Serosurveillance of foot and mouth disease in Karnataka state, India: a 3 years study

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Abstract A prospective serological investigation was conducted to determine the prevalence and distribution of foot-and-mouth disease (FMD), as well as to monitor the effectiveness of the FMD control programme (FMD-CP) through vaccination in Karnataka, India. Random serum samples were collected every year between May and August before the start of vaccination in 2011, and subsequently following two phases of vaccination in 2012 and 2013. Infection status (seroprevalence) was inferred by subjecting the sera to indirect r3AB₃ non-structural protein-ELISA, using kits developed by the Project Directorate on FMD, India. The seromonitoring of FMD-CP was carried out by detecting antibodies deemed to be protective in the pre- and post-vaccinal sera, using liquid-phase blocking-ELISA for structural proteins. The results revealed significant decrease in seroprevalence from 58 to 21 %, providing more definitive data supporting our earlier findings obtained through clinical observations (Hegde et al. in *Virusdisease* 25:504–509, 2014), and detecting active infection in some of the populations which were considered to be free based on passive surveillance. On the other hand, after four rounds of vaccination, a gradual and significant increase from 4.5 to 59 % of animals carrying antibody levels deemed to be protective was observed against all the three serotypes. The findings of this study could be useful for further strategizing to strengthen the ongoing FMD-CP in Karnataka State, India.

Keywords Foot and mouth disease · Serosurveillance · Structural proteins · Non structural proteins · ELISA

Introduction

Foot-and-mouth disease (FMD) is a highly contagious viral disease which affects all cloven-hooved domestic animals including cattle, buffaloes, sheep, goats and pigs (Office International des Epizooties (<http://www.oie.int/doc/ged/D7710.pdf>)). The disease is rarely fatal in adult animals, but is dreaded owing to nearly 100 % morbidity, rapid spread, severe decrease in livestock production, and mortality in young animals. The seven serotypes of FMD virus (FMDV), O, A, Asia-1 and South African Territories (SAT)-1, -2, and -3, are immunologically distinct but produce a clinically indistinguishable disease (<http://www.oie.int/doc/ged/D7710.pdf>). Most of the developed countries are free from FMD whereas the disease is endemic in Africa, the Middle East and Asia. However, the disease is a global concern due to increased movement of livestock as well as trade in livestock products as a result of the globalized economy [25].

Foot-and-mouth disease is endemic in India with the prevalence of serotypes O, A and Asia-1. Serotype O is the most prevalent (83–93 % of the outbreaks) followed by Asia-1 (3–10 %) and A (3–6.5 %), whereas serotype C has not been reported since 1995 [24]. The disease situation in India is complicated due to the plurality of the circulating virus strains, unrestricted movement of animals and asymptomatic or subclinical infection of mainly small ruminants. Vaccination-based FMD control programme (FMD-CP), which involves biannual vaccination of all cattle and buffaloes in selected areas, followed by regular active surveillance and antibody monitoring in the vaccinated population is on-going in India with the objective of creating FMD free zones [24].

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Animals infected with FMDV produce antibodies to viral structural and non-structural proteins [18, 26], whereas animals vaccinated with purified vaccines are expected to produce antibodies to structural proteins only (<http://www.oie.int/doc/ged/D7710.pdf>). Conventional serological tests detect antibodies to structural proteins, and are hence suitable for FMD surveys [12]. In scenarios where both vaccinated and infected animals co-exist, such as in India, antibodies directed at FMDV structural proteins are expected to be induced by both inactivated viruses (vaccines) and live viruses (in infected or carrier animals) [13]. In such cases, testing for antibodies to viral non-structural proteins (NSPs) is used to monitor infection or virus circulation [7, 12, 21]. Serological surveys have been used in FMD-endemic countries such as Thailand [10], Cameroon [5], Taiwan [6], Lao PDR [3], Uganda [1], Egypt [19], Bhutan [11] and Cambodia [28]. In India, serological survey is being carried out under a national programme to determine the prevalence of FMD as well as to assess the implementation and effectiveness of FMD-CP.

