Stillbirth rates and its spatial patterns in India: An exploration of HMIS data

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Summary

Background High prevalence of stillbirths is a significant concern for the health system of India. This necessitates a closer scrutiny of the prevalence, spatial pattern and the risk factors of stillbirth at both national and local level.

Methods We analysed stillbirth data of three financial years (April 2017–March 2020) from Health Management Information System (HMIS) of India which provides majorly public facility level data for stillbirths up to the district level on a monthly basis. National and state level prevalence of stillbirth rate (SBR) were estimated. Spatial patterns of SBR at district level was identified using local indicator of spatial association (LISA). Risk factors of stillbirths were studied by triangulation of HMIS and National Family Health Survey (NFHS-4) data using bivariate LISA.

Findings National average of SBR in 2017–18, 2018–2019 and 2019–2020 are 13.4 [4.2–24.2], 13.1 [4.2–22.2] and 12.4 [3.7–22.5] respectively. Districts of Odisha, Madhya Pradesh, Rajasthan and Chhattisgarh (OMRC) form a contiguous east-west belt of high SBR. Body mass index (BMI) of the mother, antenatal care (ANC), maternal anemia, iron-folic acid (IFA) supplementation and institutional delivery show significant spatial autocorrelation with SBR.

Interpretation Maternal and child health programme delivery should prioritise targeted intervention in the hotspot clusters of high SBR, considering the locally significant determinants. The findings show inter alia, the need to focus on ANC to reduce stillbirth in India.

Funding The study is not funded.

Keywords: HMIS; Stillbirths; Stillbirth rate; Spatial patterns; NFHS-4

Introduction

Stillbirth is one of the serious maternal and child health problems across the globe. Stillbirth rate (SBR) is defined as the number of babies born with no sign of life at 28 weeks or more of gestation, per 1000 total births. Globally 13.9 stillbirths per 1000 births have been reported in 2019.[1,2] More than one third of these stillbirths were concentrated in India (17.3% with SBR 13.9) along with Pakistan (9.7%) and Nigeria (8.7%).[2] Pregnancy complications, including anaemia, eclampsia and other hypertensive disorders, antepartum and intrapartum haemorrhage, abnormal fetal position, breech presentation and obstructed labour significantly increase the odds of stillbirth.[3] Hence high incidence of stillbirths is a reflection of status of the antenatal care (ANC) in a given region.[2] Although maternal and child mortality rates have fallen in India over the past two decades, the high magnitude of stillbirths has not received much attention and not included as a specific target in the Sustainable Development Goals (SDGs).[2] However, in response to the global Every New-born Action Plan (ENAP) launched at the World Health Assembly (2014) to attain 'Single Digit Neonatal Mortality Rate (NMR) by 2030' and 'Single Digit SBR by 2030', Indian government developed New-born Action Plan (INAP) for the country.[4]

Though the Sample Registration System (SRS) is the preferred source for estimates of mortality rates in

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Research in context

Evidence before this study

Literature review on published work was done in PubMed and Google Scholar using the search terms "HMIS", "stillbirth in India", "stillbirth rate", "factors affecting stillbirth". Sample Registration System (SRS) and Annual Health Survey (AHS) though have documented stillbirth rate (SBR) in India but the information of SBR at local level was not optimum. In individual cohort studies, stillbirth and its risk factors were studied for selected states, such as Bihar, Haryana and Chandigarh, using population-based case control study. One of the population-based survey in Bihar reported an increased risk of stillbirths in deferred and referred deliveries in addition to demographic and clinical risk factors for antepartum and intrapartum stillbirths. A systematic literature review exploring factors associated with stillbirth in low- and middle-income countries reported advanced maternal age as a significant risk factor associated with stillbirth in many developing countries.

Added value of this study

There are limited studies in India that has looked at prevalence of stillbirth at both national and at micro level. This study fills that gap using Health Management Information System (HMIS) data that provides facility level data of stillbirths at the micro level of the district. In comparison to other database such as SRS or AHS, use of HMIS database in the present analysis has given understanding of stillbirth at more local level. This study has presented the high burden clusters of stillbirth in India through univariate local indicator of spatial association (LISA), which is a useful technique in finding the local pockets of nonstationarity or hotspots. This study has also documented the geospatial correlation of stillbirth and its predisposing factors using bivariate LISA. Bivariate LISA assesses the relation between two different variables together, in an area and in its nearby areas (spatial lag). Identifying the hotspots of high stillbirth prevalence in India will help the policy makers to design focused intervention in the prioritized area and sensitize the local government to implement the same.

Implications of all the available evidence

Two broad components such as (i) maternal health in terms of age, body mass index (BMI), haemoglobin status and (ii) compliance towards health facility utilisation, such as antenatal care (ANC), IFA consumption, institutional delivery have been identified as determining factors to prevent stillbirths in India. Overall, antenatal check-up is coming out as a very crucial factor which can address all the afore-mentioned factors. Proper training of community health and nutrition workers ('ASHAs' and 'Anganwadi workers') on early identification of high-risk pregnancies and awareness generation on compulsory and full ANC visits (at least four during the entire duration of pregnancy) could facilitate addressing the stillbirth issue. Bivariate LISA mapping technique will help to make targeted action plan and focused intervention with key messages for the corresponding clusters.

India, it provides data only up to the state level.[5] Health Management Information System (HMIS) is the only regular source of public facility level data on maternal and child health indicators in India below the state level.[6] It provides the data on various maternal and child health indicators right up to sub-district level since 2008.[7] To the best of our knowledge, analysis of stillbirth prevalence at national and local level in India using country-wide database is not available in literature. The present analysis therefore looks at the HMIS database to (i) understand the existing prevalence of stillbirth for three years prior to the pandemic, (ii) identify the spatial patterns of SBR and high burden clusters (hotspots) and (iii) study the possible risk factors of stillbirth using triangulation of National Family Health Survey (NFHS-4) and HMIS dataset.

