

# The SARS-CoV-2 infection (COVID-19) era impact on incidence of sudden deaths due to myocardial infarction (Heart Attack) in States and Union Territories of India- A cross-sectional comparative study (2018-2022)

## Abstract

Background-COVID-19 has increased the risk of developing CVD (Cardiovascular Disease). There is a lack of research paper, on the comparative assessment of the incidence of sudden death due to Myocardial Infarction (MI), during COVID-19. This study aimed to quantify this assessment. Another search to start this study is that several studies have reported that COVID-19 vaccine is also associated with myocarditis/cardiomyopathy. Methods and results-This study was based on the NCRB data, Government of India, on sudden death due to MI, between 1 January 2018 and 31 December 2022. The five coastal states of India accounts for majority (70%), of all MI cases related sudden deaths. The base year 2018 was having the least whereas the last year 2022 was having the largest number of MI cases related mortality detected in one individual year. The largest percent change in sudden death due to MI in males is found in 2022, when it increased by 14.26% (is it due to delayed cardiomyopathy due to COVID-19 or Vaccine? This will be a matter of research in coming era). This study revealed that there is 25.80 percent increase in total number of new MI cases related mortality in 2022 in comparison to pre-COVID-19 year 2018. There is an overall increase of 11.24 percent sudden death, due to MI cases in males during the COVID-19 period. The Male sudden death due to MI increased during COVID-19 year 2022 by 26.71 percent in comparison to pre- COVID-19 year 2018. Sudden death due to MI increased in all age groups of male and female during COVID-19.

**Keywords:** COVID-19 • Myocardial infarction • Heart attack • Incidence • Health

**Abbreviations:** COVID-19: Coronavirus Disease-2019; SARS-CoV-2: Severe Acute Respiratory Coronavirus 2; WHO: World Health Organization; PHEIC: Public Health Emergency of International Concern; CVD: Cardiovascular Disease, CCU/ICCU: Intensive Coronary Care Unit; MI: Myocardial Infarction; NCRB: National Crime Records Bureau; UT: Union Territories; NCD: Non-Communicable Disease; MCCD: Medical Certification of Cause of Death

## Introduction

Novel coronavirus disease which emerged in December 2019 (popularly known as COVID-19) is caused by SARS-CoV-2 (severe acute respiratory coronavirus 2) infection in human beings [1]. The COVID-19 is highly communicable disease due to which this disease became pandemic in a very short period affecting several nations worldwide. On 5 May 2023, WHO (World Health Organization) declared end of COVID-19 status (first made a public health emergency of international concern by

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the WHO on 30 January, 2020) of a global health emergency by lifting COVID-19's Public Health Emergency Of International Concern (PHEIC) status [2]. Until 2002 CoVs (Coronavirus) were considered minor pathogens of human being, however the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2002 was linked to a new CoV (SARS-CoV) which primarily causes a respiratory illness [3]. COVID-19 is found to cause a spectrum of multi-organ disease with increased risk of CVDs (cardiovascular diseases) both in the short and long-terms, causing venous thromboembolism, cardiac arrhythmias, myocardial infarction, stroke, and bleeding etc [4]. Hence COVID-19 infections are likely to be associated with worse prognosis in patients suffering from cardiac diseases as well as quality of life will be compromised in such cases by increasing the risk of morbidity and mortality.

Despite of having, several latest cardiovascular drugs, new advanced treatment protocols with CCU/ICCU (Intensive Coronary Care Unit), several decades of research like ongoing longitudinal cohort study of Framingham (ongoing cardiovascular study of residents of the city of Framingham, Massachusetts), as well as various population based strategies to prevent and control mortality/morbidity due to MI (myocardial infarction-popularly known as Heart Attack), global improvement against Cardiovascular Disease (CVD) is flat-lining [5]. Globally CVD are the leading cause of mortality and disability, in India during year 2017, it was responsible for 26.6% (25.3%-27.4%) of total mortality and 13.6% (12.5%-14.6%) of total Disability Adjusted Life Years (DALYs), compared with 15.2% (13.7-16.2) and 6.9% (6.3-7.4), respectively, in 1990 [6]. 17.9 million people died in 2019 from CVDs, accounting for 32% of all global mortality and out of this 85% deaths were due to heart attack and stroke [7]. coronavirus disease 2019 (COVID-19) patients have an elevated risk of death after infection is demonstrated by several research studies [8]. In studies conducted earlier during severe acute respiratory syndrome coronavirus 2 (SARS) and Middle East Respiratory Syndrome related coronavirus (MERS) epidemics and also during the recent COVID-19 pandemic, it is found that cardiac damage can be caused by multiple mechanisms [9]. COVID-19 affects the cardiovascular system leading to myocardial damage and dysfunction mainly *via* (ACE-2) the Angiotensin-converting enzyme 2 receptor [10-13]. Another fact is that practically it seems impossible to eradicate COVID-19 forever like its predecessors and of course sequel of its infection.

Another search to start this study is that several studies have reported COVID-19 vaccine-associated myocarditis/cardiomyopathy, in particular with mRNA vaccination (BNT162b2 and mRNA-1273) [14]. The incidence of myocarditis following vaccination is about 10 per 100,000 affecting mostly males of 16-30 years age [15]. However, the long-term complications from the resultant myocarditis/cardiomyopathy following vaccination requiring

medical support, is noteworthy.

Hence we must timely evolve treatment protocol to protect the global population from the morbidity and mortality hazards erupting due to wide spectrum of presentation as well as involvement of multiple organs of human body by COVID-19. The cardiovascular complications of acute COVID-19 are well described in several research studies, but the mortality incidence due to myocardial infarction during COVID-19 era have not yet been comprehensively evaluated, compared (with pre COVID-19 era) or characterized in research studies. A comprehensive comparative assessment of mortality due to MI (myocardial infarction) before and during COVID-19 is not yet available. This research study is an attempt to address this knowledge gap in order to alert policy and decision makers to develop post- COVID-19 cardiovascular care strategies. Till date no nationwide comparative studies are published on this aspect of COVID-19, which includes MI related sudden death registered in the country during COVID-19 era from a nationalized accredited data source. There are studies done in other countries related to this topic [16].

### Objective

As discussed above the COVID-19 increased the risk of CVDs. There is lack of availability of research papers on comparison of sudden death due to MI during and before COVID-19. Hence, we aimed to quantify the incidence of sudden death due to MI during and before COVID-19.

### Materials and Methods

This study aimed to assess the impact of COVID-19 era on annual incidence (new cases number only) of mortality due to MI in different states and Union Territories (UT) of India. This study is cross-sectional, quantitative, and retrospective in nature. We included all individual states and UTs of India. The first case of COVID-19 infection in India was notified in January 2020 [17]. Hence this study considered the period before 1<sup>st</sup> January 2020 as pre COVID-19 era and from 1<sup>st</sup> of January 2020 till 5 May 2023 as COVID-19 era, in the light of above mentioned WHO declaration, although the new COVID-19 cases reduced from 2022, it is important to evaluate long term impact of COVID-19 [18]. For this study we collected the data from NCRB (National Crime Records Bureau) platform of Government of India, which is highly accredited nationalized data source. The annual MI related mortality incidence (new cases) from the states and UTs of India were collected for this novel study. This study was based on NCRB data of all individuals who died suddenly due to MI in different states and Union Territories (UT) of India between 1 January 2018 and 31 December 2022.

This study considered MI related sudden death incidence (new cases) in males and females between 1 January 2018 and 31

December 2022, which is obtained from NCRB (National Crime Records Bureau), Government of India. Mean and percentage change in number of MI related sudden death during the COVID-19 period will be compared to pre-pandemic period for this study purpose.

