0 2^{\kappa(t)t}$$

We estimate them from the data by,

1. For every time t, fit a quadratic curve to $log_2(D(t))$ for the 7 days, $t' = t-3, \ldots, t+3$,

   $$log_2 D(t') = log_2 \bar{D} + \kappa(t'-t) + 0.5\kappa_1(t'-t)^2$$

   The best fit value of κ and its uncertainty is the growth rate $\kappa(t)$ and its uncertainty, $\Delta\kappa(t)$.
2. The doubling time, $t_d(t)$, and its uncertainty, $\Delta t_d(t)$ are,

$$t_d(t) = \frac{1}{\kappa(t)} \qquad \Delta t_d(t) = \frac{\Delta\kappa(t)}{\kappa(t)^2}$$

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The distribution of comorbidities

Since diabetes leads to other co-morbidities, any death with diabetes either alone or with other co-morbidities are classified under diabetes. The meaning of the fractions in the chart are as follows:

Diabetes+	Diabetes and possibly other corbidities
Hypertension+	Hypertension without diabetes but possibly other cormbidities
Heart disease+	Heart disease without diabetes and hypertension but possibly other cormbidities
Others	With comorbidities other than the above three
No-Comorbity	Without any comorbidity

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The prevalence of the comorbidities in Tamil Nadu

Sources:

1. Diabetes: The increasing burden of diabetes and variations among the states of India: the Global Burden of Disease Study 1990-2016. Lancet Glob Health 2018; 6: e1352-62
2. Hypertension: Hypertension screening, awareness, treatment, and control in India: A nationally representative cross-sectional study among individuals aged 15 to 49 years. PLoS Med 16(5): e1002801.
3. Heart diseases: Prevalence of coronary heart disease in rural and Urban Vellore: A repeat cross-sectional survey. Indian Heart J. 2016; 68(4); 473-9

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Admission to death times and hospital survival curves

1. For all the deceased patients admitted to a hospital in a 30 day period, $t_1, \ldots, t_1 + 29$, we count the number who died between $m-1$ and m days after admission to hospital, for $m = 1, \ldots, 30$. We denote this number by n_m.
2. The total number of patients admitted during the 30 day period is $N = \sum_{m=0}^{30} n_m$. The fraction of patients who died m days after admission is n_m/N.
3. The fraction of patients who survived for m days after admission is, S_m,

$$S_m = 1 - \frac{1}{N} \sum_{l=1}^{30} n_m$$

4. Less than 0.1% of the patients survived for more that 30 days after admission

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Symptoms onset to death times

In the case of some of the patients, information of when the symptoms were noticed is also given in the daily bulletins. Example:

Death Case No.7376:

A 37 Years old Female from Thiruvallur having COVID-19 RTPCR Positivity on 25.08.2020 admitted on 28.08.2020 at 08.52pm in a private hospital with complaints of Fever,Cough and Diffiuclty in Breathing for 3 days died on 31.08.2020 at 01.15am due to **ARDS /COVID-19 Pneumonia**.

The two graphs plot the data taken from 2498 such reports.

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The Gamma distribution

Denote the fraction of the sample of 2498 patients who died x days after the onset of symptoms by $f(x)$
This data has been fitted to the function,

$$f(x) = a\, x^{\alpha-1} e^{-\beta x}$$

The fitting was done by the least squares method. The best fit values of the parameters obtained were

$$\alpha = 2.52 \pm 0.08, \qquad \beta = 0.201 \pm 0.009\ d^{-1}$$

The mean mumber of days between the onset of symptoms implied by these parameters is 12.7 ± 0.7 days. The median, found directly from the data is 11 days.
The mean is lower than 17.8 ± 0.6 days reported by Verity and others, (Lancet Infect. Dis. 2020, https://doi.org/10.1016/S1473-3099(20)30243-7)

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Estimating the CFR

- At the end of the epidemic, when the number of active cases are very small, the CFR is given by $CFR \equiv D/C = D/(R+D)$.
- During the epidemic, both are inaccurate, since on day t, $CFR(t) = D_c(t)/C(t)$, where $D_c(t)$ are the number of the cases detected by day t who eventually die.
- Since our data shows that more than 90% of the deaths deaths occur within 15 days of detection, $D_c(t-15)$ can be well estimated from the death details. The value CFR two weeks before the current date t is then well estimated by $D_c(t-15)/C(t-15)$.
- All the three estimates will be the same when $A = C - R - D = 0$. The agreement between them will be better, the smaller the value of A/C.

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Age dependent CFR

- The age and gender distribution of the recovered patients are not available. Hence our estimates of the age and gender dependence of the CFR are D/C.
- The Tamil Nadu daily bulletins give a very coarse grained distribution of the age dependence of the detected cases. Only three age groups, 0-12, 13-60 and > 60. However, the Greater Chennai Corporation, in daily tweets gives a more fine grained distribution, at intervals of 10 years.
- This graph assumes that the fine grained distribution detected cases in Chennai is approximately the same as in Tamil Nadu.

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