THE FORECASTING AND CONTROL OF CHOLERA EPIDEMICS IN INDIA.¹

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Great Britain has a weighty and world-wide responsibility regarding cholera. During the nineteenth century six great pandemics of cholera spread from India over Europe, and five of them reached America, that of 1840-49 carrying off one million people in Russia and 53,293 in England. The most important route is the overland one through the Punjab and Afghanistan to South Russia, the first great pandemic of 1826-37 having taken five years to travel from Bengal to South Russia in the absence of railways, but the last, in 1892, travelled from the Punjab to Russia in five months with more rapid communications. This may happen again at any time if nothing is done to control the spread in India itself, where severe epidemics continue to occur at irregular intervals, the causation of which has not hitherto been worked out, in spite of the accumulation of monthly cholera mortalities and meteorological data for all British-governed India over a period of from fifty to sixty years. After establishing close relationship between climate and the incidence of leprosy, tubercle, pneumonia and small-pox in India, enabling most epidemics of the last to be foreseen in future, I have now spent nearly two years in tabulating, charting and mapping out over 70,000 data regarding climate and cholera incidence in India, with results which appear to be of considerable practical importance, a brief account of which is given in this paper, with illustrative lantern slides of maps and diagrams to elucidate a somewhat complicated study.

The Century-Old Theory that Cholera Spreads over India in Epidemic Waves from Bengal.

The first great Indian cholera epidemic of which we have good records began in Bengal in the latter part of 1817, declined as usual in the cold weather months in Western Bengal (now Bihar and Orissa), increased again as usual in March, 1818, and spread with a rapidity never since equalled north-west over the United Provinces to the Punjab, and south through Central India, Hyderabad State and the Bombay Deccan, overran Madras by the end of the year, and passed to Ceylon in January, 1819, the Indian Peninsula having been free from cholera for some years previously.

Later writers up to the present time have regarded the course of the 1817-19 epidemic as typical of later ones, and Bryden traced and mapped out several similar epidemics between 1854-68 for Northern and Central India, with which alone he dealt; while fortunately Cornish did the same for the Madras and Bombay Provinces for 1859-70; so I have worked out a map (fig. 2), of the 1863-65 epidemic for all India. Bryden included in his Bengal endemic area, from which all cholera spread over India, Western Assam, all Lower Bengal, Orissa and Eastern Bihar, from which the disease spread in the first year of an epidemic over his Eastern epidemic area extending north-west as far as Agra, and travelled in the second year into the Punjab, this route constituting his northern epidemic highway; or it might spread to the Central Provinces in the first year, and in the second
to Sind and Gujarat by his southern epidemic highway as it did in 1863 and 1864, also infecting Bombay and most of Madras in the latter year as shown by Cornish; and in 1865 both the Punjab and the remaining southeast parts of Madras were overrun, thus completing the spread, an epidemic usually lasting four years before dying down again completely. As late as

1925 the Acting Director of Public Health of Bengal informed the Office Internationale d’Hygiène that Bengal continues to be the home of cholera, from whence it spreads over India. I commenced my inquiry firmly imbued with the truth of this century-old theory, and spent much time in charting the monthly incidence for many years of different divisions of Bengal with comparative climatic data in order to try to discover the causation of the epidemics spreading from Bengal, but without success. Now Bryden,
writing long before the cholera vibrio was discovered, and with only Army and jail data, pointed out that the extension of cholera from Bengal over Northern India could not be explained as a spread through human intercourse, as the disease first increased in the sub-Himalayan divisions of the United Provinces with no railways in his day, and only became epidemic in the Punjab in June with the onset of the monsoon. These facts have never been hitherto explained, because the climatic factor which I have found responsible was not then known, and this factor throws an entirely new light on the whole subject of cholera epidemiology.

Fig. 3.

The Seasonal Incidence of Cholera in India in Relation to Climate.

The two outstanding facts in cholera distribution in India are: (1) the remarkably similar monthly incidence of the disease in each area year by year, although this differs most widely in different parts of India; and (2) the extraordinary variation in the annual incidence of the disease from year to year in the areas liable to epidemics, which has several times amounted to a thousand-fold increase in a whole province in a single year, quite irrespective of the small variations in the sanitary conditions from year to year.
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year. We must evidently first ascertain the reasons for the seasonal variations, for which purpose I worked out the average monthly incidence over a series of years, both for the different provinces and for a number of smaller areas, and studied these in relation to the monthly climatic variations. The results were most instructive, the provincial data being illustrated in the accompanying chart (fig. 3), together with maps giving the rates per mille in each area for the different seasons.