Karnataka, the seventh largest state in India (191,791 km² area, 5.8 % of the country), is situated between 11°40' and 18°27'N latitude and 74°50' and 78°33'E longitude, in the centre of the western peninsular India. The state has a topography ranging from the narrow stretch of coastal plains to elevated terrains of the Western Ghats sloping gently to the West to the drier plateau regions in the East. The state has 30 revenue districts, subdivided into 176 talukas (district subdivisions) and can be divided into 10 agroclimatic zones: Northeastern transition, Northeastern dry, Northern dry, Central dry, Eastern dry, Southern dry, Southern transition, Northern transition, Hilly, and Coastal. The state has a passive disease surveillance system based on hierarchical reporting of disease outbreaks: livestock owners report to the local veterinarians, who in turn report to Assistant Director at the taluka level, who report to the Deputy Director at the district level. From each district, the disease data is transmitted to the state level Deputy Director, Disease Surveillance and Monitoring, who in turn compiles the data for the whole state. The laboratory confirmation of FMD is carried out at the Bengaluru Centre of the All-India Coordinated Research Project on FMD (AICRP-FMD).

We have earlier reported on a retrospective study on the epidemiology of FMD in Karnataka, India, for the period between 1977 and 2012–2013 based on data collected through passive and active clinical surveillance [16]. However, many outbreaks likely went unnoticed or unreported because of the endemic nature of the disease, low mortality and due to reasons such as remoteness of the villages and lack of incentives for disease reporting. In addition, all the reported outbreaks were not confirmed due to various reasons

such as ignorance of the farmers, wrong presumptive diagnosis, not collecting samples, improper/insufficient/mistimed sample collection, and/or improper storage or transport of the samples. Therefore, there was a need to validate the findings of passive and active clinical surveillance through active serological surveys. In addition, it was also necessary to assess the penetration of FMD-CP against reported vaccination coverage, and to evaluate the effectiveness of the vaccine by comparing serological reactivity against outbreak incidence. The present study was therefore carried out under FMD National Serosurveillance Programme to determine the seroprevalence of FMD in cattle and buffaloes by measuring NSP antibody prevalence and to determine the effect of vaccination under FMD-CP by measuring the antibody response to FMDV structural proteins.

Given the absence of prior data on the serosurveillance, the present study was carried out under FMD National Serosurveillance Programme to determine the seroprevalence of FMD in cattle and buffaloes by measuring NSP antibody prevalence and to determine the effect of vaccination under FMD control programme by measuring the antibody response to FMDV structural proteins.

Materials and methods

Study area and design

Serosurveillance study

The serosurveillance study was carried out in all the 30 revenue districts of Karnataka and the random serum samples were collected between May and August of each of the years 2011, 2012 and 2013. For this, 100 serum samples were collected from 10 villages in each district by following a multistage convenience sampling. Since the revenue districts are subdivided into talukas and further into villages, the villages were selected using randomization calculator (RANDOM.ORG), in such a way that each taluka was represented for sampling. Serum samples were collected from the selected villages following simple random sampling in which each member of the subset had an equal probability of being chosen with an unbiased representation. Every year, different villages were selected following the same criteria and a fixed but higher number (3000 from 30 districts) of samples were collected. For the purpose of this paper, traditionally maintained herds are defined as those that are either stall-fed or are maintained by letting the animals out daily for grazing in and around their usual place of residence and do not take part in seasonal migration. At the time of blood collection, information on vaccination status was also collected. For the serosurveillance study, 8877 serum samples were collected

from apparently healthy animals over the 3-year period and screened for NSP antibodies.

Post vaccination seromonitoring study

The study involved measuring the antibody responses to structural proteins after vaccination under FMD Control Programme (FMD-CP), which is being implemented since September 2011, wherein all cattle and buffaloes are vaccinated biannually (September and February) using a trivalent oil adjuvant vaccine containing three FMDV serotypes O, A, and Asia-1 prevailing in the country. The study was carried out by screening 200 pre-vaccinated and 200 post-vaccinated serum samples collected from ten villages in each revenue district by employing the liquid phase blocking ELISA (LPB-ELISA). The post-vaccination serum samples were collected after 28 days of vaccination. The FMD-CP seromonitoring samples were collected during September–October 2011, February–March 2012, September–October 2012 and February–March 2013 for FMDCP vaccination Phase I, II, III and IV respectively. The details of the pre and post vaccination serum samples screened at every phase of vaccination are given in Table 1.

Sample collection

Blood sample was collected from jugular vein of individual animals using Vacutainer tube (Greiner bio-one/BD) containing serum clot activator. The sample was immediately mixed, transported to the laboratory on wet ice and refrigerated overnight. The separated serum was centrifuged at $1000\times g$, aliquoted, labelled and stored at -20°C for up to 4 months before testing.

