Forecasting the size, peak and fading out of novel coronavirus outbreak using current confirmed cases and deaths

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Abstract

Background:

In the middle of December 2019, an atypical cluster of pneumonia cases with unknown etiology was reported from Wuhan City, Hubei Province, China. Later on, at 31st December 2019, the outbreak of novel coronavirus was reported to World Health Organization (WHO). Finally, on 7th of January 2020, the Chinese authorities isolated a new type of coronavirus (novel coronavirus, nCoV), which was then named 2019nCoV by WHO on 12th January. WHO announced the event as public health emergency of international concern on January 31.

Methods:

Since report of novel coronavirus outbreak to WHO in 31 December 2019, the real time data on confirmed cases and deaths has been published worldwide. Using these data enabled many scientists and epidemiologists to nowcast, forecast and predict the future of current 2019 nCoV outbreak. In this study the number of confirmed cases and deaths published daily by National Health Commission (NHC) of China and World Health Organization (WHO) have been used to design a statistic model to forecast the number of cases daily with number of deaths attached to that. Comparing daily confirmed cases, the progress is estimated and future cases forecasted. In addition, the number of deaths was calculated, similarly with respect to the number of forecasted cases. The Microsoft Excel 2016 were used for data management and analysis.

Results:

The statistical model indicated that the current outbreak of novel coronavirus will be peaked on 20 February 2020 with 91265 confirmed cases and 1655 deaths worldwide. Later on, the number of cases and deaths will decline towards end of March 2020. It will be died out by first week of April, 2020. The comparison of actual cases and deaths as with forecasted cases and deaths are close to each other for last couple of days.

Conclusion:

There are many mathematic models developed and used to forecast the peak and size of outbreaks. The models including current one will be affected by integrated measures, level of interventions, population mobility, contact of people and transmission of virus. This model could be followed until end of outbreak to see its effectiveness. If working, could be used for forecasting of future outbreaks.

Keywords:

Outbreak, Novel Coronavirus, Forecasting, Modeling, Peak of outbreak

Introduction

In the middle of December 2019, an atypical case of pneumonia with unknown etiology was reported from Wuhan City, Hubei Province, China. Later on, at 31st December 2019, the disease outbreak due to novel coronavirus was reported to World Health Organization (WHO). Finally, on 7th of January 2020, the Chinese authorities isolated the new type of coronavirus (novel coronavirus, nCoV), which was then called 2019nCoV by WHO on 12th January (1). As of 7th February, 31481 confirmed cases and 639 deaths have been reported worldwide (2). Human to human transmission was confirmed when two local infections in the Chinese province of Guangdong with no direct visit to Wuhan were confirmed on 20th January 2020 (3). The one case in Hong Kong turned into 5 as the entire family of an infected person came down with the disease (4). Recently many other cases without contact with animals are confirmed.

Coronaviruses (CoV) are a large family of viruses that cause illness ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV). A novel coronavirus (nCoV) is a new strain that has not been previously identified in humans. Coronaviruses are zoonotic, meaning they are transmitted between animals and people. Detailed investigations found that SARS-CoV was transmitted from civet cats to humans and MERS-CoV from dromedary camels to humans. Several known coronaviruses are circulating in animals that have not yet infected humans. Common signs of infection include respiratory symptoms, fever, cough, shortness of breath and breathing difficulties. In more severe cases, infection can cause pneumonia, severe acute respiratory syndrome, kidney failure and even death. Standard recommendations to prevent infection spread include regular hand washing, covering mouth and nose when coughing and sneezing, thoroughly cooking meat and eggs (5). The World Health Organization (WHO) has declared the outbreak a public health emergency of international concern, prompting countries to take unprecedented measures (6).