**Data sources**

The data source is available at the link given below:

<https://ncrb.gov.in/>

The data for this study is collected, cleaned and analyzed with Microsoft office and stata software. From the huge dataset of NCRB, we have separated the data needed for this study, which is presented in (Tables 1A-1E).

West Bengal	48	6	0	54
A & N islands	18	3	0	21
Chandigarh	23	1	0	24
D & n Haveli and daman & Diu	30	2	0	32
Delhi (Ut)	293	35	0	328
Jammu & Kashmir	43	12	0	55
Lakshadweep	3	0	0	3
Puducherry	36	7	0	43
Ladakh	3	1	0	4
Total (All India)	28005	4402	3	32410

**Table 1A:** Sudden death due to Myocardial Infarction in states and union territories of India during 2022.

State/UT	Male-sudden deaths (heart attack)-2022	Female-sudden deaths (heart attack)-2022	Trans-gender-sudden deaths (heart attack)-2022	Total-sudden deaths (heart attack)-2022
Andhra Pradesh	162	14	0	176
Arunachal Pradesh	23	1	0	24
Assam	29	4	0	33
Bihar	90	39	0	129
Chhattisgarh	389	79	0	468
Goa	32	7	0	39
Gujarat	2529	324	0	2853
Haryana	1080	104	0	1184
Himachal Pradesh	315	32	0	347
Jharkhand	148	23	0	171
Karnataka	1814	256	0	2070
Kerala	3374	619	0	3993
Madhya Pradesh	1477	195	0	1672
Maharashtra	10699	1890	2	12591
Manipur	43	0	0	43
Meghalaya	20	1	0	21
Mizoram	56	1	0	57
Nagaland	0	0	0	0
Odisha	438	63	0	501
Punjab	833	75	0	908
Rajasthan	1238	184	0	1422
Sikkim	19	2	0	21
Tamil Nadu	1435	194	1	1630
Telangana	257	27	0	284
Tripura	82	22	0	104
Uttar Pradesh	654	112	0	766
Uttarakhand	272	67	0	339

**Table 1B:** Sudden death due to Myocardial Infarction in states and union territories of India during 2021.

State/UT	Male-sudden deaths (heart attack)-2021	Female-sudden deaths (heart attack)-2021	Trans-gender-sudden deaths (heart attack)-2021	Total-sudden deaths (heart attack)-2021
Andhra Pradesh	85	12	0	97
Arunachal Pradesh	9	0	0	9
Assam	23	2	0	25
Bihar	103	28	0	131
Chhattisgarh	359	65	0	424
Goa	9	1	0	10
Gujarat	2611	337	0	2948
Haryana	1062	97	0	1159
Himachal Pradesh	313	24	0	337
Jharkhand	128	24	0	152
Karnataka	1551	204	0	1755
Kerala	3231	640	1	3872
Madhya Pradesh	1378	209	1	1588
Maharashtra	8833	1655	1	10489
Manipur	20	0	0	20
Meghalaya	19	1	0	20
Mizoram	40	7	0	47
Nagaland	0	0	0	0
Odisha	307	73	0	380
Punjab	867	84	0	951
Rajasthan	1060	149	0	1209
Sikkim	12	0	0	12
Tamil Nadu	1146	128	0	1274
Telangana	280	27	0	307
Tripura	77	22	0	99
Uttar Pradesh	440	66	0	506
Uttarakhand	161	16	0	177
West Bengal	0	0	0	0

A & N islands	18	3	0	21
Chandigarh	35	5	0	40
D & N Haveli and daman & Diu	29	2	0	31
Delhi (Ut)	255	47	0	302
Jammu & Kashmir	31	1	0	32
Lakshadweep	2	0	0	2
Puducherry	16	7	0	23
Ladakh	0	0	0	0
Total (All India)	24510	3936	3	28449

**Table 1C:** Sudden death due to myocardial infarction in states and union territories of India during 2020.

State/UT	Male-sudden deaths (heart attack)-2020	Female-sudden deaths (heart attack)-2020	Trans-gender-sudden deaths (heart attack)-2020	Total-sudden deaths (heart attack)-2020
Andhra Pradesh	92	5	0	97
Arunachal Pradesh	2	1	0	3
Assam	18	5	0	23
Bihar	96	29	0	125
Chhattisgarh	392	65	0	457
Goa	48	6	0	54
Gujarat	2315	264	0	2579
Haryana	1011	97	0	1108
Himachal Pradesh	310	34	0	344
Jharkhand	202	26	0	228
Karnataka	2084	349	1	2434
Kerala	2867	598	0	3465
Madhya Pradesh	1483	262	0	1745
Maharashtra	9491	1987	0	11478
Manipur	16	1	0	17
Meghalaya	13	1	0	14
Mizoram	10	3	0	13
Nagaland	0	0	0	0
Odisha	249	77	0	326
Punjab	728	81	0	809
Rajasthan	744	130	0	874
Sikkim	9	0	0	9
Tamil Nadu	1005	117	0	1122
Telangana	234	28	0	262
Tripura	103	22	0	125
Uttar Pradesh	218	60	0	278
Uttarakhand	146	16	0	162
West Bengal	0	0	0	0
A & N islands	20	5	0	25

Chandigarh	96	19	0	115
D & N Haveli and daman & Diu	19	0	0	19
Delhi (Ut)	229	38	1	268
Jammu & Kashmir	32	1	0	33
Lakshadweep	2	0	0	2
Puducherry	59	8	0	67
Ladakh	0	0	0	0
Total (All India)	24343	4335	2	28680

**Table 1D:** Sudden death due to Myocardial Infarction in states and union territories of India during 2019.

State/UT	Male-sudden deaths (heart attack)-2019	Female-sudden deaths (heart attack)-2019	Trans-gender-sudden deaths (heart attack)-2019	Total-sudden deaths (heart attack)-2019
Andhra Pradesh	80	7	0	87
Arunachal Pradesh	6	1	0	7
Assam	34	3	0	37
Bihar	122	43	0	165
Chhattisgarh	398	103	0	501
Goa	42	3	0	45
Gujarat	2594	294	0	2888
Haryana	943	71	0	1014
Himachal Pradesh	258	24	0	282
Jharkhand	252	74	0	326
Karnataka	1376	177	1	1554
Kerala	2537	540	0	3077
Madhya Pradesh	1524	202	0	1726
Maharashtra	9342	1944	0	11286
Manipur	34	6	0	40
Meghalaya	10	4	0	14
Mizoram	15	0	0	15
Nagaland	2	0	0	2
Odisha	287	46	0	333
Punjab	856	85	1	942
Rajasthan	857	94	0	951
Sikkim	11	3	0	14
Tamil Nadu	1137	139	1	1277
Telangana	211	26	0	237
Tripura	102	24	0	126
Uttar Pradesh	404	49	0	453
Uttarakhand	165	23	0	188
West Bengal	0	0	0	0
A & N islands	33	8	0	41
Chandigarh	45	9	0	54

D & n Haveli and daman & Diu	27	1	0	28
Delhi (Ut)	129	30	0	159
Jammu & Kashmir	52	3	0	55
Lakshadweep	0	0	0	0
Puducherry	75	6	0	81
Ladakh				
Total (All India)	23960	4042	3	28005

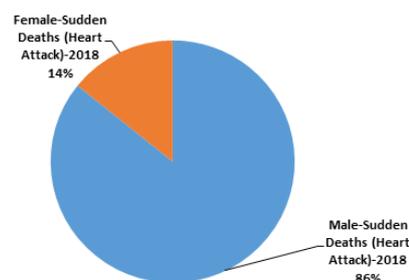
Lakshadweep	0	0	0	0
Puducherry	72	15	0	87
Ladakh				
Total (All India)	22101	3663	0	25764