Methods

Database, data input and processing

The study used the data from two national health database i.e. HMIS[7] (2017–18, 2018–19, 2019–20), and NFHS-4.[8] HMIS database largely provides public health facility service-based data on maternal, neonatal, child and adult health indicators at the national, district and sub-district level.[6] The reporting timeline for HMIS is the financial year calendar, from April–March, in line with the health budgets which follow the same calendar. This web-based monitoring information system is used for the monitoring and evaluation of government health programmes.[6] NFHS-4 is a quadrennial national survey, collecting information on indicators pertaining to demographic, health and nutrition status for various age and physiological groups both at state and district level involving about 600,000 households.[9]

For the present study, secondary data of stillbirths was pooled from the open access online available database of HMIS portal (https://hmis.nhp.gov.in/#!/)[7] using python pandas in a desired format as required for analysis. HMIS is a facility-based report majorly collecting data from public facilities across the country with meagre reporting from private facilities.[6] To ensure reliability and validity of data, HMIS uses various steps in terms of tracking missing values, double-checking of outliers, and inter-data validation. Pre-set criteria are used by HMIS to maintain internal logical consistency in reporting of various indicators.[6] At our end, we also checked the consistency of the stillbirths data across the three years by regressing state level stillbirth data of 2018–19 and 2019–20 on the data of 2017–18.[7] The risk factors for antepartum and intrapartum stillbirth such as institutional delivery, caesarean section delivery, home delivery conducted by skilled health personnel, women married before 18 years of age, women having body mass index (BMI) below normal (BMI <18.5 kg/m2), pregnant women aged 15–49 years who are anaemic, mothers who consumed iron-folic acid (IFA) tablet for 100 days or more when they were pregnant, mothers who had antenatal check-up in the first trimester, mothers who had at least four ANC visits and mothers who had full ANC were taken from NFHS-4 (2015–16). NFHS-4 data was extracted from the district factsheet.[8]

Prevalence of stillbirth rate

While HMIS is a facility-based data, it does report on births, both through institutional and home deliveries. It provides the data on total live births and associated birth details. The primary outcome variable, SBR was computed as total number of stillbirths per 1000 total births (live births + stillbirths). SBR was also computed for four categories i.e., deliveries in rural and urban India, deliveries conducted in public and private health facilities.

Spatial pattern of stillbirth rate

The current study aimed to explore the spatial heterogeneity of SBR across the districts of India. Geospatial techniques of local indicator of spatial association (LISA) was applied to identify the spatial distribution of stillbirth burden in India in terms of the hot spots and cold spots. When the values for a random variable tend to cluster in space, it is termed as positive spatial autocorrelation and when a region tends to be surrounded by neighbours with very dissimilar values, it is termed as negative spatial autocorrelation. The neighbours were identified using the 'Queen contiguity' which is based on shared vertices and boundaries, and the spatial weight matrix was computed by giving a value of 1 and 0 to the neighbours and non-neighbours respectively. Similarly, the spatial lag variables were generated by summing the products of these spatial weights and each of the neighbourhood values. The degree of spatial autocorrelation that exists in a dataset across the geographical unit was quantified by Moran's *I*. A Moran's *I* value ranges from −1 to +1; value close to +1.0 signifies clustering, zero signifies randomness and a value close to −1.0 implies dispersion.[10,11]

Moran's *I* is defined as

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} (X_i - \overline{X}) (X_j - \overline{X})}{\sum_i (X_i - \overline{X})^2} \quad (1)$$

where N is the number of spatial units indexed by I and j; X is the variable of interest; $\overline{X}$ is the mean of X; and w_{ij} is an element of a matrix of spatial weights.

The LISA statistics were illustrated using two maps i.e., the cluster map and significance map. The cluster map reveals four different geographical clusters of the study variable. The 'high–high' category, or the hotspots, indicate districts having an above-average prevalence of the parameter with the neighbours also sharing above-average values as well. Likewise, the 'low–low' category or the cold spots show below-average prevalence surrounded by regions having below-average values. The 'high-low' category shows the regions with above-average values of the study variable, surrounded by regions having below-average values, and the opposite of this comes under the 'low-high' classification. The districts with significant local Moran statistics were reflected through different shades of green in the LISA significance map and these significant districts colour coded by the type of spatial autocorrelation was illustrated in the LISA cluster map. The prevalence of stillbirths using district level data of HMIS is shown with univariate LISA cluster and significance map (p = 0.1) for three years from 2017–18 to 2019–20. Univariate LISA with the SBR data for different years was initially plotted at significance level 0.05, which showed similar hotspots of SBR as brought out at significance level 0.1. The Moran's *I* was significant for all the graphs at significance level 0.05 as well as at 0.1. However, significance level was considered at 0.1 as the clustering of SBR became more pronounced at this level.

Risk factors of stillbirth in India

The bivariate LISA technique was applied to study the geo-correlation between SBR and its risk factors. Bivariate LISA assesses the relation between two different variables together, in an area and in its nearby areas (spatial lag). The bivariate LISA considers two different variables, one for the location and another for the average of its neighbours. The calculated SBR from HMIS data is taken as the outcome variable, and the other data—exposure variables, are taken from the fourth round of NFHS. We only included those districts in our analysis which were part of both datasets, NFHS-4 and HMIS for the year 2015–16 for bivariate LISA. We didn't consider the data from NFHS-5 (2019–21) for bivariate analysis as NFHS-5 data was collected both in pre-pandemic and post-pandemic scenario while this study considered only the pre-pandemic data from

HMIS. The various exposure variables studied with respect to the SBR were institutional delivery, caesarean section delivery, home delivery conducted by skilled health personnel, women married before 18 years of age, women having BMI below normal (BMI <18.5 kg/m2), pregnant women aged 15–49 years who are anaemic, mothers who consumed IFA tablets for 100 days or more when they were pregnant, mothers who had antenatal check-up in the first trimester, mothers who had at least four ANC visits and mothers who had full ANC. Hence, the spatial autocorrelation between the predictor variables and the weighted average of SBR (dependent variable) was measured using the bivariate LISA. These spatial analyses were conducted using GeoDa 1.8 and QGIS 3.16.13.