The usefulness of developing approaches to infectious disease forecasting for minimizing the public health impacts of an epidemic is discussed in literature (7). Predicted measures typically include peak time and height, magnitude and spread. Comparing approaches can be challenging since the gold standard varies and successful prediction is not always clearly defined (8). A mathematical model indicated that the national epidemic of 2019nCov in China may lead to a total of 8042 (95%CI: 4199-11884) infections and 898 (3681429) deaths. Furthermore, the model estimated that the basic reproduction number (R0) of 2019-nCov, an indication of the initial transmissibility of the virus, to be 4.71 (4.50-4.92) when the epidemic started on 12th December 2019, but its effective reproduction number (*Re*) has dropped to 2.08 (1.99-2.18) on 22nd January 2020. If the declining trend continues with the assumption of no resurges of the epidemic, *Re* will drop below one within three months of the epidemic initiation, suggesting that the epidemic will gradually decline (9). It should be noted that the R0 for SARS was 4.91 in Beijing, China (10), in 2003, for MERS in Jeddah was 3.5-6.7 and in Riyadh (2.0-2.8), Kingdom of Saudi Arabia, in 2014 (11). An early estimate by one research group put R0 at 3.8 and later revised it down to 3.11 with new data, while another reports an estimate of 3.3. Estimates for R0 are likely to keep shifting with more information becoming available over the next few weeks (12).

An analysis by Gabriel Leung at the University of Hong Kong estimated that there could have been as many as 43,590 people infected by 2019-nCoV by Jan 25 and the outbreak may peak between late April and early May (13). On 28 January, Zhong Nanshan, a renowned scientist at China's National Health Commission, expressed to a Xinhua news agency that the outbreak "will not increase at a large scale"

and he believed that it should reach a peak in a week or around ten days (14). Furthermore, a doctor who led the World Health Organization's response to the 2002-03 SARS outbreak said it's too early to tell when the new coronavirus will peak, but it appears the disease is still on the increase (15). Another article on February 6th, says that there 4 ways this outbreak could take a turn for the worse. China can't contain the new coronavirus, the new coronavirus spreads in countries with weak health systems, the virus is actually deadlier than it seems right now and finally travel bans isolate countries, spread xenophobia — and exacerbate outbreaks. The report also stated that there are 4 things that could unfold and would prevent a pandemic such as China contains the virus, local clusters of the disease in other countries don't grow, the virus can't spread in poorer countries with hotter climates and we learn the virus is not as deadly as it seems (16). John Nicholls, clinical professor of pathology at the University of Hong Kong (HKU), said the SARS outbreak was brought to an end in July 2003 by good hygiene practices and environmental factors such as high temperature and humidity in the summer months. Therefore, he mentioned that it will be the same for coronavirus and his feeling is that the current outbreak is just going to be like SARS and the world is going to get basically a very bad cold for about five months (17).

According to modeling the timely diagnosis for quarantine and integrated interventions such as the promotion of face mask use and reduction of travel, are essential for curbing the epidemic. If the current intervention continues, the number of infected individuals is expected to peak in early March 2020. The current duration from symptom onset to isolation is about six days. The model indicated that every one-day reduction in this duration would reduce the peak population size by 72-84% and the cumulative infected cases and deaths both by 68-80%. It estimated that every additional 10% decay in the transmission rate due to integrated interventions would reduce the peak population size by 20-47%, the cumulative infected cases and deaths both by 23-49% (9). By this study we predicted the outbreak size of nCoV, peak time and fading out based on existing epidemiological confirmed data and a dynamic model.

Methodology

Since report of novel coronavirus outbreak to WHO in 31 December 2019 by China, the real time data on confirmed cases and deaths are available and published worldwide. Using these data may enable many scientists and epidemiologists to nowcast, forecast and predict the future of current 2019 nCoV in terms of size, cases, peak time and dying out. There are articles, expressions and viewpoints published on websites, journals and social media giving information regarding peak and size of outbreaks. In addition, using traditional techniques to identify the reproductive number of cases some predictions are published in literature recently.