**Table 1E:** Sudden death due to Myocardial Infarction in states and union territories of India during 2018.

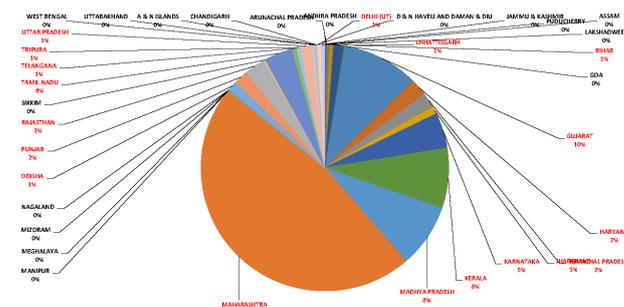
State/UT	Male-sudden deaths (heart attack)-2018	Female-sudden deaths (heart attack)-2018	Trans-gender-sudden deaths (heart attack)-2018	Total-sudden deaths (heart attack)-2018
Andhra Pradesh	67	9	0	76
Arunachal Pradesh	3	0	0	3
Assam	49	13	0	62
Bihar	132	19	0	151
Chhattisgarh	273	49	0	322
Goa	33	5	0	38
Gujarat	2838	368	0	3206
Haryana	927	80	0	1007
Himachal Pradesh	247	73	0	320
Jharkhand	142	35	0	177
Karnataka	1423	170	0	1593
Kerala	1767	290	0	2057
Madhya Pradesh	1624	305	0	1929
Maharashtra	8671	1724	0	10395
Manipur	18	2	0	20
Meghalaya	3	2	0	5
Mizoram	10	2	0	12
Nagaland	2	0	0	2
Odisha	284	50	0	334
Punjab	674	66	0	740
Rajasthan	808	102	0	910
Sikkim	24	6	0	30
Tamil Nadu	1006	137	0	1143
Telangana	191	21	0	212
Tripura	91	19	0	110
Uttar Pradesh	388	54	0	442
Uttarakhand	85	17	0	102
West Bengal	0	0	0	0
A & N islands	41	4	0	45
Chandigarh	18	3	0	21
D & n Haveli and daman & Diu	14	1	0	15
Delhi (Ut)	141	20	0	161
Jammu & Kashmir	35	2	0	37

**Results**

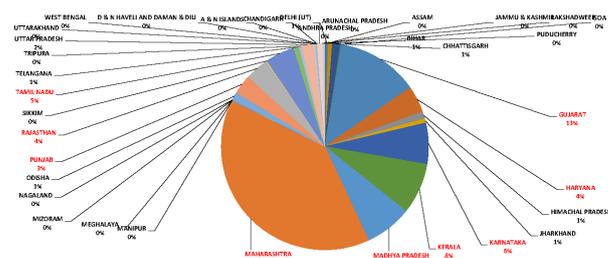
Sudden death due to Myocardial Infarction in 2018: During the base year 2018 of this study (pre- COVID-19 era) total numbers of MI cases related sudden death were 25,764, out of which 22,101(85.78%) were males and 3663(14.22%) were females (Figure 1A). Figures 1B and 1C shows the state wise percentage share of female and male MI cases related sudden death in 2018. During the base year 2018 of this study the female sudden deaths caused by MI were mostly in Maharashtra (47%), Gujarat (10%), Kerala (8%), Madhya Pradesh (8%), Karnataka (5%), Tamil Nadu (4%), and Rajasthan (3%). Out of the above 7 states except Madhya Pradesh and Rajasthan all other 5 are coastal states accounting for 74% of all MI cases related sudden death in 2018.



**Figure 1A:** Percentage of male and female sudden death in 2018 due to MI. Note: (■): Male sudden deaths; (■): Female sudden deaths.



**Figure 1B:** Shows the state wise percentage share of female MI cases related sudden death in 2018. Note: \*less than 1 % is marked as 0%



**Figure 1C:** The state wise percentage share of male MI cases related sudden death in 2018.

During the year 2018 the male sudden deaths caused by MI were mostly in Maharashtra (39%), Gujarat (13%), Kerala (8%), Madhya Pradesh (7%), Karnataka (6%), Tamil Nadu (5%), and Rajasthan (4%). Out of the above 7 states except Madhya Pradesh and Rajasthan all other 5 are coastal states accounting for 71% of all MI cases related sudden death in 2018. Is this an impact of geographical location like the one seen in COVID-19 mortality incidence in coastal states and UTs of India [19]? Further study and research is needed to correlate the incidence of MI death and COVID-19 incidence in coastal states and UTs of India as the above referenced study found that the total numbers of death from COVID-19 is highest in coastal states and union territories of India.

**Sudden death due to myocardial infarction in 2019**

In the year 2019 (pre-COVID-19 era) total numbers of MI cases related sudden death were 28,005, out of which 23,960 (85.57%) were males and 4,042 (14.43%) were females, and 3 transgender (Figure 2A). The data on transgender is very less hence not taken for evaluation.

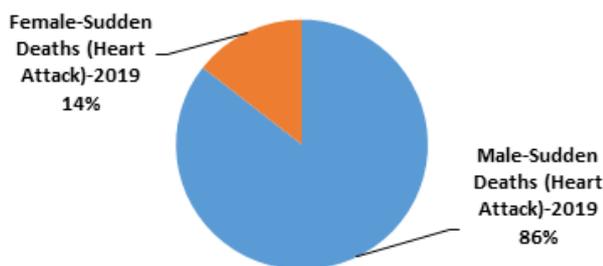


Figure 2A: Percentage of male and female sudden death in 2019 due to MI.

Figures 2B and 2C shows the state wise percentage share of female and male MI cases related sudden death in 2019. Like the previous year, during the year 2019 of this study the female sudden deaths caused by MI were mostly in Maharashtra (48%), Gujarat (7%), Kerala (13%), Madhya Pradesh (5%), Karnataka (4%), Tamil Nadu (3%), Punjab (2%) and Rajasthan (2%). Out of the above 8 states except Madhya Pradesh and Rajasthan, Punjab all other 5 are coastal states accounting for 75% of all MI cases related sudden death in 2019. The coastal states mentioned above have shown a similar trend like previous year 2018.

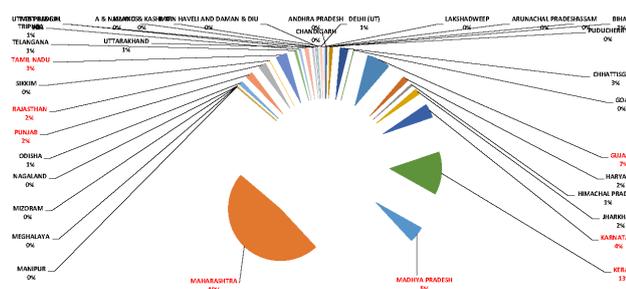


Figure 2B: State wise percentage share of female MI cases related sudden death in 2019.

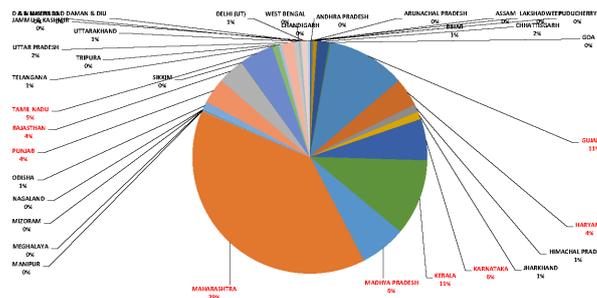


Figure 2C: The state wise percentage share of male MI cases related sudden death in 2019..