Role of funding source
The study is not funded.

Results

Prevalence of stillbirth

The SBR data from the HMIS is quite consistent during the studied years from 2017 to 2020. The consistency was found very high in the linear fit with $R^2 = 0.99$ and a slope close to 1 (0.99 and 0.95) [Supplementary Fig. S1]. SBR at the all- India level is found 13.4 (n = 277,942), 13.1 (n = 272,688) and 12.4 (n = 263,331) in 2017–18, 2018–2019 and 2019–2020 respectively [Supplementary Table S1]. In all the three consecutive financial years, high SBR is observed across different districts in Chhattisgarh, Madhya Pradesh (MP), Odisha, Rajasthan in the central belt; Assam, Meghalaya, and Tripura in the northeast along with Delhi and Chandigarh (Union Territories) [Figs. 1(a), (c), (e)]. The northern belt starting from Himachal and Uttarakhand till West Bengal (WB) through Punjab, Haryana, Uttar Pradesh (UP) and Bihar is found in the intermediate SBR range, though worry about the quality of data does remain in case of UP and Bihar. The low figures of stillbirth data from UP and Bihar would merit a cross verification from an independent survey data. All the southern states, Andhra Pradesh, Kerala, Tamil Nadu (TN), Telangana along with Goa, Maharashtra and Gujarat have low SBR across three consecutive years with Kerala performing the best [Supplementary Table S2]. Two districts in Arunachal Pradesh have reported no stillbirths in 2019–20. About 518 districts have reported consistent trends in SBR across the three years (2017–18, 2018–19 and 2019–20) while 179 districts have reported variation in SBR in consecutive years [Supplementary Tables S3 and S4]. The prevalence of SBR across urban, rural and private, public institution deliveries has not changed much in the last three consecutive years [Supplementary Tables S1, S5–S7].

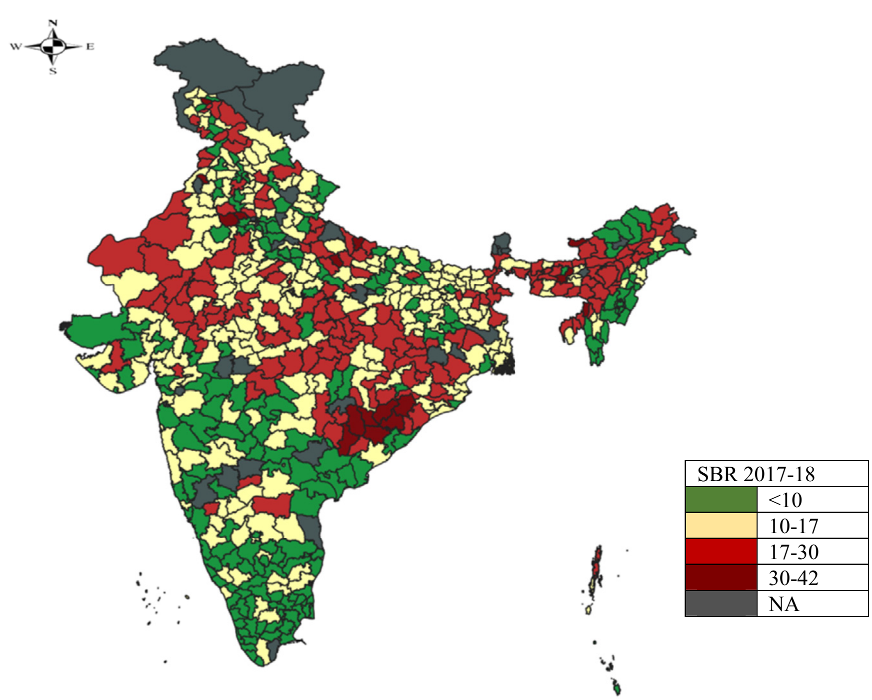

Fig. 1a: **Prevalence of stillbirth rates across the districts in India, HMIS 2017–18 (Moran's *I*: 0.372).**

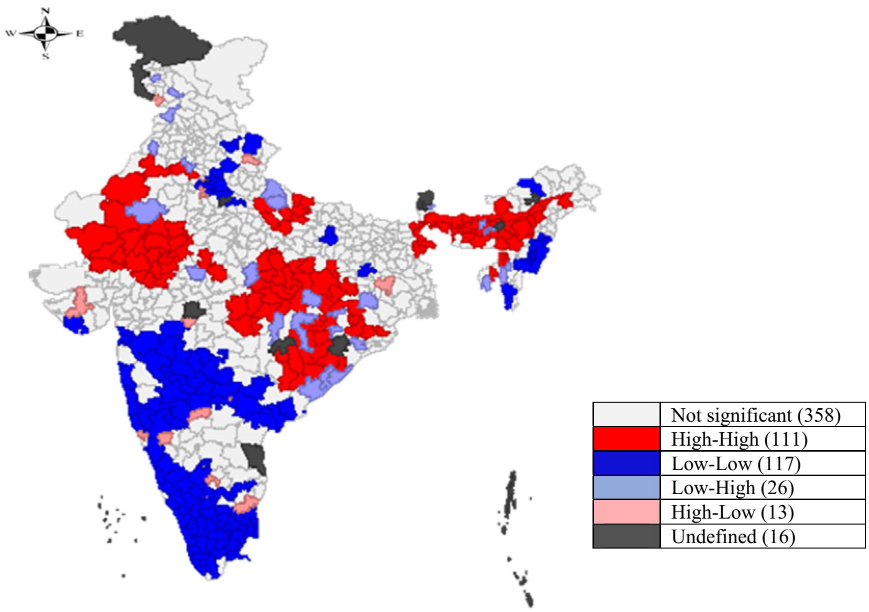

Fig. 1b: **Univariate LISA cluster map of stillbirth rates across the districts in India, HMIS 2017–18 (*p* = 0.1)**. Note: Presents 111 districts (majorly in Odisha, Chattisgarh, MP, Rajasthan, Assam, Meghalaya and Arunachal Pradesh) in high–high clusters, 117 districts (majorly in Kerala, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh) in low–low clusters, 26 districts (discreetly in UP, MP, Rajasthan, Odisha and Chattisgarh) in low-high clusters, 13 districts (discreetly in Gujarat, Karnataka, Tamil Nadu) in high-low clusters.