In this study the number of confirmed cases and deaths published daily by National Health Commission (NHC) of China and World Health Organization (WHO) have been used to design a mathematic/statistic model to forecast the number of cases daily with number of deaths attached to that. Comparing daily confirmed cases, the progress rate day of day have been identified. By means of the available data, the case fatality rate was developed or forecasted cases. In addition, the number of deaths were calculated using the case fatality rates with respect to the number of forecasted cases. The Microsoft Excel 2016 were used for data management and analysis. It should be noted that the model was developed on 1st February, 2020. Here are the main formulas used in this model.

1. $Progression\ rate = \frac{D2}{D1}$, *the D1 is day one and D2 is day two (number of cases)*
2. $Progressions\ Diffirence = Progression\ rate\ D2 - Progression\ rate\ D1$
3. $Average\ progression\ = Progressrate\ Difference\ of\ D1\ to\ D15/15$
5. $Average\ progression\ rate = Progression\ rate - Average\ progression\ of\ 15\ days$
6. $Forecasted\ confirmed\ case = Average\ progression\ rate * Cofirmed\ cases\ prveious\ day$

It should be mentioned that the same concept was used for forecasting the number of deaths. Here are the formulas.

1. $Case\ Fataliry\ Rate = \frac{Number\ of\ Deaths}{Total\ number\ of\ cases}$
2. $CFR\ Diffirence = Reduction\ CFR\ D2 - Reduction\ on\ CFR\ on\ D1$
3. $Average\ \ Reduction\ CFR\ = Reduction\ of\ CFRof\ D1\ to\ D15/15$
5. $Average\ Reduction\ CFR = CFR - Average\ Reduction\ of\ CFR\ of\ 15\ days$
6. $Forecasted\ Deaths = Average\ Reduction\ of\ CFR\ * Cofirmed\ cases\ prveious\ day$

Using this procedure, we identified and forecasted the number of cases and deaths for two months and developed graphs showing the size, peak and fading out of this current outbreak.

Results

The model was designed on first of February 2020, therefore data were entered until 1st February reported. Totally the there was 14557 confirmed cases and 305 deaths for first of February published on 2nd. Following table shows how the model was designed using available data.

Table 1. Calculation Model of confirmed cases and progress rates

SN	Dates	Cases	Progress rates	Progress Difference
1	1/17/2020	45	0	
2	1/18/2020	62	1.377777778	-0.573835125
3	1/19/2020	121	1.951612903	0.315249267
4	1/20/2020	198	1.636363636	0.166666667
5	1/21/2020	291	1.46969697	-0.042330522
6	1/22/2020	440	1.512027491	0.214300219
7	1/23/2020	571	1.297727273	-0.15586292
8	1/24/2020	830	1.453590193	-0.097012217
9	1/25/2020	1287	1.55060241	0.016025875
10	1/26/2020	1975	1.534576535	0.145209446
11	1/27/2020	2744	1.389367089	-0.256041075
12	1/28/2020	4515	1.645408163	0.322263091
13	1/29/2020	5974	1.323145072	0.032385112
14	1/30/2020	7711	1.29075996	0.033854241
15	1/31/2020	9692	1.256905719	0.024136425

16	2/1/2020	11948	1.232769294	0.014406388
17	2/2/2020	14557	1.218362906	
Average of Progress Difference				0.010627658