Serological assays

Serosurveillance by r3AB₃ NSP ELISA

An indirect ELISA using the validated r3AB₃ NSP ELISA kit (PDFMD, Mukteswar) was performed as described to

assess antibodies against 3AB₃ NSP of FMDV [21, 27]. The r3AB₃ NSP indirect ELISA was considered to be valid if the mean absorbance of the positive control was ≥ 0.8 and the test plate was rejected if the mean absorbance of the supplied negative control was >0.3 , or the OD in the background control wells was >0.10 ; the sample was declared positive if percent positivity (PP) value was >40 . The PP value was calculated by dividing the OD of the test serum by that of the positive control serum and then multiplying by 100.

Seromonitoring by liquid phase blocking ELISA (LPB-ELISA)

Serotype-specific antibody titres to structural proteins were quantitatively measured by LPB-ELISA to assess the overall herd immunity status against FMD virus serotypes O, A and Asia-1 using the in-house LPB-ELISA kit (PD-FMD, Mukteswar) as per the procedure described. For each serum dilution, the results were expressed as follows:

$$\% \text{ reactivity} = \left(\frac{\text{Mean OD of test wells}}{\text{Mean OD of antigen control wells}} \right) \times 100$$

The antibody titres were expressed as logarithm of reciprocal of serum dilutions giving 50 % of the absorbance recorded in the antigen control wells. As per the guidelines issued by PDFMD(ICAR), the samples showing $\log_{10}$ titre of ≥ 1.8 against all three vaccine component serotypes O, A and Asia-1 were considered as having sufficient level of antibodies deemed to be protective.

The laboratory confirmation of FMD was done at the AICRP-FMD centre at Bengaluru. The clinical samples collected and/or received by the centre were processed and tested by sandwich ELISA as per the protocol standardised by PD-FMD.

Data analysis

The data was analysed for seroprevalence and the 95 % minimal length confidence intervals (CI) by using survey toolbox for livestock diseases (Epitools epitools.ausvet.com.au/content.php). Pearson's Chi square test was used to

Table 1 Details of serum samples tested at each phase of vaccination under FMD-CP

Phase of vaccination	Number of serum samples tested		% of animals showing protective titres $\geq 1.8\log_{10}$						% of animals protected against all three serotypes	
			Serotype O		Serotype A		Serotype Asia-I			
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I	4587	4266	40	56	15	40	09	25	4.5	17
II	5401	4631	50	67	27	47	39	51	21	39
III	3864	3075	42	46	25	31	49	52	20	38
IV	5053	5225	48	62	79	86	76	82	44	59

detect significant differences in the NSP level between districts. The ARCSINE transformation and ANOVA was carried out to know the significant difference in NSP between years.

Results

Serosurveillance (r3AB₃ NSP ELISA)

A total of 8877 blood samples were collected over a 3-year period from apparently healthy cattle ($n = 7031$) and buffaloes ($n = 1846$) from 3961 herds located in 957 villages in the 30 revenue districts of the Karnataka. Year-wise, 3062 (2582 cattle, 480 buffaloes), 2824 (2384 cattle, 440 buffaloes), and 2991 (2065 cattle, 926 buffaloes) samples were collected respectively during 2011, 2012, and 2013.

As assessed by the NSP ELISA, the overall seroprevalence of FMD in Karnataka was 62 % in 2011, 18 % in 2012 and 21 % in 2013 (Table 2). Since we have observed that no anti-NSP antibodies could be detected in vaccinated animals maintained under organized settings (manuscript in preparation), it is very likely that seroprevalence as assessed by NSP ELISA represents apparent FMDV infection. Accordingly, the apparent infection status was 64, 19 and 22 % for cattle and 48, 15 and 20 %, for buffaloes respectively for the years 2011, 2012 and 2013. The prevalence of anti-NSP antibodies varied significantly between the districts. There was significant decrease in the level of NSP antibodies between the years ($F = 88$, $p < 0.01$) (Table 2). Considering at least one animal being positive, samples from 757 out of 957 screened villages were positive for anti-NSP antibodies. As far as the various revenue districts are concerned, 63 % (19 of 30) districts showed seroprevalence rates at animal level of >50 % in 2011 whereas all the districts had seroprevalence rates of ≤ 50 % in both the subsequent 2 years as analysed by NSP ELISA. Indeed, 73.3 % of the districts had seroprevalence rates of <25 % in 2012 whereas 63.3 % had <25 % rates in 2013 (Table 3; Fig. 1).