During the year 2019 the male sudden deaths caused by MI were found mostly in Maharashtra (39%), Gujarat (11%), Kerala (11%), Madhya Pradesh (6%), Karnataka (6%), Tamil Nadu (5%), Haryana (4%), Punjab (4%) and Rajasthan (4%). Out of the above 9 states the 5 coastal states accounts for 72% of all MI cases related sudden death in 2019.

**Sudden death due to myocardial infarction in 2020**

In the year 2020 (COVID-19 era) total numbers of MI cases related sudden death were 28,680, out of which 24,343(84.88%) were males and 4,335(15.12%) were females, and 2 transgender (Figure 3A). The data on transgender is very less hence not taken for evaluation.

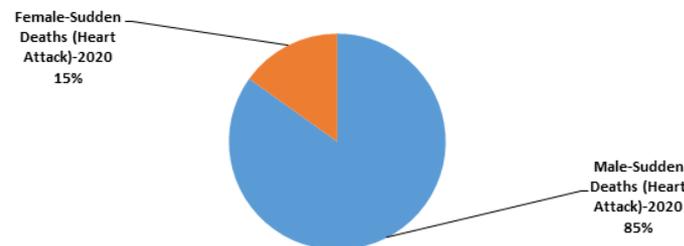


Figure 3A: Percentage of male and female sudden death in 2020 due to MI.

Figures 3B and 3C shows the state wise percentage of female and male sudden death due to MI cases in 2020. Like the previous year, during the year 2020 (COVID-19 era) of this study the female sudden deaths caused by MI were mostly in Maharashtra (46%), Gujarat (6%), Kerala (14%), Madhya Pradesh (6%), Karnataka (8%), Tamil Nadu (3%), Punjab (2%), Odisha (2%) and Rajasthan (3%). Out of the above 9 states except 5 are coastal states accounting for 77% of all MI cases related sudden death in 2020. The coastal states mentioned above have shown a similar trend like previous years 2018 and 2019. One study also found that the coastal states and UTs of India had largest incidence of COVID-19 and related mortality as compared to other geographical locations of India [20]. This study revealed that the Coastal states are also having more incidence of MI cases related sudden death compared to other geographical locations of India, this may be correlated with largest incidence of COVID-19 in coastal states. During the year 2020 (COVID-19 era) the male

sudden deaths caused by MI were found mostly in Maharashtra (39%), Gujarat (10%), Kerala (12%), Madhya Pradesh (6%), Karnataka (9%), Tamil Nadu (4%), Haryana (4%), Punjab (3%) and Rajasthan (3%). Out of the above 9 states the 5 coastal states accounts for 74% of all MI cases related sudden death in 2020.

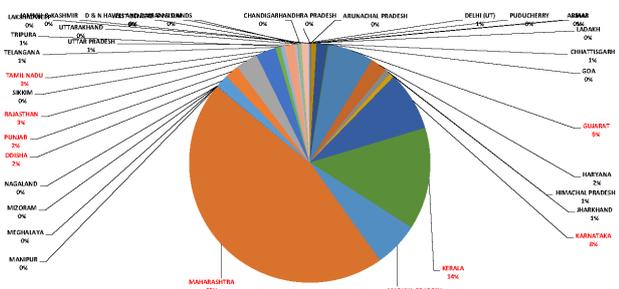


Figure 3B: state wise percentage share of female MI cases related sudden death in 2020.

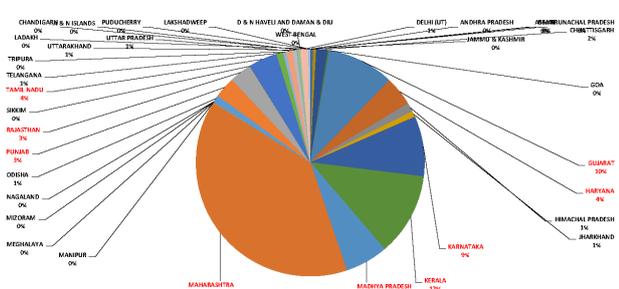


Figure 3C: The state wise percentage share of male MI cases related sudden death in 2020.

**Sudden death due to myocardial infarction in 2021 Data sources**

In the year 2021 (COVID-19 era) total numbers of MI cases related sudden death were 28,449, out of which 24,510 (86.16%) were males and 3,936 (13.84%) were females, and 3 transgender (Figure 4A). The data on transgender is very less hence not taken for evaluation. Figures 4B and 4C shows the state wise percentage of female and male sudden death due to MI cases in 2021. In the year 2021 (COVID-19 era) of this study the female sudden deaths caused by MI were mostly in Maharashtra (42%), Kerala (16%), Gujarat (9%), Madhya Pradesh (5%), Karnataka (5%), Tamil Nadu (3%), Punjab (2%), Odisha (2%), Uttar Pradesh (2%), Chhattisgarh (2%), Haryana (2%), and Rajasthan (4%). Out of the above 12 states 5 are coastal states accounting for 75% of all MI cases related sudden death in 2021. The coastal states mentioned above have shown a similar trend like previous years 2020. During the year 2021 (COVID-19 era) the male sudden deaths caused by MI were found mostly in Maharashtra (36%), Gujarat (11%), Kerala (13%), Madhya Pradesh (6%), Karnataka (6%), Tamil Nadu (5%), Haryana (4%), Punjab (4%), Uttar Pradesh (2%), and Rajasthan (4%). Out of the above 10 states the 5 coastal states accounts for 71% of all MI cases related sudden death in 2021.

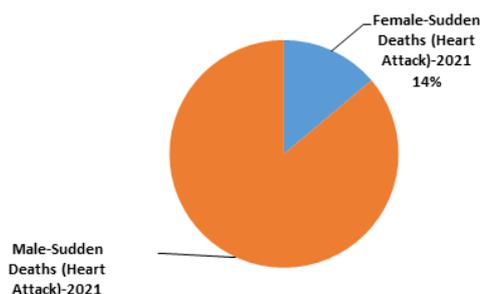


Figure 4A: Percentage of male and female sudden death in 2021 due to MI.

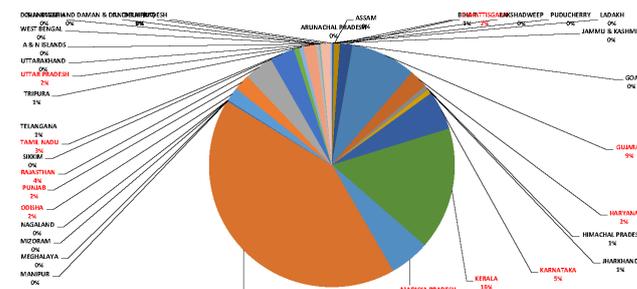


Figure 4B: State wise percentage share of female MI cases related sudden death in 2021.

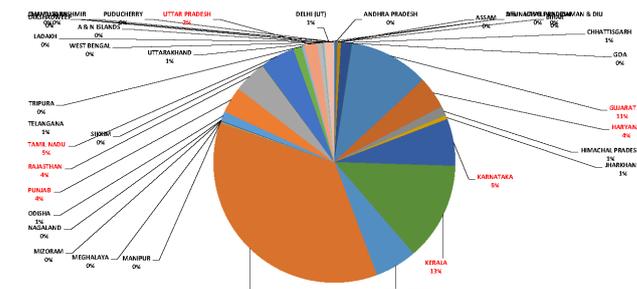


Figure 4C: The state wise percentage share of male MI cases related sudden death in 2021.

**Sudden death due to myocardial infarction in 2022**

In the year 2022 (COVID-19 era) total numbers of MI cases related sudden death were 32,410, out of which 28,005 (86.42%) were males and 4,402 (13.58%) were females, and 3 transgender (Figure 5A). The data on transgender is very less hence not taken for evaluation.