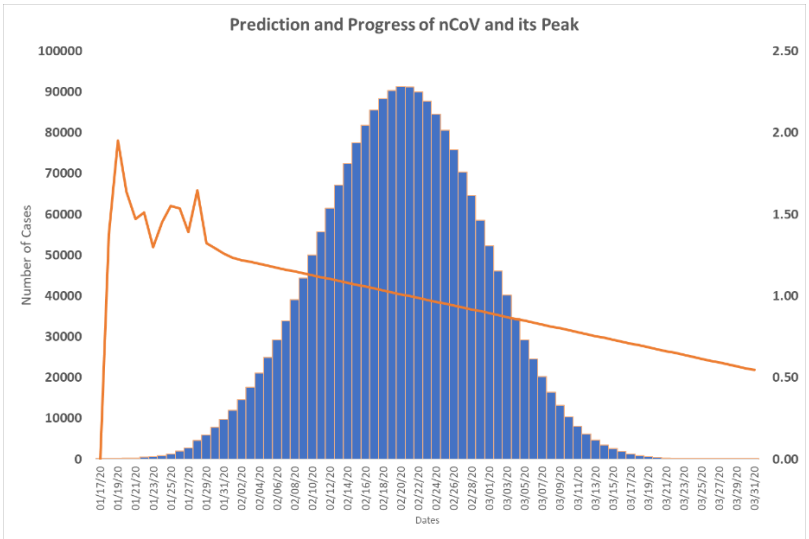
Using the average difference of the last column in table one the following table were forecasted for confirmed cases. It based on trend of progression and number of confirmed cases since start of the outbreak. Table 2 shows the forecasted cases using progress rate (forecasted).

Table 2. Progress in number of confirmed cases of outbreaks of nCoV				
SN	Dates	Cases	Progress rates	Progress Difference
1	2/3/2020	17581	1.207735248	0.011615271
2	2/4/2020	21029	1.196119977	0.011615271
3	2/5/2020	24909	1.184504706	0.011615271
4	2/6/2020	29215	1.172889434	0.011615271
5	2/7/2020	33927	1.161274163	0.011615271
6	2/8/2020	39005	1.149658892	0.011615271
7	2/9/2020	44389	1.138043621	0.011615271
8	2/10/2020	50001	1.12642835	0.011615271
9	2/11/2020	55742	1.114813079	0.011615271
10	2/12/2020	61494	1.103197808	0.011615271
11	2/13/2020	67126	1.091582537	0.011615271
12	2/14/2020	72494	1.079967266	0.011615271
13	2/15/2020	77449	1.068351994	0.011615271
14	2/16/2020	81843	1.056736723	0.011615271
15	2/17/2020	85536	1.045121452	0.011615271
16	2/18/2020	88402	1.033506181	0.011615271
17	2/19/2020	90337	1.02189091	0.011615271
18	2/20/2020	91265	1.010275639	0.011615271
19	2/21/2020	91143	0.998660368	0.011615271
20	2/22/2020	89962	0.987045097	0.011615271
21	2/23/2020	87752	0.975429826	0.011615271
22	2/24/2020	84577	0.963814554	0.011615271
23	2/25/2020	80534	0.952199283	0.011615271
24	2/26/2020	75749	0.940584012	0.011615271
25	2/27/2020	70368	0.928968741	0.011615271
26	2/28/2020	64553	0.91735347	0.011615271
27	2/29/2020	58468	0.905738199	0.011615271
28	3/1/2020	52277	0.894122928	0.011615271
29	3/2/2020	46135	0.882507657	0.011615271
30	3/3/2020	40179	0.870892386	0.011615271

31	3/4/2020	34525	0.859277114	0.011615271
32	3/5/2020	29265	0.847661843	0.011615271
33	3/6/2020	24467	0.836046572	0.011615271
34	3/7/2020	20171	0.824431301	0.011615271
35	3/8/2020	16396	0.81281603	0.011615271
36	3/9/2020	13136	0.801200759	0.011615271
37	3/10/2020	10372	0.789585488	0.011615271
38	3/11/2020	8069	0.777970217	0.011615271
39	3/12/2020	6184	0.766354946	0.011615271
40	3/13/2020	4667	0.754739674	0.011615271
41	3/14/2020	3468	0.743124403	0.011615271
42	3/15/2020	2537	0.731509132	0.011615271
43	3/16/2020	1826	0.719893861	0.011615271
44	3/17/2020	1294	0.70827859	0.011615271
45	3/18/2020	901	0.696663319	0.011615271
46	3/19/2020	617	0.685048048	0.011615271
47	3/20/2020	416	0.673432777	0.011615271
48	3/21/2020	275	0.661817505	0.011615271
49	3/22/2020	179	0.650202234	0.011615271
50	3/23/2020	114	0.638586963	0.011615271
51	3/24/2020	72	0.626971692	0.011615271
52	3/25/2020	44	0.615356421	0.011615271
53	3/26/2020	27	0.60374115	0.011615271
54	3/27/2020	16	0.592125879	0.011615271
55	3/28/2020	9	0.580510608	0.011615271
56	3/29/2020	5	0.568895337	0.011615271
57	3/30/2020	3	0.557280065	0.011615271
58	3/31/2020	2	0.545664794	0.011615271

