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Economic losses due to hemorrhagic septicaemia in India

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ABSTRACT

Hemorrhagic Septicemia (HS) is one of the most widely reported diseases in India. The present study aims to estimate economic losses due to it. The study uses a stratified multistage sampling technique, covering the major agro-climatic regions of the country, to ascertain the morbidity and mortality rates of HS. The sample size comprised of 10,839 dairy animals. The economic loss due to HS in bovines was worked out as sum of mortality loss, direct milk yield loss, losses due to increased abortions, drought power loss, cost of treatment and extra labour costs. Simple mathematical models were developed for the purpose of computing component-wise losses due to the disease. The economic loss per animal due to HS in India was estimated ₹ 11,904; ₹ 13,044 and ₹ 20,296 in case of indigenous and crossbred cattle and buffaloes, respectively. The share of buffaloes in total economic loss was highest (55%), followed by indigenous (28%) and crossbred (16.5%) cattle. Taking into account the uncertain ties associated the epidemiological and economic parameters, stochastic modeling was used to estimate the economic impact of HS. The expected annual economic loss due to HS in India ranges from ₹ 58.63 billion to ₹ 175.72 billion; the most likely range of expected economic losses is between ₹ 126.28–127.58 billion. Thus, from policy perspective, HS is one of the most important diseases when it comes to mitigating losses due to diseases in dairy animals.

Keywords: Bovines, Economic impact, Hemorrhagic Septicaemia, Morbidity, Mortality, Stochastic estimates

Hemorrhagic Septicemia (HS), an acute and highly fatal septicaemia with high mortality rate (≈60%), is one of the most widely reported diseases in India. It has emerged as a disease of considerable economic importance in India where cattle and buffaloes are large in number (as reported by National Animal Disease Referral Expert System, around 97% of the HS outbreaks occur in large ruminants). Several researchers have documented economic losses due to HS in India. Singh *et al.* (2014) had reported annual economic loss of ₹ 52.54 billion in India due to bovine HS based on morbidity and mortality rates reported in various survey studies (based upon clinical symptoms) from four Indian states (mostly from northern and western regions of the country) carried out at different times during the period 2000–2012. The morbidity and mortality rates, as obtained from the survey studies, carried out in few locations, were scaled up to the national level. Thus, the estimates of economic loss as obtained from such studies were not based on representative sample. Govindaraj *et al.* (2017) had documented economic losses due to HS, however, this study was restricted to Karnataka. Further, the mathematical models used in these studies were deterministic, based upon single values of various epidemiological and economic parameters. Such approaches also leave no scope for accounting for uncertainties in these parameters.

The present study aims to address these research gaps by using a structured sampling methodology to obtain estimates of incidence of Hemorrhagic Septicemia (HS) through a stratified multistage sampling technique, covering major agro-climatic regions of the country and give stochastic estimates of annual economic losses due to HS in India.

MATERIALS AND METHODS

The study was planned according to the overall framework given by Rushton *et al.* (1999) to assess the impact of livestock diseases. The study was conducted at the farm level and the target groups were owners of large ruminants in India. The authors relied upon primary data collected on the farm in the major agro-climatic regions of the country.

Sampling: Primary data were collected using a household survey in 12 of the 15 different Indian agro-climatic regions (as identified by the Planning Commission of India). The study was restricted to mainland India, so the island region was not covered. The Eastern Coastal Plains and Hills region and the Western Coastal Plains and Ghat region are two thin strips of land on either side of the coast in the lower part of India. These two regions have low livestock

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densities, and so were not covered in the survey. A stratified multi-stage sampling technique was used to select the households (the ultimate sampling unit). For each agro-climatic zone, the state with the largest population of large ruminants was selected. Uttar Pradesh, the largest Indian state in terms of geographical area, covers three agro-climatic zones. Two districts were selected from each agro-climatic zone in each selected state. One of these districts was the one with the largest population of large ruminants; the other was selected randomly (Supplementary Appendix 1). Two blocks were selected within each district, and three villages were randomly selected from each block. From each village, 20 households, with at least one dairy animal, were interviewed. A total of 10, 839 large ruminants, comprising of 3,533 indigenous cattle, 3,573 crossbred cattle and 3,724 buffaloes were included in the survey (see Supplementary Appendix 2 for further details).

