

ORIGINAL RESEARCH ARTICLE

Syndromic surveillance of infectious bursal disease in chickens using lesion indicators: Analysis of clinical records (2008–2018)

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Abstract

Infectious bursal disease (IBD) outbreaks significantly undermine chicken production. Syndromic surveillance based on lesion indicators is an established tool for monitoring the disease following reports of morbidity and mortality. This study aimed to develop an epidemiological profile of the IBD burden, including syndromic outbreak prevalence rates, yearly trends, mortality rates, and lesion patterns, used for surveillance. Records of IBD outbreaks from two veterinary hospitals in Maiduguri, Nigeria, were extracted from all reported disease outbreaks in chicken flocks between 2008 and 2018. IBD outbreaks accounted for 493 cases (7.6%; 95% confidence interval [CI]: 7.0–8.3%) of 6,486 recorded disease outbreaks. Annual prevalence ranged from 1.6% (95% CI: 0.9–2.3%) to 17.3% (95% CI: 12.9–21.7%) and showed a linear trend ($r = -0.73$; $p < 0.01$), with a significant association across years ($p < 0.001$). Prevalence varied significantly with chicken type ($p < 0.05$), with the highest rate observed in Noilers (25.0%), followed by cockerels (17.5%), local chickens (9.1%), broilers (7.2%), and layers (7.1%). Affected chickens were aged 2–27 weeks, with a modal age of 4–5 weeks and a mean age of 5.0 ± 1.7 weeks. The overall mortality rate was 12.6% (95% CI: 12.3–12.9) based on a total flock size of 38,485 from 2015 to 2018, the period for which flock size and mortality records were available. Key lesions used for syndromic detection of acute IBD included inflammatory swelling of the bursa of Fabricius (90.9%), hemorrhages in thigh, leg, and/or breast muscles (72.2%), mucosal hemorrhages at the proventriculus–ventriculus junction, with and without enteritis (24.9%), and kidney lesions (7.7%). This syndromic surveillance system enables outbreak monitoring and can inform the planning of control measures to reduce disease-associated production losses.

Keywords: Infectious bursal disease; Outbreak detection; Syndromic surveillance; Lesion indicator; Chicken; Nigeria

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1. Introduction

In Nigeria, acute infectious bursal disease (IBD) in chickens, caused by virulent IBD virus (IBDV) infections,^{1,2} is characterized by clinical signs including decreased appetite and

watery to mucoid greenish-white or yellowish diarrhea, often accompanied by mortality. Postmortem findings typically include inflammatory enlargement of the bursa of Fabricius (BF), congestion and hemorrhage of the thigh, leg, and pectoral muscles, mucosal hemorrhages at the junction of proventriculus and ventriculus, kidney lesions, and mucous exudate on intestinal mucosa.^{3,4} Outbreaks have been reported in both vaccinated and unvaccinated chickens across the country.^{3–29} Several factors contribute to the occurrence of IBD outbreaks, including the virulence of the IBDV,^{1,2,30} stressors such as overcrowding or movement of birds,^{4,23} improper vaccination at inappropriate age,^{12,31,32} lack of booster vaccinations,³ IBD vaccine or immunization failures,¹² reversion of vaccine virus to virulence,¹ and antigenic mismatch between vaccine strains and circulating field viruses.³³ Phylogenetic analyses of Nigerian IBDV field strains revealed a unique cluster related to imported classical and very virulent IBDV strains,¹ as well as other strains without foreign lineage that represent reassortant IBDVs.³⁴ These reassortant strains exhibit mutations in the hypervariable regions of the VP2 gene.^{34,35}

Local veterinary diagnostic centres with inadequate resources are often not able to conduct definitive laboratory diagnosis after outbreak detection during passive disease surveillance. Veterinarians make presumptive diagnoses based on clinical signs and postmortem lesions³⁶ after examining dead or moribund chickens submitted during disease outbreaks, and the records of diagnosed diseases are useful for epidemiological monitoring of spatial and temporal trends.³⁷ The lack of nationwide surveillance data in Nigeria has undermined the evidence-based assessment of the disease burden and the effectiveness of control measures. Outbreak prevalence rates of IBD have been reported from surveillance centers in northern Nigeria,^{37–46} ranging from 6.6% to 32.9% across different times and locations. However, comparable data from southern Nigeria are lacking, despite sporadic reports of IBD outbreaks^{5–11,16–17} in the area.