As we assessed the above table 2, it seems number of cases will be reach to its peak on 20th of February with 91265 cases. Later on, it will decline and will be fading out and die on 31 March 2020. The histogram chart of forecasted data was developed in following figure.

Figure 1: Progression of 2019 nCoV size, peak and fading out



Furthermore, the deaths were also entered in the model and the forecasted table were developed.

Table 3. Trend of Case Fatality Rate of nCoV					
SN	Dates	Cases	Number of Deaths	CFR	Difference
1	1/10/2020	41	1	2.439024	0
2	1/11/2020	41	1	2.439024	0
3	1/12/2020	41	1	2.439024	0
4	1/13/2020	41	1	2.439024	-2.005420054
5	1/15/2020	45	2	4.444444	0
6	1/16/2020	45	2	4.444444	1.218637993
7	1/17/2020	62	2	3.225806	1.57291389
8	1/18/2020	121	2	1.652893	0.137741047
9	1/19/2020	198	3	1.515152	-0.546704155
10	1/20/2020	291	6	2.061856	0.138778747
11	1/21/2020	312	6	1.923077	-0.08137742
12	1/22/2020	449	9	2.004454	-1.031259943
13	1/23/2020	560	17	3.035714	0.073628978
14	1/24/2020	844	25	2.962085	-0.004629598
15	1/25/2020	1382	41	2.966715	0.289850661
16	1/26/2020	2092	56	2.676864	-0.152335895
17	1/27/2020	2863	81	2.8292	0.515294879
18	1/28/2020	4581	106	2.313905	0.136406086
19	1/29/2020	6062	132	2.177499	0.107531859
20	1/30/2020	8261	171	2.069967	-0.12999137
21	1/31/2020	9682	213	2.199959	0.03223187
22	2/1/2020	11948	259	2.167727	0.072514891
23	2/2/2020	14557	305	2.095212	
Average					**0.015627839**

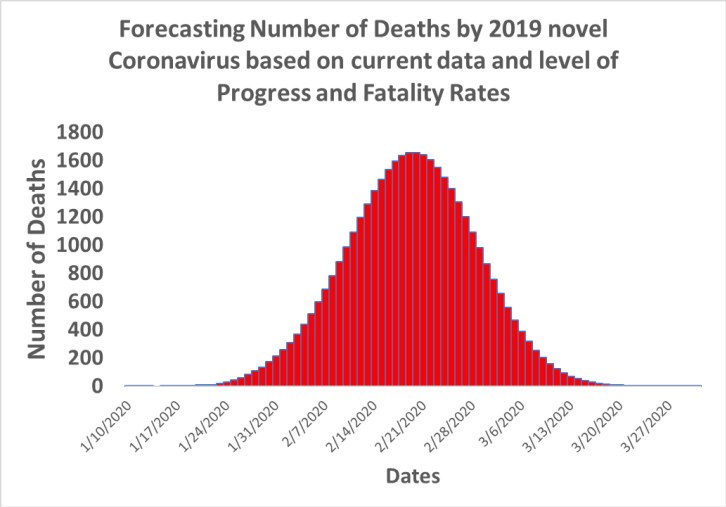
Using the above forecasting trend of case fatality rate the forecasted deaths were developed. Table 4 shows these predicted number of deaths.