Data: Data were collected on the epidemiological and economic parameters of HS using indirect visual surveillance (Roeder and Obi, 1999) and participatory disease surveillance techniques like using checklists, photographs and other participatory methods (Hussain *et al.* 2008, Jost *et al.* 2010). Disease identification by such approach does not give confirmatory diagnosis of the incidence of disease. However, it is widely acknowledged that, for diseases such as HS, farmers are well aware of the symptoms associated with these diseases, mostly specific syndromes which usually have fairly descriptive names in the local languages. Each household selected in the sample was surveyed to collect information on HS outbreak using a disease identification checklist, based on specific clinical symptoms (viz. fever, dullness, reluctance, salivation, serous nasal discharge, oedematous swellings in the pharyngeal region spreading to the ventral cervical region and brisket, and respiratory distress) and photographs. A questionnaire was also administered to the sample farms to collect data on epidemiological and economic parameters associated with HS. The questionnaire was comprehensive and pre-tested.

Estimation of morbidity and mortality rates: The morbidity and mortality rates, as observed in the survey, were scaled up to specific regional levels for different age groups (calves, young animals and adult breedable animals in case of females and young animals and adult animals in case of males) of different breeds/species of animals, viz. indigenous cattle, crossbred cattle and buffaloes. The total population of animals in each age group for different states belonging to the selected states, from the agro-climatic regions covered, was obtained from Livestock Census, 2012 (Government of India). Once, the morbidity and mortality rates, as observed in the survey, were imputed upon the age group-wise population of each breed/species in each region, the total number of region-specific cases and deaths were obtained.

Estimation of economic loss due to HS in bovines: The total economic loss due to HS in bovines was worked out as sum of mortality loss (A), direct loss in milk yield (B), losses due to increased abortions (C), loss in animal draught power (D), cost of treatment of affected animals (E) and extra labour costs (F). The models used to estimate the different components of economic losses for cattle and buffalo are given as under:

Mortality loss

$A = A_F$ (Mortality loss in females) + A_M (Mortality loss in males)

$$A_F = P_{F1} \times D_1 \times V_1 + P_{F2} \times D_2 \times V_2 + P_{F3} \times D_3 \times V_3$$

$$A_M = P_{M1} \times D_4 \times V_4 + P_M2 \times D_5 \times V_5$$

Direct milk loss (B)

$$B = P_{F3} \times P_L \times C_1 \times D \times M_L \times P$$

Losses due to increased abortions

$$C = C_1 + C_2$$

C.1.: Milk Loss due to increased abortion

$$C1 = \left(\frac{12}{ICP} - \frac{12}{ICP + LS + DE}\right) P_{F3} \times P_L \times C_1 \times A \times L \times M_Y \times P$$

C.2: Value of calves lost due to increased abortion

$$P_{F3} \times P_L \times C_1 \times A \times V_C$$

Loss in animal draught power

$$D = P_{M2} \times C_2 \times D_W \times H_W$$

Treatment Cost

$$E = P_A \times P_T \times T_C$$

Extra Labour Cost

$$F = P_A \times P_T \times L_H \times W_R \times D$$

The original models were deterministic, based upon single values of various epidemiological and economic parameters. To take account of variation and uncertainty, a stochastic simulation model was developed to determine variations in the economic losses (Pfeiffer *et al.* 1997). Simulation runs were carried out, based on 2, 500 iterations. The output from these iterations was used to develop probability distributions of expected economic losses due to HS in India.

RESULTS AND DISCUSSION

Morbidity and mortality patterns: The morbidity rate was highest in case of crossbred cows (4.18%), followed by buffaloes (3.27%) and indigenous cows (2.04%). Mortality rate was highest in case of buffaloes (2.06%), followed by crossbred cows (1.86%) and indigenous cows (0.86%). Morbidity rates in cattle and buffaloes as reported by Bangar (2011), Chaudhary (2012), Dohare (2011) and Sharma (2012) ranged between 0.9% to 2.68%, while mortality rates ranged between 0.55% to 1.90%. The case fatality rate was higher in case of buffaloes (63%) as compared to crossbred cattle (44%) and indigenous cattle (42%). Analysis of proportionate distribution of cases (proportional morbidity) across various breeds/species revealed that buffaloes accounted for the highest number of cases (43%), followed by indigenous cattle (37%) and crossbred cattle (20%). Proportional mortality was also highest for buffaloes (52%), followed by that of indigenous cattle (31%) and crossbred cattle (17%). It can thus be inferred that buffaloes are more inclined to contract the disease and succumb to it than cattle. There is ample evidence in published literature that buffaloes are more susceptible than cattle (Khan *et al.* 2006, Tasneem *et al.* 2009, Benkirane and de Alwis, 2002).