Figures 5B and 5C shows the state wise percentage of female and male sudden death due to MI cases in 2022. In the year 2022 (COVID-19 era) of this study the female sudden deaths caused by MI were mostly in Maharashtra (43%), Kerala (14%), Gujarat (7%), Madhya Pradesh (4%), Karnataka (6%), Tamil Nadu (4%), Punjab (2%), Uttar Pradesh (3%), Uttarakhand (2%), Chhattisgarh (2%), Haryana (2%), and Rajasthan (4%). Out of the above 12 states 5 are coastal states accounting for 70% of all MI cases related sudden death in 2022. The coastal states mentioned above have shown a similar trend like previous years 2021. During the year 2022 (COVID-19 era) the male sudden deaths caused by MI were found mostly in Maharashtra (38%), Gujarat (9%),

Kerala (12%), Madhya Pradesh (5%), Karnataka (6%), Tamil Nadu (5%), Haryana (4%), Punjab (3%), Odisha (2%), Uttar Pradesh (2%), and Rajasthan (4%). Out of the above 10 states the 5 coastal states accounts for 70% of all MI cases related sudden death in 2022.

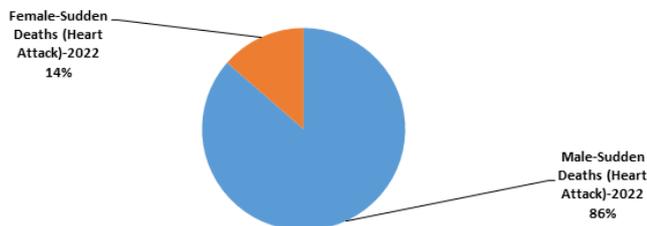


Figure 5A: Percentage of male and female sudden death in 2022 due to MI.

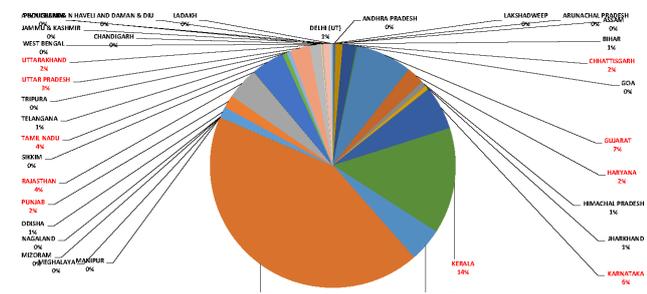


Figure 5B: State wise percentage share of female MI cases related sudden death in 2022.

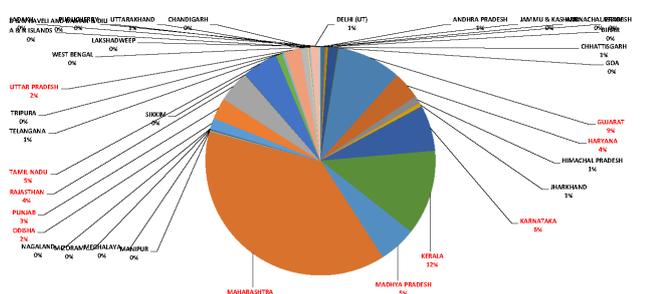


Figure 5C: The state wise percentage share of male MI cases related sudden death in 2022.

The total number of MI cases related sudden death during the study period i.e. from 1<sup>st</sup> January 2018 to 31<sup>st</sup> December 2022 is 1, 43,308, obtained by adding individual new MI cases related mortality detected by the states and UTs of India. The transgener data is not evaluated due to fewer amounts of data.

Table 2 elaborates the percent change in sudden death due to MI in males and females in comparison to previous year among various States and UTs of India. The percent change in total sudden death due to MI in males is never negative (indicates that it is continuously increasing) during the study period but in case of females it was negative (indicates that it reduced in 2021) in 2021 compared to 2020. The individual state and UTs percent change in sudden death due to MI in males and females is clearly elaborated,

and we are not discussing it in details to reduce the length of this article. The largest and noteworthy percent change in sudden death due to MI in males is found in 2022 when it increased by 14.26% (is it due to delayed cardiomyopathy due to COVID-19 or its due to Vaccine? This will be a matter of research in coming era). The largest and noteworthy percent change in sudden death due to MI in females is also seen in 2022 when it increased by 11.84%.

**COVID-19 period comparison with pre-COVID-19 era**

The annual number of total new MI cases related mortality detected by the states and UTs of India, during a year i.e. 1<sup>st</sup> January to end i.e. 31<sup>st</sup> December is 25,764; 28,005; 28,680; 28,449 and 32,410; for years 2018, 2019, 2020, 2021, and 2022 respectively. The annual number of total new MI cases related mortality detected during the pre-COVID-19 as well as in COVID-19 period have similar increasing trends separately except a slight fall in 2021. The base year 2018 is having least whereas the last year 2022 is having the largest number of total new MI cases related mortality detected in one individual year.

Table 3, Comparison of mean mortality in males due to MI during COVID-19 period and pre- COVID-19 period with percentage change in COVID-19 period compared to pre COVID-19 period.

This study revealed that there is 25.80 percent increase in total number of new MI cases related mortality in 2022 in comparison to pre-COVID-19 year of 2018. The mean of total number of MI cases related sudden death during pre-COVID-19 period (2018-2019) is 26,884.5 whereas during the COVID-19 period (2020-2022) it increased to 29846.33. There is an overall increase of 11.02 percent in new MI cases related mortality during the COVID-19 period.

Table 3, shows the comparison of mean sudden death in males due to MI during COVID-19 period and pre- COVID-19 period with percentage change in COVID-19 period compared to pre COVID-19 period, in different states and UTs of India (Figures 6A and 6B). The total number of new MI cases related mortality in males during the study period is 1, 22,919, obtained by adding individual new MI cases related mortality detected by the states and UTs of India. The mean number of total new MI cases related mortality in males during pre-COVID-19 period (2018-2019) is 23,030.5 whereas during the COVID-19 period (2020-2022) it increased to 25619.33 (Figures 6A and 6B).

There is an overall increase of 11.24 percent in sudden death due to MI cases in males during the COVID-19 period, (Figures 6A-6B). The finding of this study is that the total number of Male-Sudden death due to Myocardial Infarction cases detected increased continuously during pre-COVID-19 years and during COVID-19 years.