Table 4. Forecasted trend of Case Fatality Rate and deaths for nCoV					
SN	Dates	Cases	Number of Deaths	CFR	Difference
1	2/3/2020	17581	366	2.079584	0.015628
2	2/4/2020	21029	434	2.063956	0.015628
3	2/5/2020	24909	510	2.048328	0.015628
4	2/6/2020	29215	594	2.032701	0.015628
5	2/7/2020	33927	684	2.017073	0.015628
6	2/8/2020	39005	781	2.001445	0.015628
7	2/9/2020	44389	881	1.985817	0.015628
8	2/10/2020	50001	985	1.970189	0.015628
9	2/11/2020	55742	1090	1.954561	0.015628
10	2/12/2020	61494	1192	1.938934	0.015628
11	2/13/2020	67126	1291	1.923306	0.015628
12	2/14/2020	72494	1383	1.907678	0.015628
13	2/15/2020	77449	1465	1.89205	0.015628
14	2/16/2020	81843	1536	1.876422	0.015628
15	2/17/2020	85536	1592	1.860794	0.015628
16	2/18/2020	88402	1631	1.845166	0.015628
17	2/19/2020	90337	1653	1.829539	0.015628
18	2/20/2020	91265	1655	1.813911	0.015628
19	2/21/2020	91143	1639	1.798283	0.015628
20	2/22/2020	89962	1604	1.782655	0.015628
21	2/23/2020	87752	1551	1.767027	0.015628
22	2/24/2020	84577	1481	1.751399	0.015628
23	2/25/2020	80534	1398	1.735772	0.015628
24	2/26/2020	75749	1303	1.720144	0.015628
25	2/27/2020	70368	1199	1.704516	0.015628
26	2/28/2020	64553	1090	1.688888	0.015628
27	2/29/2020	58468	978	1.67326	0.015628
28	3/1/2020	52277	867	1.657632	0.015628
29	3/2/2020	46135	758	1.642005	0.015628
30	3/3/2020	40179	653	1.626377	0.015628
31	3/4/2020	34525	556	1.610749	0.015628
32	3/5/2020	29265	467	1.595121	0.015628
33	3/6/2020	24467	386	1.579493	0.015628
34	3/7/2020	20171	315	1.563865	0.015628
35	3/8/2020	16396	254	1.548238	0.015628

36	3/9/2020	13136	201	1.53261	0.015628
37	3/10/2020	10372	157	1.516982	0.015628
38	3/11/2020	8069	121	1.501354	0.015628
39	3/12/2020	6184	92	1.485726	0.015628
40	3/13/2020	4667	69	1.470098	0.015628
41	3/14/2020	3468	50	1.454471	0.015628
42	3/15/2020	2537	37	1.438843	0.015628
43	3/16/2020	1826	26	1.423215	0.015628
44	3/17/2020	1294	18	1.407587	0.015628
45	3/18/2020	901	13	1.391959	0.015628
46	3/19/2020	617	8	1.376331	0.015628
47	3/20/2020	416	6	1.360703	0.015628
48	3/21/2020	275	4	1.345076	0.015628
49	3/22/2020	179	2	1.329448	0.015628
50	3/23/2020	114	2	1.31382	0.015628
51	3/24/2020	72	1	1.298192	0.015628
52	3/25/2020	44	1	1.282564	0.015628
53	3/26/2020	27	0	1.266936	0.015628
54	3/27/2020	16	0	1.251309	0.015628
55	3/28/2020	9	0	1.235681	0.015628
56	3/29/2020	5	0	1.220053	0.015628
57	3/30/2020	3	0	1.204425	0.015628
58	3/31/2020	2	0	1.188797	0.015628