Table 2 Seroprevalence of FMD in Karnataka, India, as assessed by NSP ELISA

Year	Number tested	% prevalence (95% CI)	χ^2 for districts ($df = 29$)
2011	3062	62 (60–65)	568**
2012	2824	18 (16–20.5)	231**
2013	2991	21 (19–23)	263**

$F = 87.5^{**}$ between the years; ** significant at 0.01; *ns* non significant

Seromonitoring (LPB-ELISA)

Seromonitoring following FMD-CP revealed that levels of antibodies deemed to be protective (SP-Ab) were observed in 62, 86 and 82 % of the cattle/buffaloes against serotype O, A and Asia-1, respectively, as against a vaccination coverage of 80 % after the fourth phase of vaccination in February 2013 (Table 1; Fig. 2). There was a gradual increase from Phase I through Phase IV in the proportion of samples showing levels of SP-Ab. The level of SP-Ab against all the three serotypes was just 4.5 % at the beginning of Ist phase of vaccination. This has significantly increased to 59 % ($F = 27.3$, $p < 0.001$) at the end of IVth phase of vaccination (Table 1; Fig. 2). Further, evaluation of the effectiveness of FMD-CP showed that both the number of districts reporting and the total number of reported outbreaks had reduced gradually to about 30–40 % by the end of the fourth round of vaccination. The reported outbreaks of FMD reduced from 169 at the beginning of FMD-CP to 116 at the end of fourth phase of vaccination. The outbreaks, however, continue to be caused mostly by serotype O, though serotype A and Asia-1 also circulating (Table 4). Majority of the outbreaks investigated were observed in unvaccinated animals.

Discussion

This is the first serological study providing information on the status of FMD in Karnataka state, India. The results of the study demonstrate that FMD is endemic in the state, with all the 30 revenue districts showing seroprevalence as evidenced by NSP ELISA. There has been a significant decrease in prevalence of anti-NSP antibodies from the years 2011 to 2013 and gradual increase in antibodies to structural proteins in the years subsequent to the introduction of the systematic vaccination under FMD-CP since 2011. Similar observations have been made in Haryana state, where seroprevalence reduced from 31 % before the start of FMD-CP to 18 % before start of the fourth phase [17] and further reduced to 12 % at the start of the eighth phase of vaccination [2] (www.pdfmd.ernet.in).

Table 3 District level seroprevalence (% positive with 95 % CI) of FMD in Karnataka as assessed by NSP (3AB)ELISA

	District	Actual bovine population	2011 %Prevalence (95 % CI)	2012 %Prevalence (95 % CI)	2013 %Prevalence (95 % CI)
1	Bagalkot	507,723	18 (12–27)	28 (19–37)	30 (21–39)
2	Bengaluru urban	124,990	63 (53–71.5)	14 (7–21)	22 (14–30)
3	Bengaluru rural	125,195	81 (72–88)	8 (3–13)	14 (7–21)
4	Belagavi	1,284,292	34 (25–44)	30 (21–39)	22 (14–30)
5	Ballari	507,778	83 (74–89)	18 (9–27)	8 (3–13)
6	Bidar	378,092	70 (61–79)	8 (3–13)	38 (28–47)
7	Vijayapura	373,105	20.5 (13–28)	4 (0.2–8)	8 (3–13)
8	Chamarajnagar	321,905	89 (82–94)	5 (1–9)	50 (40–60)
9	Chikkamagalur	304,650	48 (38–58)	24 (16–32)	9 (4–14)
10	Chikkaballapur	229,210	61 (51–70.5)	7 (2–12)	34.5 (26–43)
11	Chitradurga	423,033	45.5 (36–55)	12 (6–18)	26 (17–35)
12	Dakshina Kannada	309,929	60 (51–69)	14 (7–21)	43 (33–53)
13	Davangere	463,064	78 (70–86)	22 (14–30)	17 (10–24)
14	Dharwad	292,795	32 (23–41)	16 (9–23)	7 (2–12)
15	Gadag	236,130	36 (26.5–45)	30 (21–40)	17 (10–25)
16	Kalburgi	504,650	63 (53.5–72)	6 (1.5–19)	38 (28–47.5)
17	Hassan	827,505	50.5 (40–59)	11 (5–17)	14 (7–21)
18	Haveri	375,639	44 (35–53)	13 (6–19.5)	24 (16–32)
19	Kodagu	112,890	75 (66.5–83)	35 (26–44)	7 (2–12)
20	Kolar	224,356	24.5 (16–33)	30 (21–39)	39 (29–48.5)
21	Koppal	353,814	85 (78–92)	11 (5–17)	27 (18–36)
22	Mandya	449,646	70 (61–79)	36 (26.5–45)	10 (4–16)
23	Mysuru	576,110	73 (64–82)	30 (21–39)	11 (5–13)
24	Raichur	424,994	79 (71–87)	20 (2–37.5)	1 (0.1–5)
25	Ramanagara	229,231	63 (54–72)	6 (1–11)	17 (10–24)
26	Shivamogga	666,365	58 (48–68)	21 (13–29)	10 (4–16)
27	Tumakuru	537,319	82 (74–89.5)	5.5 (1–12)	6 (0.2–11)
28	Udupi	251,840	39 (30–48)	18 (10–25.5)	39 (29–49)
29	Uttara Kannada	370,012	33 (24–41.5)	28 (19–37)	30 (21–39)
30	Yadgiri	431,388	91 (73.5–89)	22.5 (8–37)	10 (4–16)
	Total for the State	12,217,653	62 (60–65)	18 (16–20.5)	21 (19–23)