Spatial pattern of stillbirth rate in India

The prevalence of stillbirths using district level data of HMIS is presented with univariate LISA cluster maps [Figs. 1(b), (d), (f)]. All clusters are significant at p=< 0.1 for SBR [Supplementary Fig. S2 (a), (b), (c)]. Significant hotspot clusters of high SBR are observed in 75 districts (2019–20). There is one contiguous east-west belt from Odisha to Rajasthan through Chhattisgarh and MP, and another in the north-eastern states. The contiguous belt of hotspots is found to persist over the period from 2017–18 to 2019–20. Cold spots having 88 districts (2019–20) are observed mostly in the states of Maharashtra, Kerala, TN, Andhra Pradesh. A distinct north–south divide is found to exist with the southern states forming a contiguous belt of low SBR and the northern-central belt with high SBR. On the other hand, nine districts show high SBR surrounded by regions having below average SBR (2019–20). About nine districts are found in the 'low-high' category which can be considered as the positive deviant districts as these districts have below average rates of stillbirths surrounded by districts having above average SBR (2019–20) [Figs. 1(b), (d), (f)].

Risk factors of stillbirth

The prevalence of stillbirths for FY 2015–16 is presented with univariate LISA cluster and significance map [Supplementary Fig. S3 (a), (b), (c)]. More than 300 districts have SBR of 15 and more. Significant clusters of high–high spatial association are observed in 61 districts, mostly from the states of Odisha, Chhattisgarh, MP, Rajasthan, Maharashtra, UP and the north-eastern states. About 95 districts show 'low–low' associations. Moran's *I* value for SBR was 0.4. Institutional delivery, caesarean delivery, early age marriage, low BMI of mothers, pregnant mothers availing ANC and consuming IFA tablets show the strongest spatial distribution with Moran's *I* value of 0.7 [Supplementary Table S8]. Maternal anemia, mothers availing ANC in first trimester and delivery attended by skilled health personnel show moderate spatial distribution (Moran's *I* = 0.4–0.6). All these risk factors, show significant but mild spatial autocorrelation with SBR in the bivariate LISA [Supplementary Table S9].

The bivariate LISA maps for SBR against the correlates are presented in Figs. 2–5, significance maps in Supplementary Figs. S4, S5, S6, S7 and the bivariate Moran's *I* values in Supplementary Table S9. Correlates like BMI of the mother, ANC, IFA supplementation and caesarean deliveries, show relatively stronger significant spatial autocorrelation with SBR. A significant positive spatial autocorrelation is seen between SBR and mothers having below normal BMI (Moran's *I* = 0.24) and anaemia in pregnant women (Moran's *I* = 0.20). A significant negative spatial autocorrelation is seen between SBR and other correlates, namely mothers having caesarean delivery (Moran's *I* = –0.29), full ANC

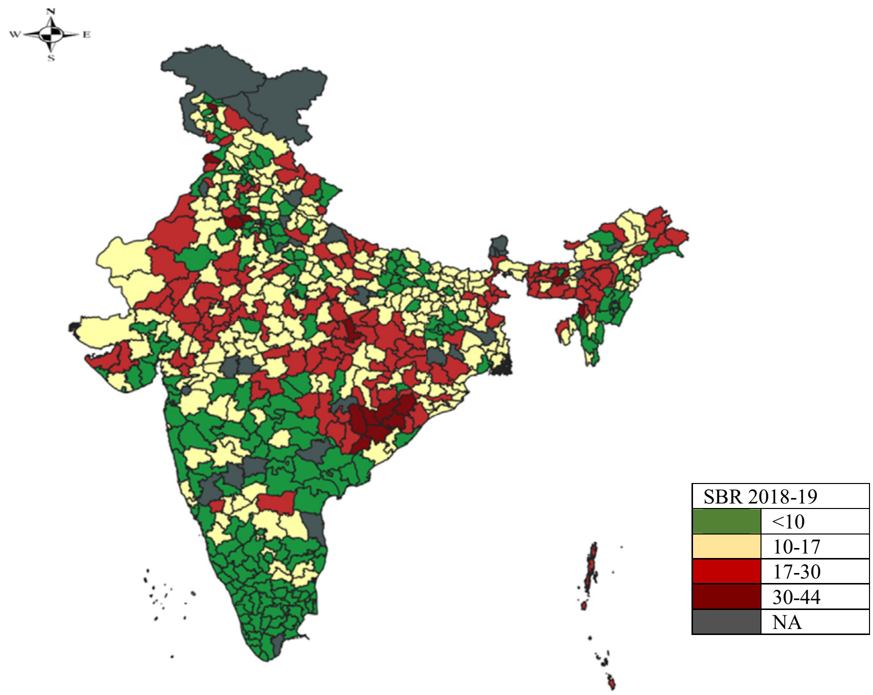

Fig. 1c: **Prevalence of stillbirth rates across the districts in India, HMIS 2018–19 (Moran's *I*: 0.4).**

(Moran's $I = -0.24$), and mothers who consumed IFA for 100 days or more during pregnancy (Moran's $I = -0.23$).

Bivariate LISA cluster map of SBR with mother's BMI, indicates that about 55 of 640 districts had above average SBR and high percentage of mother's having below normal BMI. These districts are in the states of Odisha, MP, Chhattisgarh, Rajasthan, and UP. About 76 districts, majority from Kerala and TN, have low percentage of mothers having poor BMI as well as low SBR [Fig. 2]. Significant clusters of districts having both high SBR and high prevalence of anaemia among pregnant women are found in 51 districts located mainly in Odisha, MP, Chhattisgarh, Rajasthan, and Assam whereas 63 cold spot clusters are found in Kerala, Manipur, Mizoram, and southern Karnataka [Fig. 3]. Inverse spatial correlation between SBR to that of mother's having compliance to full ANC and caesarean section deliveries are observed to form significant clusters [Figs. 4 and 5]. It can also be noted that districts having above average prevalence of ANC visits and consumption of IFA are having low rates of stillbirths.