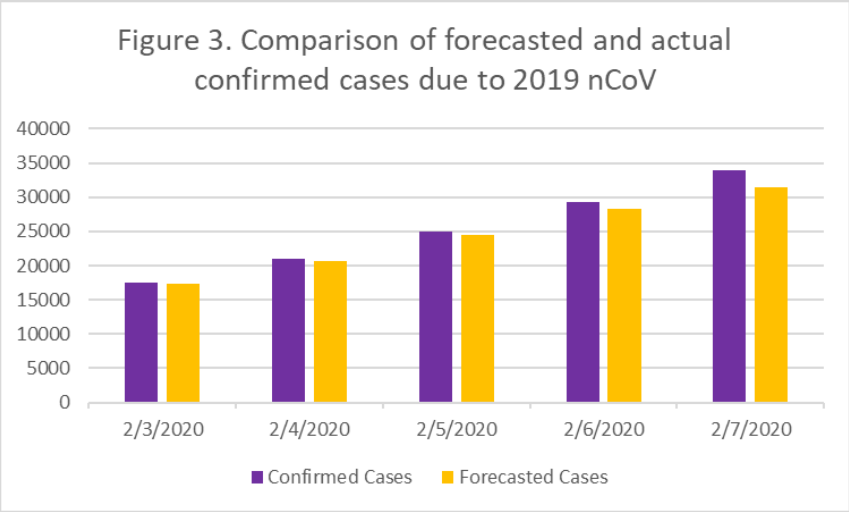
Taking into account table 4 regarding the forecasted case fatality rates and its predicted number of deaths, following histogram were developed. You can see the deaths forecasting in figure number 2.

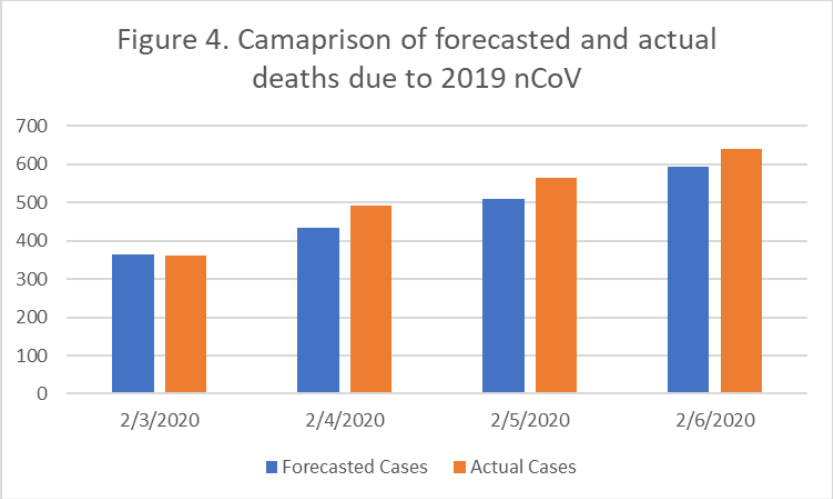
Figure 2. Forecasted deaths reflect in histogram



Based on above histogram of forecasted deaths and its related table 4, it is reflected that total number of deaths will be 1655 in 20 February, 2020. Later on, the cases and deaths will be declined and until last week of March 2020 the number of deaths will reach to zero and finally the outbreak will die out.

As the report is written now (February 7) we can compare the number of cases and deaths of the model with actual cases and deaths occur for one week. Here in figures 3 and 4 the comparison is reflected in bar charts.





Discussion

There are various techniques and methods which is using mathematics and statistics to forecast or predict the events including progression of outbreaks. However, all these models are influenced by many known and unknown factors. In our model in which the confirmed number of cases and deaths for first two weeks are used reflected that the outbreak of current novel coronavirus for 2019 will be reached to its peak on 20 February 2020 in terms of cases and deaths. Total number of cases on 3rd week of February will be more than 90,000 and the number of deaths more than 1600. Whereas it will decline and die out at the end of March. It should be mentioned that this model is forecasting using the current data, however it will be affected by level of preventive interventions, restriction of movements,

implementation of integrated practices, public awareness, transmissibility and virulence of nCoV and many other factors.

It should be noted that the confidence interval could be calculated for these forecasted figures and margin of error will show how much the figures we be over or under the average. Lastly, the comparison should be continued until end of outbreak to see how the model is working and the design cold be developed and implemented in similar cases in future.

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