Economic losses due to HS: The economic loss due to HS component-wise and breeds/species-wise, was computed using the models as described earlier and the various epidemiological and economic parameters as obtained from the survey. These parameters are presented in Table 1. Per animal loss was highest in buffalo (₹ 20,296), followed by that of crossbred cow (₹ 13,044) and indigenous cow (₹ 11,904).

Among different components, the maximum loss of about 66%, 78% and 81%, respectively in indigenous cows, crossbred cows and buffaloes was due to mortality. Major component of morbidity loss was due to treatment cost in case of crossbred cows and buffaloes (14% and 11% respectively). In case of indigenous cows, major proportion of morbidity loss was accounted for by loss in animal draught power (18%). This might be due to the fact that greater proportion of adult males used for draught purpose in India are of indigenous breeds.

There are very few studies, across countries, which have documented economic losses due to HS at national level. Chaudhry and Khan (1978) estimated economic losses of about 1.89 billion Pakistani rupees due to this disease. In another study, Anonymous (1996) reported a loss of about 2.17 billion Pakistani rupees due to HS per year. Ahmed (1996) computed direct economic losses (taking into account market value of animals that died and treatment cost) resulting from three important endemic diseases, Anthrax, Blackquarter and HS at 2.3 million US dollars. The economic

Table 1. Estimates of parameters for HS effects in bovines

Parameter	Notation	Ind. Cows	CB Cows	Buffalo
Female Population below 1 yr. of age	P_{F1}	18037665	7028377	20155173
Female Population in 1–3 yrs. age group (CB 1–2.5 yr)	P_{F2}	15769050	5464061	15857841
Female Population above 3 yrs. (CB above 2.5 yr)	P_{F3}	55417058	21268022	56586061
Male Population below 2 yrs. age (CB below 1.5 yr)	P_{M1}	15204721	3838718	10805080
Male Population above 2 yrs. age (CB above 1.5 yr)	P_{M2}	46743801	2132632	5297967
Proportion of females aged below 1 yrs died.	D_1	0.007576	0.016317	0.03125
Proportion of females aged in 1–3 yrs. age group died.	D_2	0.007538	0.037037	0.035928
Proportion of females above 3 yrs. died	D_3	0.006173	0.014666	0.016045
Proportion of males aged below 2 yrs died.	D_4	0.004545	0.033473	0.009494
Proportion of males aged above 2 yrs died.	D_5	0.020561	0.021277	0.033613
Average market value of females aged below 1 yrs.	V_1	3442.424	3554.128	6739.485
Average market value of females aged between 1–2.5 yrs.	V_2	10241.75	15760.04	17156.68
Average market value of females above 2.5 yrs.	V_3	20460.37	39875.78	43216.02
Average market value of males aged below 1.5 yrs.	V_4	1982.547	1861.538	6547.476
Average market value of males aged above 1.5 yrs.	V_5	16204.51	11764.71	24907.69
Proportion of female animals above 2.5 yrs. in-lactation	P_L	0.482716	0.65019	0.617537
Average value of new born calves (INR)	V_C	1300	2443	2700
Proportion of in-milk animals infected	C_1	0.024297	0.042607	0.030816
Average duration of the disease (days)	D	10.3	6.8	10.4
Milk loss per day per animal (Ltrs.)	M_L	2.96	8.5	6.84
Price of milk (INR/Lt.)	P	30.8	31.4	38.1
Increased abortion rate	A	0	0.0135	0
Average Lactation length (days)	L	272	293	291
Average per day milk yield (Ltrs.)	M_Y	4.111	9.87	6.74
Inter-calving period (months)	ICP	14.9	14.59	15.59
Lactation stage at which abortion occurred (months)	LS	0	6.7	0
Delay in next oestrus (months)	DE	0	3	0
Proportion of adult males (>2 yrs.) affected	C_2	0.033645	0.042553	0.033613
Proportion of young females (<1 yrs.) affected	C_3	0.020202	0.018648	0.032895
Proportion of females (between 1–3 yrs.) affected	C_4	0.007538	0.061728	0.043912
Proportion of adult females (>3 yrs.) affected	C_5	0.021605	0.044541	0.032463
Proportion of young males (<2 yrs.) affected	C_6	0.011364	0.041841	0.015823
Average duration of disease in adult males (days)	D_W	6	3.5	5.3
Average hiring charges per day (INR)	H_W	710	720	666
Average cost of treating an animal	T_C	1337	1800	2292
Total no. of extra labour hours per day per animal	L_H	1	1.59	1.3
Wage rate prevailing in the region (INR)	W_R	230	230	230