**Table 2:** Percent change in sudden death due to MI in males and females in comparison to previous year.

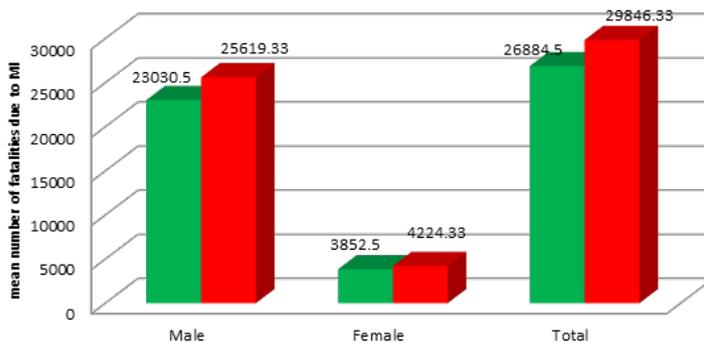
State/UT	Male-percent change in sudden death due to mi in 2022 compared to 2021	Male-percent change in sudden death due to mi in 2021 compared to 2020	Male-percent change in sudden death due to mi in 2020 compared to 2019	Male-percent change in sudden death due to mi in 2019 compared to 2018	Percent change in female sudden death due to MI in 2022 compared to 2021	Percent change in female sudden death due to MI in 2021 compared to 2020	Percent change in female sudden death due to MI in 2020 compared to 2019	Percent change in female sudden death due to MI in 2019 compared to 2018
Andhra Pradesh	90.59	-7.61*	15	19.4	16.67	140	-28.57	-22.22
Arunachal Pradesh	155.56	350	-66.67	100	NA**	-100	0	NA
Assam	26.09	27.78	-47.06	-30.61	100	-60	66.67	-76.92
Bihar	-12.62	7.29	-21.31	-7.58	39.29	-3.45	-32.56	126.32
Chhattisgarh	8.36	-8.42	-1.51	45.79	21.54	0	-36.89	110.2
Goa	255.56	-81.25	14.29	27.27	600	-83.33	100	-40
Gujarat	-3.14	12.79	-10.76	-8.6	-3.86	27.65	-10.2	-20.11
Haryana	1.69	5.04	7.21	1.73	7.22	0	36.62	-11.25
Himachal Pradesh	0.64	0.97	20.16	4.45	33.33	-29.41	41.67	-67.12
Jharkhand	15.63	-36.63	-19.84	77.46	-4.17	-7.69	-64.86	111.43
Karnataka	16.96	-25.58	51.45	-3.3	25.49	-41.55	97.18	4.12
Kerala	4.43	12.7	13.01	43.58	-3.28	7.02	10.74	86.21
Madhya Pradesh	7.18	-7.08	-2.69	-6.16	-6.7	-20.23	29.7	-33.77
Maharashtra	21.13	-6.93	1.59	7.74	14.2	-16.71	2.21	12.76
Manipur	115	25	-52.94	88.89	NA	-100	-83.33	200
Meghalaya	5.26	46.15	30	233.33	0	0	-75	100
Mizoram	40	300	-33.33	50	-85.71	133.33	NA	-100
Nagaland	NA	NA	-100	0	NA	NA	NA	NA
Odisha	42.67	23.29	-13.24	1.06	-13.7	-5.19	67.39	-8
Punjab	-3.92	19.09	-14.95	27	-10.71	3.7	-4.71	28.79
Rajasthan	16.79	42.47	-13.19	6.06	23.49	14.62	38.3	-7.84
Sikkim	58.33	33.33	-18.18	-54.17	NA	NA	-100	-50
Tamil Nadu	25.22	14.03	-11.61	13.02	51.56	9.4	-15.83	1.46
Telangana	-8.21	19.66	10.9	10.47	0	-3.57	7.69	23.81
Tripura	6.49	-25.24	0.98	12.09	0	0	-8.33	26.32
Uttar Pradesh	48.64	101.83	-46.04	4.12	69.7	10	22.45	-9.26
Uttarakhand	68.94	10.27	-11.52	94.12	318.75	0	-30.43	35.29
West Bengal	NA	NA	NA	NA	NA	NA	NA	NA
A & N islands	0	-10	-39.39	-19.51	0	-40	-37.5	100
Chandigarh	-34.29	-63.54	113.33	150	-80	-73.68	111.11	200
D & n Haveli and daman & Diu	3.45	52.63	-29.63	92.86	0	NA	-100	0
Delhi (Ut)	14.9	11.35	77.52	-8.51	-25.53	23.68	26.67	50
Jammu & Kashmir	38.71	-3.13	-38.46	48.57	1100	0	-66.67	50
Lakshadweep	50	0	NA	NA	NA	NA	NA	NA
Puducherry	125	-72.88	-21.33	4.17	0	-12.5	33.33	-60
Ladakh	NA	NA	NA	NA	NA	NA	NA	NA
Total (All India)	14.26	0.69	1.6	8.41	11.84	-9.2	7.25	10.35

**Note:** - \*Denotes decrease \*\* not available due to lack of data-NA

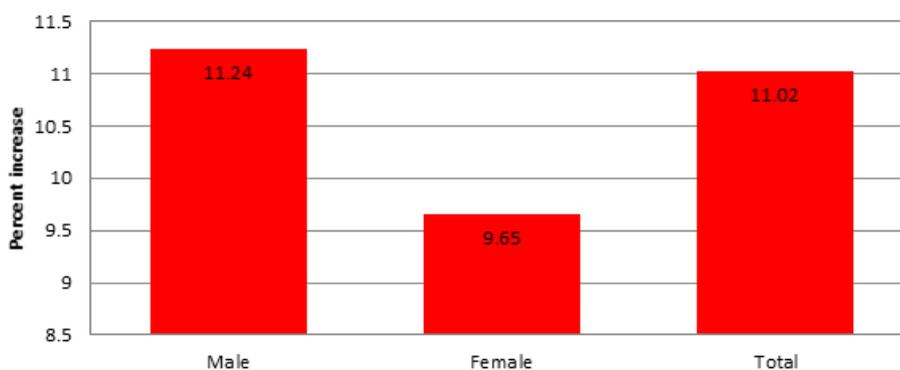
**Table 3:** Comparison of mean mortality in males due to MI during COVID-19 period and pre- COVID-19 period with percentage change in COVID-19 period compared to pre COVID-19 period.

State/UT	COVID-19 period-mean-male mortality due to MI	PRE COVID-19 period-mean-male mortality due to MI	Male mortality due to MI -percent change in mean COVID-19 period compared to pre COVID-19 period
Andhra Pradesh	113	73.5	53.74
Arunachal Pradesh	11.33	4.5	151.78
Assam	23.33	41.5	*-43.78
Bihar	96.33	127	-24.15
Chhattisgarh	380	335.5	13.26
Goa	29.67	37.5	-20.88
Gujarat	2485	2716	-8.51
Haryana	1051	935	12.41
Himachal Pradesh	312.67	252.5	23.83
Jharkhand	159.33	197	-19.12
Karnataka	1816.33	1399.5	29.78
Kerala	3157.33	2152	46.72
Madhya Pradesh	1446	1574	-8.13
Maharashtra	9674.33	9006.5	7.41
Manipur	26.33	26	1.27
Meghalaya	17.33	6.5	166.62
Mizoram	35.33	12.5	182.64
Nagaland	0	2	-100
Odisha	331.33	285.5	16.05
Punjab	809.33	765	5.79
Rajasthan	1014	832.5	21.8
Sikkim	13.33	17.5	-23.83
Tamil Nadu	1195.33	1071.5	11.56
Telangana	257	201	27.86
Tripura	87.33	96.5	-9.5
Uttar Pradesh	437.33	396	10.44
Uttarakhand	193	125	54.4
West Bengal	16	0	NA
A & N islands	18.67	37	-49.54
Chandigarh	51.33	31.5	62.95
D & n Haveli and daman & Diu	26	20.5	26.83
Delhi (Ut)	259	135	91.85
Jammu & Kashmir	35.33	43.5	-18.78
Lakshadweep	2.33	0	NA
Puducherry	37	73.5	-49.66
Ladakh	1	0	**NA
Total (All India)	25619.33	23030.5	11.24

**Note:** \*-Denotes decrease \*\* not available due to lack of data-NA



**Figure 6A:** Comparison of mean fatalities due to MI during COVID-19 period with pre-pandemic period. Note: (■) Pre COVID-19 Period Mean; (■) COVID-19 Period-Mean



**Figure 6B:** Percent increase in Mean fatalities due to MI in COVID-19 period compared to pre COVID-19 period. Note: (■) Percentage Increase in mean fatalities due to MI in COVID-19 period compared to pre COVID-19 period.

The male-sudden death due to myocardial infarction increased during COVID-19 year 2022 by 26.71 percent in comparison to 2018 pre-COVID-19 year. Percent wise topmost state reporting sudden death due to MI in males is Maharashtra, while Kerala, Gujarat, Madhya Pradesh, Karnataka, Tamil Nadu, Haryana, Punjab, Odisha, Uttar Pradesh, and Rajasthan are also important contributors.