Discussion

The overall rate of stillbirth from HMIS dataset is found to be about 12.9 per 1000 total births during 2017–2020. Across the years, though the rate didn't change much but widely varied across the states with lowest SBR in Kerala (3.7) while highest in Chandigarh (22.5) and Meghalaya (22.3) in 2019–20. Previously, similar wide regional variation in stillbirth (4.2 to 14.8 with average SBR 10 per 1000 total births) was documented in the analysis of Annual Health Survey (AHS) from nine Indian states.[3] To the best of our knowledge, this is the first study which has documented stillbirth spectrum across the nation over three years and analysed the spatial patterns as well as risk factors of SBR using large scale data at the national, state and district level. High SBR is found to be concentrated in the central belt of the country covering the districts of Chhattisgarh, MP, Odisha, and Rajasthan. Delhi, Chandigarh and north-eastern states such as Sikkim, Meghalaya, and Tripura have also reported consistently high SBR for the three consecutive financial years. The findings from the spatial analysis have pointed the need of special attention to bring in these hotspot areas.

Though the completeness and consistency of the HMIS data in terms of childbirth are asserted in literature, abnormally low prevalence of stillbirth data in UP and Bihar is of concern which needs a separate scrutiny.[12] Several other studies have also reported similar concern.[13–16] These discrepancies could be due to the reporting of stillbirth in HMIS largely at the facility level whereas community-based stillbirths (mainly for home deliveries) are grossly under-reported. It is pertinent to

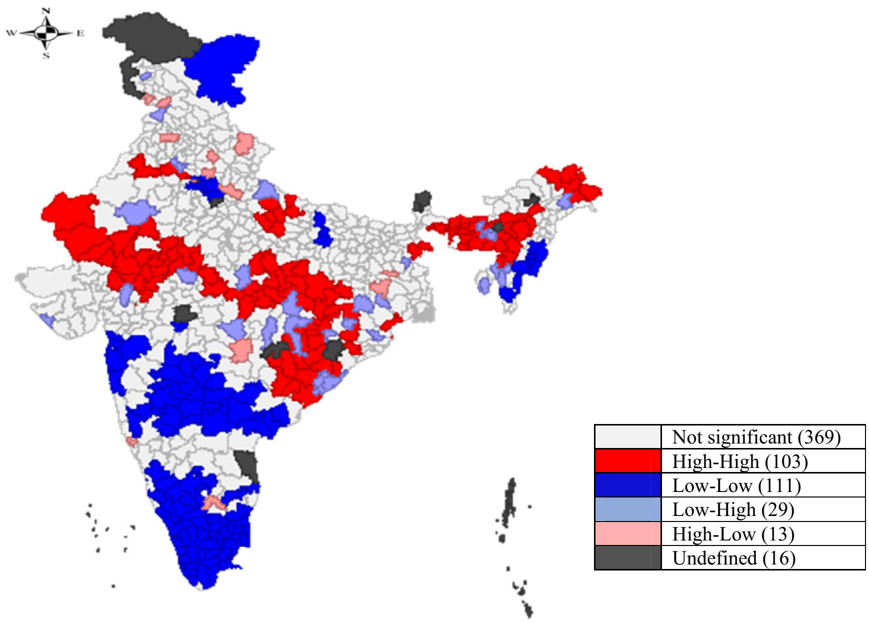

Fig. 1d: **Univariate LISA cluster map of stillbirth rates across the districts in India, HMIS 2018–19 (*p* = 0.1)**. Note: Presents 103 districts (majorly in Odisha, Chattisgarh, MP, Rajasthan, Assam, Meghalaya and Arunachal Pradesh) in high–high clusters, 111 districts (majorly in Kerala, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh) in low–low clusters, 29 districts (discreetly in UP, MP, Rajasthan, Odisha and Chattisgarh) in low-high clusters, 13 districts (discreetly in UP, Uttarakhand, Maharashtra, Tamil Nadu) in high-low clusters.

point out that UP and Bihar together account for 70% of the home deliveries in the country as observed in the HMIS data of 2019–20. The under-reporting of stillbirths might be because of societal stigma towards miscarriage/unsuccessful pregnancy or misclassification with neonatal deaths due to lack of uniformity in reporting practises of primary health professionals. It is therefore important to closely examine the reporting of stillbirths data in HMIS to identify the hot spots at the micro as well as macro level and recognize it as an early marker of the efficacy of the maternal and child health programme.

The spatial clustering of SBR have been observed in the specific geographic pockets having high early marriages, poor maternal nutrition in terms of low BMI and high maternal anemia, poor compliance of full ANC and IFA tablet consumption. Therefore, bivariate analysis of stillbirth and its possible correlates may help to design focused intervention. Spatial autocorrelating clusters of high stillbirth along with high prevalence of maternal anemia and low maternal BMI are observed in Odisha, MP, Rajasthan and Chhattisgarh (OMRC cluster). These states are observed to perform poorly on health outcomes, especially related to maternal health. This could be due to poor socio-economic status of population as low socioeconomic status has been evidenced to be significantly associated with stillbirth.[17] Lower maternal education and maternal unemployment are found to be associated with 1.9 and 1.6 times higher odds of stillbirth respectively. This might be because of less awareness among women due to lack of enough empowerment, delaying their decisions about healthcare utilisation.[17,18] Thereby, in the present study, clusters in southern India reported low SBR with high incidence of caesarean delivery indicating better access of women to the health facility. Same argument supports the spatial autocorrelated clusters observed in OMRC with low caesarean delivery and high stillbirth because of poor compliance to the health facility. Significant negative Moran's *I* value for bivariate correlation between institutional delivery and SBR further supports this phenomenon.