The first point to note is the totally different seasonal incidence in Assam, Lower Bengal and Madras from that of all the rest of India, for in Assam and Lower Bengal cholera is at its minimum during the floods of the south-west monsoon from July to September, rises to its first maximum from October to December, falls in January and February, only to rise to its second maximum from March to May, while in south-east Madras the main rise is in December and January, when the disease is at its minimum in all central and north-west India. In the other provinces cholera is at its minimum in the late autumn and winter months, the single yearly rise commencing in March in Bihar, the sub-Himalayan United Provinces divisions, and in the Eastern Central Provinces; in April in the rest of the United Provinces and the Deccan, but not until May in the Punjab; all pointing to a steady spread from Bengal through Bihar and the United Provinces to the Punjab, although the mystery remains, as pointed out by Bryden, that this apparent spread has not become more rapid with the advent of railway communications, so could not be explained as arising by human intercourse.

Reference to the climatic data shows at once no relationship between seasonal cholera incidence and either rainfall, mean temperature or relative humidity, but when we turn to the absolute humidity data we find the clue to the problem. Now, by absolute humidity is meant the actual amount of moisture in the air as measured by its vapour tension in terms of mercury, and it is essentially a measure of combined heat and moisture, low readings, such as under 0.400, indicating both great dryness and fairly low temperature and vice versa. In the accompanying map (fig. 4) is shown the 0.400 absolute humidity line in India in January, that of February being almost the same, and it will be seen at once that Assam, Lower Bengal and south-east Madras are just those parts where the absolute humidity never falls below 0.400, and they are the only areas with high cholera incidence from December to February, when it is at its minimum in the rest of India. A further map (fig. 6) shows that the absolute humidity first rises to over 0.400 in March in Bihar and the sub-Himalayan divisions of the United Provinces, and next in April in most of the rest of the United Provinces, but not in the Punjab, except in the extreme north-west until May, exactly in the order in which cholera becomes epidemic. Further, the hitherto unexplained temporary decline of cholera in Assam and Lower Bengal in January and February is due to the near approach to the critical 0.400 absolute humidity in those months.
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FIGS. 6 AND 7.
The question whether cholera really spreads yearly from Lower Bengal clearly requires reconsideration in the light of this striking new factor in the problem, as it opens up the question whether it is a spread from Bengal, or whether only a recrudescence with the rising absolute humidity in areas where it is only temporarily suppressed during the low winter absolute humidity. We, therefore, require to define more closely the real endemic areas than has hitherto been done; for this we now have abundant data in regard to the general population mortality figures which were unknown in Bryden's day.

**The Endemic and Epidemic Cholera Areas of India.**

For this purpose I have worked out the data of forty-five divisions for three recent decades with reliable data, and noted in how many years cholera...
was absent from each. All the areas which were never free for a single one of the thirty years are shaded dark in the map (fig. 8) to indicate that they are true endemic areas, and the others are shaded more lightly in accordance with the increasing number of years of complete freedom from cholera. The results are most instructive. They show in the first place that Bryden's one Bengal endemic area forms but about half of one of three endemic areas at the present time, and Western Bihar and the whole of the eastern and sub-Himalayan divisions United Provinces form part of the great Assam-Bengal-Bihar and Orissa United Provinces endemic area. It thus becomes clear that the March rise in Bihar and the sub-Himalayan United Provinces is a recrudescence in an endemic area, and not an epidemic spreading from Lower Bengal. This all-important fact is confirmed by a glance at the map (fig. 9), in which I have entered in each division the
number of epidemic rises in forty-five consecutive years, which show only
from 13 to 16 rises in Lower Bengal, but no less than 17 in the sub-Himalayan
United Provinces, as well as in Assam, which could not have arisen from
a smaller number in Lower Bengal, as recrudescences in one year of an
epidemic commencing in the previous one have not been counted. The
other great endemic centre is the whole of the south-east of the Madras
Presidency, while a third smaller one exists in the low-lying North Konkan
coast districts of Bombay. It is most significant that these last two areas,
as well as Assam and Lower Bengal, never have an average monthly
absolute humidity below 0.400, while in Bihar and the sub-Himalayan
divisions it first rises above that point. The apparent spread of cholera
from Bengal is thus far better explained as a recrudescence in endemic
areas after temporary suppression by low absolute humidity.