The annual number of total new MI cases related mortality in males detected by the states and UTs of India, during a year i.e. 1<sup>st</sup> January to end i.e. 31<sup>st</sup> December is 22,101; 23,960; 24,343; 24,510 and 28,005; for years 2018, 2019, 2020, 2021, and 2022 respectively. The annual number of total new MI cases related mortality in males detected during the pre-COVID-19 as well as in COVID-19 period have similar increasing trends separately. The base year 2018 is having least whereas the last year 2022 is having the largest number of total new MI cases related mortality detected in one individual year. Maharashtra remained on the top in reporting Male-Sudden death due to Myocardial Infarction during the study period. The comparison of mean mortality in males due to MI during COVID-19 period and pre- COVID-19 period is elaborated with percentage change in COVID-19 period

compared to pre COVID-19 period. Mizoram with 182.64% is at top in percentage change in COVID-19 period compared to pre COVID-19 period in Male-Sudden death due to Myocardial Infarction whereas Odisha is at bottom with-100%.

**Female-sudden death due to myocardial infarction**

The total number of female-Sudden death due to Myocardial Infarction cases increased continuously during pre-COVID-19 years and during COVID-19 years, except 2021, in which a slight drop. The female-Sudden death due to Myocardial Infarction increased during COVID-19 year 2022 by 20.17 percent in comparison to 2018 pre- COVID-19 year. Percent wise top 3 states reporting sudden death due to MI in females include Maharashtra, Kerala and Gujarat.

The total number of new MI cases related mortality in female during the study period is 20,378, obtained by adding individual new MI cases related mortality detected by the states and UTs of India. The mean number of total new MI cases related mortality in female during pre-COVID-19 period (2018-2019) is 3,852.5 whereas during the COVID-19 period (2020-2022) it increased to 4,224.33. There is an overall increase of 9.65 percent in new MI cases related mortality in female during the COVID-19 period.

This study also revealed that sudden death due to MI is very less (about 14%) in females compared to males (86%), or we can say that compared to females, males are 6 times more likely to have sudden death due to MI.

The annual number of total new MI cases related mortality in female detected by the states and UTs of India, during a year i.e. 1<sup>st</sup> January to end i.e. 31<sup>st</sup> December is 3663, 4042, 4335, 3936 and 4402; for years 2018, 2019, 2020, 2021, and 2022 respectively. The annual number of total new MI cases related mortality in female detected during the pre-COVID-19 as well as in COVID-19 period have similar increasing trends separately, except 2021. The base year 2018 is having least whereas the last year 2022 is having the largest number of total new MI cases related mortality detected in one individual year. This study revealed that there is 20.17 percent increase in total number of new MI cases related mortality in females in 2022 in comparison to pre-COVID-19 year of 2018.

Maharashtra remained on the top in reporting female-Sudden death due to Myocardial Infarction during the study period. The comparison of mean mortality in females due to MI during COVID-19 period and pre- COVID-19 period is elaborated in Table 4, with percentage change in COVID-19 period compared to pre COVID-19 period. Mizoram with 266.67% is at top in percentage change in COVID-19 period compared to pre COVID-19 period in Male-Sudden death due to Myocardial Infarction whereas Manipur is at bottom with -91%. Table 5, shows the statistical analysis of sudden death due to MI during study period. It is not elaborated to reduce the length of the article. There is wide gap in minimum and maximum sudden death due to MI during study period in different States and UTs of India as shown in Table 5. Hence the 95% C.I is also having big gap as well as a huge difference in mean is also seen between males and females due to the fact that lesser number of female sudden death is found due to MI.

**Table 4:** Comparison of mean mortality in females due to MI during COVID-19 period and pre- COVID-19 period with percentage change in COVID-19 period compared to pre COVID-19 period.

State/UT	COVID-19 period-mean-female	PRE COVID-19 period-mean-female	Female-Percent change in COVID-19 period compared to pre COVID-19 period
Andhra Pradesh	10.33	8	29.17
Arunachal Pradesh	0.67	0.5	33.33
Assam	3.67	8	-54.17
Bihar	32	31	3.23
Chhattisgarh	69.67	76	-8.33
Goa	4.67	4	16.67
Gujarat	308.33	331	-6.85
Haryana	99.33	75.5	31.57
Himachal Pradesh	30	48.5	-38.14
Jharkhand	24.33	54.5	-55.35
Karnataka	269.67	173.5	55.43
Kerala	619	415	49.16
Madhya Pradesh	222	253.5	-12.43
Maharashtra	1844	1834	0.55
Manipur	0.33	4	-91.67
Meghalaya	1	3	-66.67
Mizoram	3.67	1	266.67
Nagaland	0	0	NA

Odisha	71	48	47.92
Punjab	80	75.5	5.96
Rajasthan	154.33	98	57.48
Sikkim	0.67	4.5	-85.19
Tamil Nadu	146.33	138	6.04
Telangana	27.33	23.5	16.31
Tripura	22	21.5	2.33
Uttar Pradesh	79.33	51.5	54.05
Uttarakhand	33	20	65
West Bengal	2	0	NA
A & N islands	3.67	6	-38.89
Chandigarh	8.33	6	38.89
D & n Haveli and daman & Diu	1.33	1	33.33
Delhi (Ut)	40	25	60
Jammu & Kashmir	4.67	2.5	86.67
Lakshadweep	0	0	NA
Puducherry	7.33	10.5	-30.16
Ladakh	0.33	0	NA
Total (All India)	4224.33	3852.5	9.65

**Table 5:** Statistical analysis of mortality due to MI during study period.

Variable	Obs	Mean	Std. dev.	Min	Max	Std. err.	[95% conf. interval]
Male-sudden deaths (heart attack)-2022	36	777.92	1871.3	0	10699	311.88	144.76 -1411.07
Male-sudden deaths (heart attack)-2021	36	680.83	1585.14	0	8833	264.19	144.50 -1217.17
Male-sudden deaths (heart attack)-2020	36	676.19	1668.45	0	9491	278.07	111.67 -1240.71
Male-sudden deaths (heart attack)-2019	35	684.57	1650.06	0	9342	278.91	117.76 -1251.39
Male-sudden deaths (heart attack)-2018	35	631.46	1539.11	0	8671	260.16	102.75 -1160.16
Female-sudden deaths (heart attack)-2022	36	122.28	327.18	0	1890	54.53	11.57- 232.98
Female-sudden deaths (heart attack)-2021	36	109.33	292.38	0	1655	48.73	10.41 -208.26
Female-sudden deaths (heart attack)-2020	36	120.42	342.7	0	1987	57.12	4.47- 236.37
Female-sudden deaths (heart attack)-2019	35	115.49	335.58	0	1944	56.72	.21 -230.76
Female-sudden deaths (heart attack)-2018	35	104.66	296.4	0	1724	50.1	2.840262 -206.47
Total-sudden deaths (heart attack)-2022	36	900.28	2197.48	0	12591	366.25	156.7583 -1643.80
Total-sudden deaths (heart attack)-2021	36	790.25	1875.66	0	10489	312.61	155.62- 1424.88
Total-sudden deaths (heart attack)-2020	36	796.67	2008.71	0	11478	334.78	117.02 -1476.32
Total-sudden deaths (heart attack)-2019	35	800.14	1981.98	0	11286	335.02	119.31 -1480.98
Total-sudden deaths (heart attack)-2018	35	736.11	1833.03	0	10395	309.84	106.45- 1365.78