When health facility is concerned for pregnant mothers, antenatal check-up becomes very crucial. Population based study in Haryana estimated 24% of stillbirth and perinatal deaths could be prevented every year through improved use of ANC services.[19] AHS based study indicated that women attending <4 ANC visits had 8% higher odds of stillbirth compared to women visiting ≥4 ANC check-ups.[3] The corresponding bivariate results of the present study also has reported significant high-low clusters, i.e., clusters having high compliance to ANC and low stillbirths, primarily located in the southern part of India. Higher odds of stillbirth was documented in meta-analysis to be associated with pregnancy-induced hypertension, pre-eclampsia and

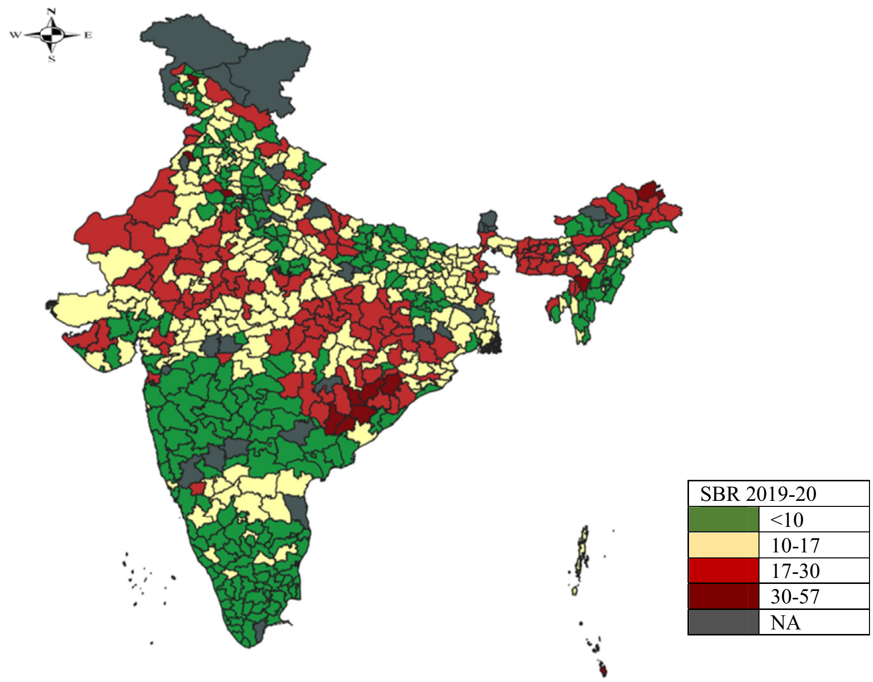

Fig. 1e: **Prevalence of stillbirth rates across the districts in India, HMIS 2019–20 (Moran's *I*: 0.372).**

eclampsia, antepartum and intrapartum haemorrhage due to obstetric complications, abnormal fetal position and obstructed labour.[20–22] If these complications are detected timely and appropriately managed, the risk of stillbirth can be reduced. Thus ensuring complete antenatal check-up is essential to reduce the stillbirth in India especially in the hotspot clusters.

Ensuring ANC visits will not only help in early diagnosis of complications but also helps in better compliance of IFA tablets as maternal anemia during pregnancy is known as a strong predisposing factor for increased risk of stillbirth (3.7–16 times higher odds).[23,24] The present study in its bivariate LISA analysis also has reported significant bivariate correlation between anemia among 15–49 years old pregnant women and stillbirth (Moran's I 0.2, $p = 0.001$). Clusters having both high maternal anemia and stillbirth are found to be located in the same OMRC cluster. This could be due to low coverage of health programmes, inadequate physical health infrastructure and poor quality of ANC leading to the high prevalence of stillbirths. Therefore, measures are needed to be taken to address these specific issues to improve maternal and child health in these districts and reduce stillbirth.

The results from the AHS (2010–13) based study covering nine high burden stillbirth states in India recognised the need to investigate quality of pregnancy care and identification of risk factors separately for antepartum and intrapartum stillbirths in India.[3] A population-based survey of births in the state of Bihar in India found that deferred delivery, minimal ANC during pregnancy, foul smelling discharge and private facility aided child birth had significantly higher odds of antepartum, while position of the baby and women from households using solid fuel had significantly higher odds of intrapartum stillbirths.[25] Higher maternal age, primigravidae, home delivery and delivery by push/forceful pull by health provider were significantly associated with both types of stillbirths.[25] Although our study has attempted to study some of the maternal and pregnancy related risk factors from NFHS-4 with respect to the SBR from HMIS, there is a need to collect the data in a way that ensures excellent capture of ante and intrapartum causes of stillbirths. This critical information if captured in HMIS can then lead to targeted interventions to reduce stillbirths.

While reporting the spatial distribution of SBR in India for the first time at district level, using large public domain facility level database remains the strength of the study, it still encountered a few limitations. Data inconsistency in terms of low reporting of stillbirth in a few states could pose challenges in interpreting the output of the analysis. Reports in HMIS for urban and private facility-based deliveries are grossly under-reported. Limited data availability of stillbirths in urban areas and private heatlh facilities due to poor coverage of these sectors in HMIS is a challenge for