It is of very great interest to note that the earlier Sanitary Commissio-
ners of the United Provinces recognized cholera to be endemic there,
and C. Planck, after pointing out that year by year the disease became
epidemic in regular order from east to west, continues thus: "But the
facts of cholera registration, although they witness in every year the same
peculiarity of epidemic prevalence, do not witness any gradual spread
of the disease from east to west. Their evidence only tends to show that
from some peculiarity of climate, or other unknown condition, the disease
becomes locally epidemic later in the year, as the districts are more
westerly." But cases are always "present from end to end of the Province,
apparently ready for increase when favouring circumstances occur." Substituting "absolute humidity over 0.400" for "some peculiarity of
climate," a more striking anticipation of any conclusions could hardly be
imagined, although I only read Planck's reports months after working out
my absolute humidity and endemic area maps.

THE EPIDEMIC AREAS.

Now that the endemic areas of constant cholera have been fairly
accurately defined, we may turn to the typically epidemic ones, from which
cholera has so completely died out for a year or two at a time that the
cases returned as cholera by the village watchmen fell below 0.01 per mille,
and there is strong evidence that such isolated returns are rarely true
cholera. The areas from which cholera has been absent, as just defined, from
three to seven or more of thirty consecutive years, include all the Punjab,
Sind, Gujarat, the Central Provinces, and the Deccan, while in all, except
the Deccan, the Nerbudda division of the Central Provinces and the eastern
Umballa division of the Punjab, the years of absence amounted to five and
over, so the Punjab and the Central Provinces form the two most important
epidemic areas for studying epidemic invasions from neighbouring endemic
areas later in this paper.
THE FREQUENCY OF EPIDEMIC CHOLERA IN ADJACENT DIVISIONS IN RELATION TO ITS SPREAD.

As I soon found that smaller areas than whole Provinces must be studied if the spread of cholera was to be traced, I spent many months in working and mapping out the annual cholera incidence per mille for forty-five years for forty-five divisions of British-governed India, and I have entered on a map (fig. 9) the number of definite rises in incidence in that period in each division, together with the number of years in which the rise took place simultaneously in two adjacent areas, with very instructive results, only a very few of which I have time to allude to. I have already mentioned the larger number of epidemics in the United Provinces than in Bengal, from which they could not all have originated, but the number falls from 17 in Oudh, etc., to only 7 to 11 in the Punjab divisions, but 13 in the North-West Frontier Province with a higher April absolute humidity; so it is clear the Punjab outbreaks may have arisen from the United Provinces, as we shall see later is almost invariably the case. Again, there were 15 rises in Orissa, with the highest cholera incidence in India, due to the Puri pilgrimages, and 13 in the neighbouring eastern Chattisgarh division of the Central Provinces, every one of the 13 being among the 15 epidemic years in Orissa, from which they were derived. Similarly, of the 18 rises in Berar, 17 occurred among the 18 epidemic years in the adjacent North Deccan, whence the disease has often been traced, and once more 14 of the 15 epidemics in the northern Jubulpore division occurred among the eighteen years of high prevalence in the neighbouring Jhansi division of the United Provinces south of the Jumna; so the Central Provinces are invaded from all around, as I shall illustrate by a map later. Similarly, Gujarat and Sind are usually invaded from the North Deccan and Konkan divisions to the south, but occasionally Sind is infected from the Punjab to the north, when the disease begins in the north of Sind. The value of this line of study is thus clear, although it has been singularly neglected owing to the sanitary reports of each Province being prepared in ignorance of those of the same year in adjacent ones.

THE SPREAD OF CHOLERA IN 1875-77 FROM THREE ENDEMIC CENTRES.

The best account I have been able to find of the spread of cholera over India in recent times is that of S. C. Townsend, when acting Sanitary Commissioner in India, from which I have worked out a map (fig. 10), clearly showing that the disease spread from the north-east endemic area over the eastern Central Provinces, and north-west to the Punjab; from the Bombay-Konkan endemic area through the Deccan into the west of the Central Provinces, largely by the Nasik pilgrims, and from Ceylon, or the extreme south of Madras, northwards through nearly the whole of that Province: thus illustrating the quite independent spread from the very three distinct endemic areas I have mapped out, and consequently showing that at least fifty years ago the theory of spread all over India from Bengal was no longer true.

(To be continued).