significance of HS in India can be gauged from the fact that it has been identified as the second most reported disease in India during 1991–2010 as per NADRES and is the cause of maximum number of deaths reported in livestock in the country. Dutta *et al*. (1990) studied epidemiological data of HS over a period of 13 years (1974–1986) in India and reported that mortality-wise, HS was first and morbidity-wise, second as compared to four other epizootic diseases, viz. FMD, Rinderpest, Anthrax and Black Quarter. The significant economic loss as reported in this study thus seem to be in line with the above observations regarding morbidity and mortality caused by HS.

The above estimate of annual economic losses due to HS in India was based on deterministic model, assuming single values of various epidemiological and economic parameters. India being a vast country, the different epidemiological and economic parameters tend to vary over different regions. To take into account the uncertainties in these parameters, the deterministic model was converted to a stochastic one, using spreadsheet software (Microsoft Excel), by taking into account the maximum and minimum values of each parameter and its standard errors. The model was run for 2, 500 iterations, using the means and standard deviation to generate the parameters on each run. Normal distributions were used for the parameters. The outputs from these iterations were used to generate the probability distribution of the expected annual economic losses due to HS in India (Fig. 1a, b & c and Fig. 2). Based upon the minimum and maximum expected economic loss—as obtained from the simulation runs—100 class intervals of losses were obtained. The X-axis in the figure represents these class intervals (the range of economic losses) and the Y-axis represents the probabilities for each of these class intervals as obtained from the simulation runs.

The expected annual economic loss due to HS in India in case of indigenous cows ranged between ₹ 20.28 billion and ₹ 52.81 billion. The most likely range of expected economic loss, based upon maximum frequencies for a class interval, was ₹ 36.54–37.19 billion. In case of crossbred cows, annual economic losses due to HS ranged between ₹ 8.77 billion and ₹ 36.09 billion, the most likely range of expected economic loss ranging between ₹ 20.48–21.13 billion. In case of buffaloes, the expected annual economic losses ranged between ₹ 24.58 billion and ₹ 116.95 billion. The most likely range of economic loss due to HS in buffaloes was ₹ 67.51–68.82 billion. The expected pooled estimates of total annual economic loss due to HS in bovines ranged between ₹ 58.63 billion to ₹ 175.72 billion. The most likely range of annual economic loss due to HS in India was ₹ 126.28–127.58 billion.

Singh *et al.* (2014) had reported annual economic loss of ₹ 52.54 billion in India due to bovine HS. The authors used the number of cases and deaths due to HS-identified on the basis of clinical signs—as reported in various Post-Graduate theses submitted to ICAR-Indian Veterinary Research Institute, Izatnagar. These separate studies were carried out in 4 states, viz. Himachal Pradesh, Madhya Pradesh, Maharashtra and Uttar Pradesh (mostly from northern and western regions of the country), at different points of time, during a four year period 2009–12. The number of cases and deaths, as obtained from these studies, were pooled to obtain the national level morbidity and mortality rates. Thus, the estimates of economic loss as obtained from such studies were not based on representative sample. Further, the 18th Livestock Census Data (2007) were used to obtain the total number of cases and deaths due to HS India as against the present study, which has used the latest official Census data (19th Livestock Census, 2012).