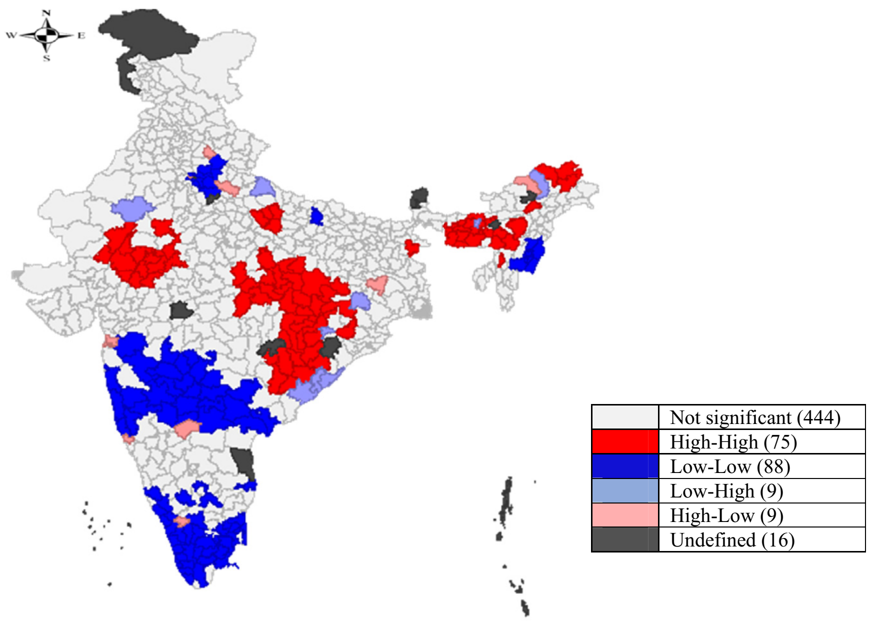

***Fig. 1f*: Univariate LISA cluster map of stillbirth rates across the districts in India, HMIS 2019–20 (*p* = 0.1)**. Note: Presents 75 districts (majorly in Odisha, Chattisgarh, MP, Rajasthan, Assam, Meghalaya and Arunachal Pradesh) in high–high clusters, 88 districts (majorly in Kerala, Tamil Nadu, Maharashtra and Andhra Pradesh) in low–low clusters, 9 districts (discreetly in UP, Rajasthan, Odisha) in low-high clusters, 9 districts (discreetly in Maharashtra, Kerala, West Bengal) in high-low clusters.

reporting absolute estimates. An array of antepartum and intrapartum risk factors of stillbirths could not be studied in-depth due to the limited data availability in HMIS though an attempt was made to find the spatial correlates through triangulation method using NFHS-4 dataset. Data from NFHS-5 (2019–21) could have been used for better triangulation with pre-pandemic HMIS data but could not be opted as NFHS-5 data was collected in two phases of pre pandemic and post-pandemic.

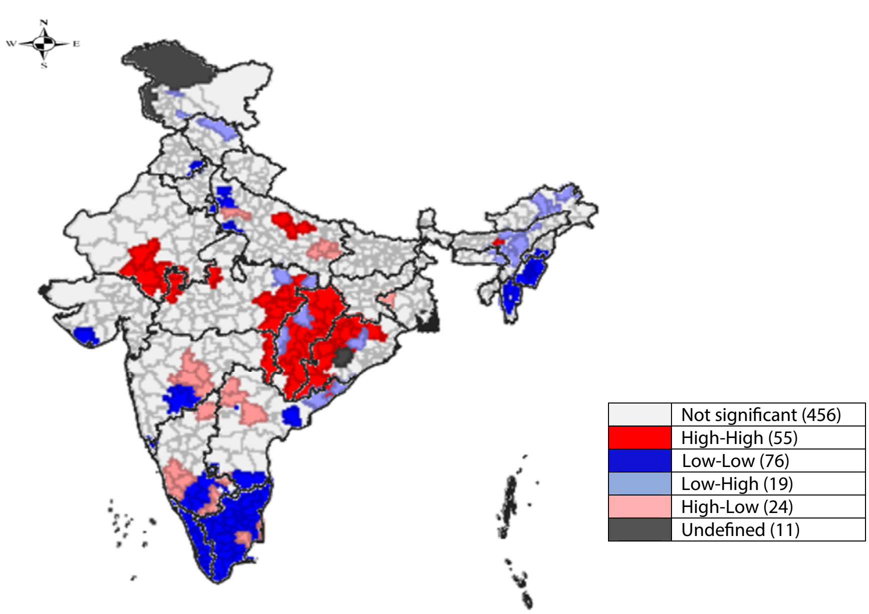

***Fig. 2*: Bivariate LISA cluster map of stillbirth rates and mothers having low BMI across the districts in India, 2015–16**.

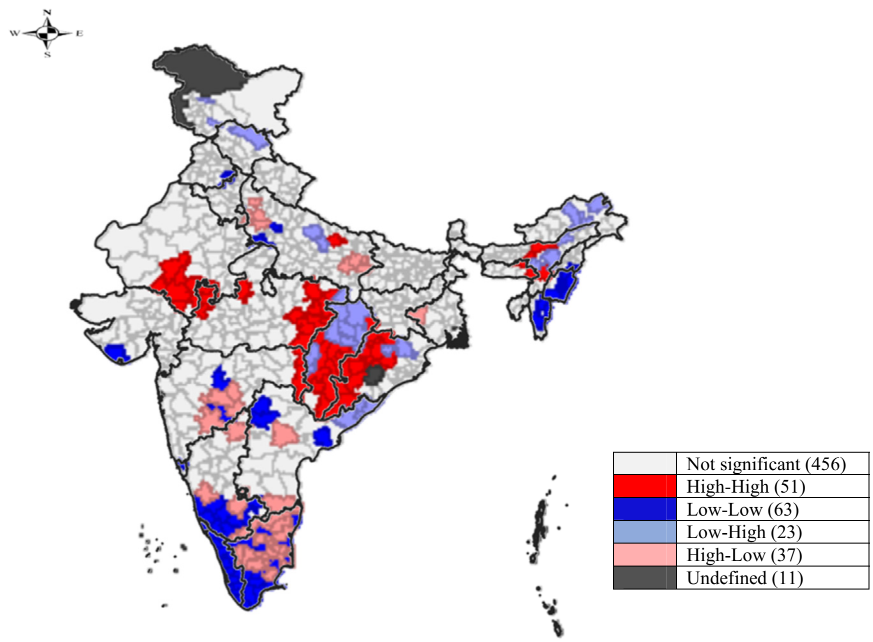

Fig. 3: **Bivariate LISA cluster map of stillbirth rates and anaemia in pregnant women across the districts in India, 2015–16.**