The samples collected for the current serosurveillance study were from a time before the systematic vaccination was implemented under FMD-CP and between two phases of vaccination. It was observed that seroprevalence varied between some districts. It should be noted that the sampling was random each year, and animals were not marked for re-sampling. Given that there is no restriction on movement of animals and that both vaccinated and infected animals would be mingling, a decrease or increase in neighbouring districts can be expected. For example, significant movement of animals occurs between Gulbarga district and its bordering state of Maharashtra, whereas large-scale buying and selling of animals takes place in the high yielding belt of Kolar district. Hence, it is not surprising that few districts may have higher prevalence of

anti-NSP antibodies compared to others. Large numbers of outbreaks were reported from the dry zones and transition zones where the majority of the susceptible livestock population is located [16]. Before the implementation of vaccination programme, seroprevalence in these zones was more than 50 % which subsequently reduced to less than 25 % at the end of IVth phase of vaccination.

We have previously reported that although FMD is prevalent in all the 30 revenue districts representing all the ten agro-climatic zones, it is not uniformly distributed. On an average, outbreaks were recorded in 21 districts every year, of which only 10.8 outbreaks were confirmed [16]. Not all the clinically reported outbreaks could be confirmed in the present study as well. A multitude of reasons at each step starting from farmers' ignorance to improper transport

Fig. 1 District level seroprevalence (% positive) of FMD in Karnataka as assessed by NSP (3AB) ELISA between 2011, 2012 and 2013. The map shows bovine population in individual districts and the seroprevalence as evinced by NSP ELISA during 2011, 2012 and 2013 respectively

of the sample contribute to the low confirmatory diagnosis. Importantly, the present study confirmed seroprevalence despite official records of no outbreaks in some villages, reaffirming underreporting as a major drawback of the passive surveillance system [11, 20, 23]. Prior to 2011, there was no control of FMD by systematic vaccination programme. Hence the sampling was not aimed at collecting from 0.5 to 1.5 year cattle and buffalo which represent the population that is susceptible. It would probably be worthwhile following this up with a more systematic study once we achieve more than 85 % herd immunity with clinical disappearance of the disease. Seroprevalence in the apparently healthy animals supports the fact that the virus is circulating, and that animals are exposed to the virus. Anti-NSP antibodies, especially the anti-3ABC antibodies,

can be detected in infected animals for up to 665 days following infection [22] and these can be potentially boosted by a clinically silent infection. Therefore, it is likely that seropositive animals had detectable levels of circulating anti-NSP antibodies derived from previous infection or exposure to the virus.

Earlier to the implementation of FMD-CP, there was no preventive vaccination in Karnataka, and vaccination was limited mostly to post-outbreak situations until 2006-07 when severely affected districts were brought under the Assistance to States for the Control of Contagious Animal Diseases (ASCAD) programme, under which livestock were vaccinated once a year. With the implementation of FMD-CP since September 2011, the vaccination coverage increased gradually from 58 % in the first phase to 80 % at