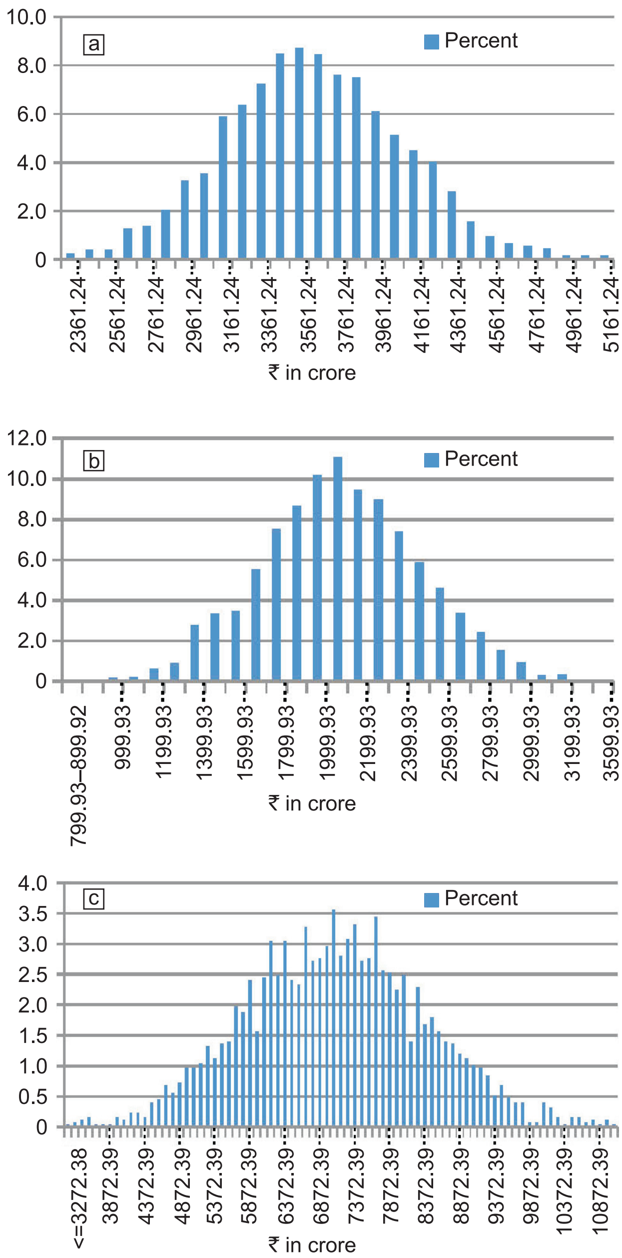

Fig. 1. **a.** Probability distributions for annual economic losses due to HS in India (Indigenous cows). **b.** Probability distributions for annual economic losses due to HS in India (Crossbred cows). **c.** Probability distributions for annual economic losses due to HS in India (Buffaloes).

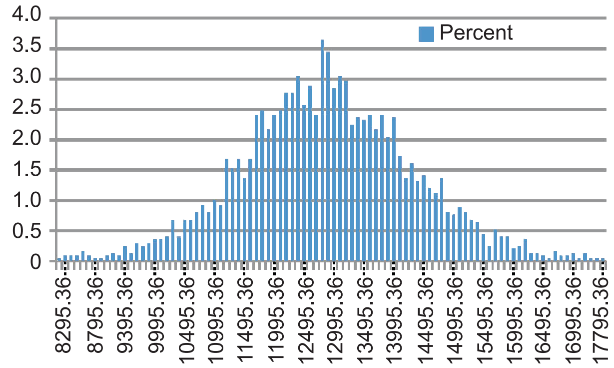

Fig. 2. Probability distributions for annual economic losses due to HS in bovines in India.

The paper has analyzed morbidity and mortality patterns of HS in bovines in India and given stochastic estimates of annual economic losses due to the disease based upon primary data obtained from household survey carried out in 12 major agro-climatic regions of the country. Buffaloes are more inclined to contract the disease and succumb to it than cattle. Milch animals accounted for the highest number of cases in all the breeds/species of dairy animals. However, for indigenous cattle, the maximum number of deaths was observed in case of adult males. Mortality rates were higher for male indigenous and crossbred cattle as compared to the females. In case of buffaloes, higher mortality was observed in case of females as compared to male buffaloes. Both morbidity and mortality were maximum during the monsoon season. Regional variations in regard to breeds/species were observed pertaining to cases and deaths. However, overall the incidence of the disease was found on the higher side in eastern plateau and hill region, central plateau and hill region, middle gangetic plain region and Gujarat plains and hills. The above findings thus would help in the prioritization of vaccination programme against HS. The study has revealed significant economic losses due to HS in India to the tune of ₹ 126.28–127.58 billion. This implies that HS, from policy perspective, is one of the most important diseases when it comes to mitigating losses due to diseases in dairy animals. This involves investment in research and vaccination schedule as preventive measures.

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