In summary, this study has presented the high burden clusters of stillbirths in India using HMIS database. Use of HMIS database in the present analysis has given understanding of stillbirth at a more local level as compared to other database such as SRS or AHS. A contiguous east-west belt of high SBR from Odisha to Rajasthan through Chhattisgarh and MP, along with north-eastern states trail has been observed. This study has also documented the spatial correlation of stillbirth and its predisposing factors. Two broad components

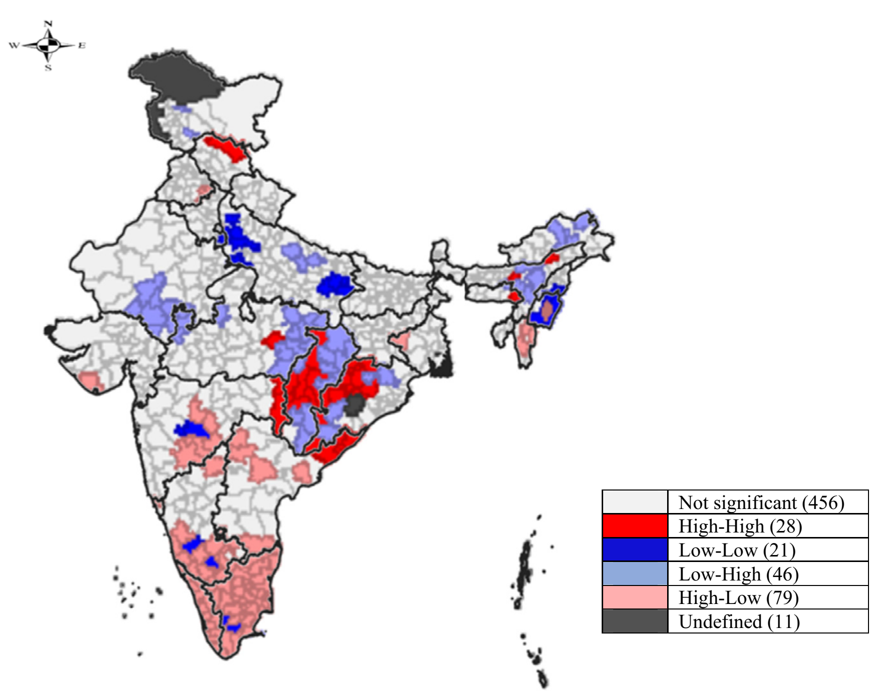

Fig. 4: **Bivariate LISA cluster map of stillbirth rates and full ANC across the districts in India, 2015–16.**

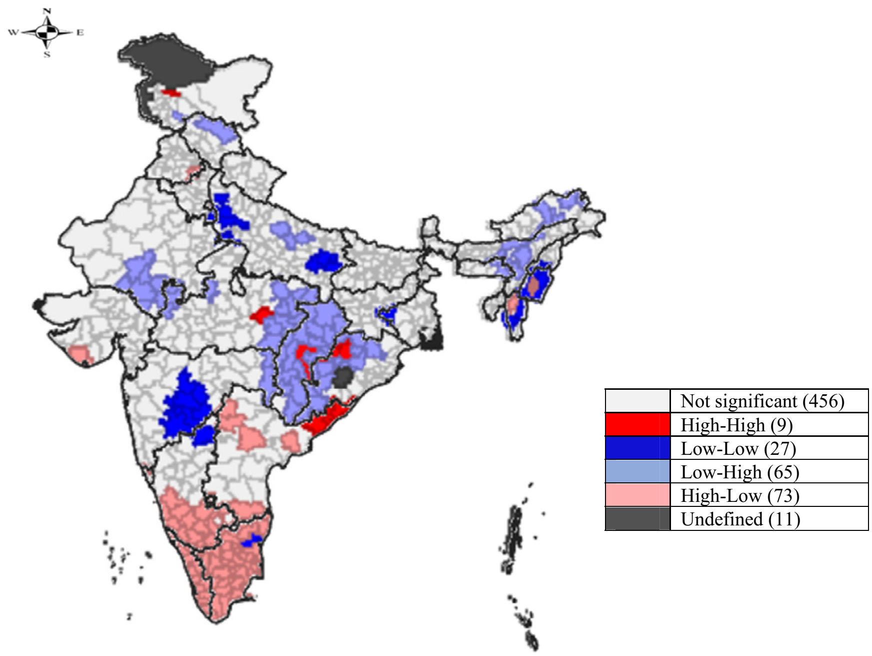

Fig. 5: **Bivariate LISA cluster map of stillbirth rates and caesarean section delivery across the districts in India, 2015–16.**

such as (i) maternal health in terms of age, BMI, haemoglobin status and (ii) compliance towards health facility utilisation, such as ANC visit, IFA consumption, institutional delivery have been identified as determining factors to reduce stillbirths in India. Overall, antenatal visit is coming out as a crucial factor which could address all the afore-mentioned factors. ANC can timely identify and effectively manage pregnancy complications as well as deliver the preventive measures for maintaining good health and nutritional status during pregnancy. Proper training of community health and nutrition workers ('Accredited Social Health Activists' and 'Anganwadi workers') on early identification of high-risk pregnancies and awareness generation on compulsory full ANC would facilitate to control the stillbirth issue. In this regard, bivariate LISA mapping technique will help to make targeted action plan and focused intervention with key messages for the corresponding clusters. It is important that health workers and community are encouraged and trained to destigmatise the issue of stillbirth so that mystery of low stillbirths can be reduced and proper reporting can be ensured. At the same time, focused intervention at the district level in the hotspot clusters considering the locally significant determinants should be prioritized in the maternal and child health programme delivery.

Contributors

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Data sharing statement

The HMIS and NFHS-4 data utilised in the study is publicly available and downloadable at https://hmis.nhp.gov.in/#!/and http://rchiips.org/nfhs/districtfactsheet_NFHS-4.shtml. Since secondary data is used for the entire analysis, the study does not require approval from institutional review board (IRB) of IIT-Bombay as per official communication by the Chairman of IRB of IIT-Bombay.

Declaration of interests

None exists.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lansea.2022.100116.

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