Fig. 2 Level of antibodies deemed to be protective in animals following vaccination. Cattle and buffaloes in all the 30 revenue districts were vaccinated twice in each year. Serum samples were obtained before (pre) vaccination and 28 days post-vaccination and subjected to LPB-ELISA as described in the materials and methods. Phase I, II, III and IV were in September 2011, February 2012, September 2012 and February 2013, respectively. Ph phase. Error bars represent 95 % CI, but are almost invisible since the highest difference is 2.09 (Asia-1, upper CI, Ph-III post)

the end of the fourth phase of FMD-CP. Under this programme, cattle, buffaloes and pigs are being vaccinated every 6 months (August–September and February–March) using a trivalent (O, A, Asia-1) oil adjuvant vaccine. The seromonitoring results indicated that the protective level of antibodies against all the three serotypes increased gradually from 4.5 to 59 %, this built up of herd immunity, in parts might have resulted in reduced disease occurrence in the state in recent times (www.pdfmd.ernet.in), though there may be many reasons for the reduction in outbreaks. It was observed that the vaccination coverage during 3rd phase was reduced to 73 %, resulting in decrease in protective titre against serotypes O and A. It is worth noting that in the southern districts of Bengaluru Urban and Rural,

Ckikkaballapur, Kolar, Hasan, Tumkur, Mandya and Mysuru, where high yielding cross-bred milch animals are present, the systematic increased vaccination coverage resulted in increased proportion of animals carrying protective titres against all the three serotypes and also a decrease in reported outbreaks. There was a parallel reduction in prevalence of anti-NSP antibodies in these districts. On the other hand, increase in disease outbreaks in Ramanagar district may be due to lower vaccination coverage of <60 % in each phase of vaccination, and that in Kalburgi and Yadgir districts, which mainly have draught animals, may be due to large-scale movement of animals between these districts and the neighbouring states of Maharashtra and Andhra Pradesh, in addition to lower vaccination coverage. However, at the end of the fourth phase of vaccination, 61 % of the population was still susceptible to FMDV attack with anyone of the three serotypes, whose circulation, incidentally, has been confirmed. In the absence of restriction on movement of animals and zoo sanitary measures, it is likely that large scale outbreak may occur. Indeed, to prevent the establishment and maintenance of FMDV in a herd, the aim should always be to attain at least 85 % and preferably 100 % vaccination coverage of the susceptible livestock [9, 14] at every phase of vaccination programme and low level of vaccination coverage can result in a perceived failure of a vaccination program [8, 15]. Since there is no scope in India for slaughter of affected and in-contact animals, the disease can be controlled only by effective vaccination of all the susceptible livestock population. It is noteworthy that the state of Haryana has achieved FMD free status since 2012-13 through effective implementation of vaccination programme, leading to herd immunity of more than 80 % and anti-NSP antibody response of <2 % [4] (http://www.pdfmd.ernet.in/index_files/Content/Reports/AR_2013_14_PDFMD_2013_14.pdf). Karnataka state may also be able to achieve a clinical

Table 4 Vaccination coverage and FMD outbreaks reported and confirmed in Karnataka state

Year/time	Vaccination coverage (%)	No. of districts reporting outbreaks	No. of districts with confirmed outbreaks	Total no. of reported outbreaks state-wide	Suspected outbreaks investigated/clinical samples received	Confirmed outbreaks	Virus serotype		
							O	A	Asia-1
2008–2009	45	22	10	190	29	24	23	1	0
2009–2010	43	21	8	187	29	22	22	0	0
2010–2011	38	17	11	169	36	36	30	0	6
Sept 2011 (Phase I)	58	12	10	152	58	51	43	0	8
Feb 2012 (Phase II)	82								
Sept 2012 (Phase III)	73	14	12	116	54	45	29	7	9
Feb 2013 (Phase IV)	80								

disappearance of the disease by effective implementation of vaccination programme covering all the livestock in each phase of FMD-CP.

The findings of the present study indicate that FMD is highly prevalent in Karnataka, supporting the passive surveillance data. On the other hand, serological surveys proved useful in detecting infection that was missed by passive surveillance. The data also confirm the gradual increase in the population of animals deemed to be protected following the biannual vaccination programme, but aim should always to achieve 100 % vaccination coverage of the susceptible livestock. Further, in case of FMD, vaccination is considered to be one of the control measures, movement control of livestock and livestock products and implementation of zoo-sanitary measures are required in addition to mass vaccination under FMD-CP. In order to further strengthen the vaccination campaign better quality control measures such as maintenance of cold chain, educating and training of all stakeholders, logistics supply and distribution and effective administration of vaccines is required. Besides, national FMD commission and independent agency for monitoring the vaccine quality may be established for the smooth functioning of this ambitious programme.

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