## Discussion

In this total-population based study incorporating all sudden death due to MI (2018-2022), the study revealed that COVID-19 era increased the sudden death due to MI. One research study found that there is fault in mortality registration due to COVID-19, which must be corrected to assess the direct and indirect impact of COVID-19 pandemic like MI [20,21]. There is a wide gap in public health management systems of various states and UTs of India, evident from NITI AAYOG reports analysis [22]. Some densely populated states like Bihar and Uttar Pradesh continue to secure bottom ranks in state health index annual report of NITI Aayog, indicating poor performance of public health management systems. Another face is that the data reported by such states is likely to have errors due to this poor performance. During the era of COVID-19 pandemic, one study found that that COVID-19 have negative impact on NCD (Non-Communicable Disease)-OPD health services such as myocardial infarction, hence there is possibility that the real count of sudden death due to MI may be more than what is reported to NCRB by states and UTs of India [23]. Another study found that some densely populated states like Bihar have very less Medical Certification Of Cause of Death (MCCD) due to a poor public health management system, and this reduced/improper data on MCCD may interfere with actual assessment of title mentioned research question [24]. There is multisystem organ involvement in COVID-19 which may increase the incidence and prevalence of NCD like CVD, DM, etc. in coming years, hence the post-COVID-19 assessment of condition like MI, DM, etc. must be monitored closely to be able to apply interventions timely to check flood in cases of NCDs in coming years as after impact of COVID-19. Screening for NCD like CVD, DM after COVID-19 must be increased, especially for high-risk individuals, or older individuals. Prompt management of any complications due to NCDs should be initiated, at mass level. Such timely interventions will to improve prognosis and quality of life in patients suffering from NCDs following COVID-19 [25].

## Strength and limitations

This is the first study as per our knowledge to assess the impact of COVID-19 era on the sudden death due to MI. Our study cannot prove the causality i.e. due to observational, cross-sectional, retrospective nature of our study. Of course the hypothesis is generated due to such studies only leading to foundations of future research. As discussed above, there is also risk for incomplete or inaccurate data due to faulty MCCD, misclassification bias, and residual confounding in register-based studies. However, if any type of misclassification, etc., which is likely to lead to underestimation of the associations. Nevertheless, the calculations and our findings remain robust. This is one of the largest studies incorporating all sudden death due to MI during COVID-19 in a country to find

out the impact of COVID-19 era on MI.

## Conclusion

This study revealed that COVID-19 era increased sudden death due to MI. COVID-19 is associated with many severe consequences due to multi-organ involvement as it is not limited to RTI like its predecessors (respiratory tract infection), it can cause even death, which makes assessing post-COVID-19 impact on various NCDs a necessary public health issue. Myocardial injury is a significant sequel of COVID-19-infection and further research investigations are needed to determine the underlying patho-physiology and manifestations to timely check a massive increase in global burden of disease due to after impact of COVID-19. Regular follow-up and clinical examination for arrhythmia monitoring and imaging studies is needed in patients with myocardial damage related to COVID-19. We recommend monitoring and follow up of the following conditions at mass level after COVID-19, particularly in vulnerable population already suffering from any previous cardiac ailments:-

- Test to assess blood clots, heart attack, stroke
- Tests to assess myocarditis, pericarditis, arrhythmias, heart failure, cardiomyopathy, cardiac arrest angina, etc.

## References

1. Kumar DP. What are the factors responsible for increase in SARS-CoV-2/ COVID-19 Pandemic related cases and death in India in 2021? How does environmental, host & agent factors of epidemiological triad do influence & can be utilised to manage ongoing pandemic cases and deaths? How does environmental, host and agent factors of epidemiological triad do influence and can be utilised to manage ongoing pandemic cases and deaths. 2021.
2. Statement on the fifteenth meeting of the IHR (2005) emergency committee on the COVID-19.2023.
3. Payne S. Family coronaviridae. *Viruses*, 149-158 (2017).
4. Katsoularis I, Jerndal H, Kalucza S, et al. Risk of arrhythmias following COVID-19: Nationwide self-controlled case series and matched cohort study. *Eur Heart J Open*. 3(6):oead120 (2023).
5. World heart report 2023 confronting the world's number one killer. (2023).
6. Kalra A, Jose AP, Prabhakaran P, et al. The burgeoning cardiovascular disease epidemic in Indians-perspectives on contextual factors and potential solutions. *Lancet Reg Health Southeast Asia*. (2023).
7. Cardiovascular diseases (CVDs)-WHO (World Health Organization).2021.
8. COVID-19 patients retain elevated risk of death for at least 18 months after infection (2023).
9. Basu-Ray I, Adeboye A, Soos MP, et al. Cardiac manifestations of coronavirus (COVID-19). (2023).
10. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA*. 323(11):1061-1069 (2020).
11. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 395(10223):497-506 (2020).

12. Hoffmann M, Kleine-Weber H, Schroeder S, et al. SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor. *Cell*. 181(2):271-280 (2020).
13. Tikellis C, Thomas MC. Angiotensin-Converting Enzyme 2 (ACE2) is a key modulator of the renin angiotensin system in health and disease. *Int J Pept*. (2012).
14. Patone M, Mei XW, Handunnetthi L, et al. Risks of myocarditis, pericarditis, and cardiac arrhythmias associated with COVID-19 vaccination or SARS-CoV-2 infection. *Nat Med*. 28(2):410-422 (2022).
15. Witberg G, Barda N, Hoss S, et al. Myocarditis after COVID-19 vaccination in a large health care organization. *N Engl J Med*. 385(23):2132-2139 (2021).
16. Katsoularis I, Jerndal H, Kalucza S, et al. Risk of arrhythmias following COVID-19: Nationwide self-controlled case series and matched cohort study. *Eur Heart J Open*. 3(6):oead120 (2023).
17. Andrews MA, Areekal B, Rajesh KR, et al. First confirmed case of COVID-19 infection in India: A case report. *Indian J Med Res*. 151(5):490 (2020).
18. COVID-19- India situation-WHO. (2021).
19. Kumar P. What impacts have geographical locations on the cases and deaths from COVID-19/Sars-Cov-2 pandemic in 36 states and Union Territories of India:-Observational analysis in India. *J Mar Res*. 5(1):1-7 (2022).
20. Kumar DP, Anupama A. What can be impact of civil authority's faulty mortality registration on COVID-19 mortality count in the state of Bihar, India-evidence from NFHS-5. (2022).
21. Kumar DP, Anupama A. Analysis of NITI AAYOG (National Institution for Transforming India) health index report on the ranking of states and union territories: Round 2 (2015–2016/2017-2018)-V2.
22. Kumar DP. Impact of COVID-19 induced lockdown on the OPD patients of Diabetes, Hypertension, Stroke (CVA), Acute heart disease, Mental illness, Epilepsy, Ophthalmic, Dental and oncology in India-A Cross-Sectional Research Study. *Mental Illness, Epilepsy, Ophthalmic, Dental and oncology in India-A Cross-Sectional Research Study*. (2022).
23. Piyush K, Anupama. What percentage of mortality were medically certified among total registered mortality in 36 states and UTS of India during 2018-2020 and COVID-19 mortality age sex distribution pattern in India: A Cross Sectional Observational Research Study. *Public H Open Acc*. 6(2): 000214 (2022).
24. Kumar P, Anupama A. The SARS-CoV-2 infection (COVID-19) era impact on incidence of sudden deaths due to myocardial infarction (heart attack) in States and Union Territories of India-A cross-sectional comparative study. (2018-2022).
25. Kumar P, Anupama A. What impact does the COVID-19 pandemic era have on the incidence of myocardial infarction-related fatalities in distinct age groups of male and female? A comparison study. *Qeios*. (2024).