Animal health intelligence encompasses the detection and monitoring of disease outbreaks and related events using traditional and non-traditional surveillance systems.⁴⁷ Syndromic (or clinical) surveillance in veterinary settings is an emerging tool for collecting data on clinical events such as abortion, mortality, and production losses, as well as other clinical indicators of disease, to support animal health monitoring.^{47–50} This type of surveillance involves monitoring cases that meet the specific clinical case definition for the disease under surveillance.⁵⁰ In this systematic surveillance approach, data are collected from clinical cases based on pre-diagnostic disease identification or classification and are used without requiring laboratory

confirmation of the causative pathogen.^{51–53} A disease syndrome with identifiable morphological features, such as IBD, can be detected during outbreaks with high sensitivity. The probability of detecting IBD cases through antemortem and postmortem examinations has been estimated at 91–97% at 95% detection percentile.⁵⁴ Rahman *et al.*⁵² used clinical signs and postmortem lesions to detect IBD outbreaks in Bangladesh, standing out as an exemplar of passive syndromic surveillance to evaluate animal health in a low-resource setting. Inadequate laboratory facilities for etiological diagnosis in a country⁵⁵ make syndromic reporting valuable in the animal disease surveillance system, where it can provide evidence-based data to support animal health decision-making and policy formulation, thereby promoting improved strategies for disease control. In northeastern Nigeria, veterinary reference laboratories for confirmatory diagnosis of animal diseases lack funding for diagnostic assets.⁵⁵ Veterinarians working as clinical and postmortem diagnosticians in surveillance centers, after receiving farm-initiated outbreak reports, resort to syndrome definitions and classifications of reported cases at necropsy, and manually record them to track outbreak trends in the local farms under their jurisdiction.

Outbreaks of IBD are notifiable epidemiological events that should be reported to local and national veterinary authorities that validate and collate confirmed data in a repository of animal disease information system suitable for real-time transmission to the World Animal Health Information System platform.⁵⁶ To better understand the temporal and spatial dynamics of IBD outbreaks, the integration of active and passive surveillance networks has been advocated, supported by syndromic reporting.⁵⁶ Such systems enable timely detection, with subsequent validation of syndromic reports through laboratory confirmation where preserved specimens are available,⁵⁷ and facilitate the prioritization of resources in response to epidemiological needs identified through surveillance. However, the absence of a standardized national syndromic surveillance system for IBD—within an already constrained and inefficient animal health information system⁵⁸—contributes to inaccurate and substantial underreporting of outbreaks.⁵⁶ This underreporting, in turn, exacerbates outbreak-related economic losses among farmers, who are already vulnerable to broader economic challenges. The main rationale for applying syndromic surveillance to IBD outbreaks is to expand the surveillance regime and engage trained experts in specific syndrome recognition, thereby enhancing the sensitivity and specificity of IBD reporting, and to reduce underreporting, especially as IBD outbreaks are forecasted to increase in the near future.⁵⁶ Although IBD can be prevented through vaccination, the absence of a national vaccination campaign and control

strategy highlights the need for effective and efficient IBD surveillance. Syndromic surveillance can monitor outbreaks and assess the effectiveness of the existing vaccination-based control measures. The objective of the study was to analyze retrospective data on the syndromic detection of acute IBD outbreaks (2008–2018) among all disease cases identified through postmortem lesion detection in chicken flocks with mortality in Maiduguri, Nigeria. The study aimed to establish an epidemiological database for IBD burden, including outbreak prevalence rate by age and chicken type, yearly trends, mortality rates, and lesion patterns, to demonstrate the utility of the existing local syndromic surveillance system for strategic adoption into an expanded national syndromic surveillance system.

2. Materials and methods

2.1. Syndromic surveillance centers and the area of coverage

The surveillance centers included the University of Maiduguri Veterinary Teaching Hospital (VTH) and the Senator Ali Modu Sheriff Veterinary Hospital (SVH), located in Maiduguri, the capital of Borno State, Nigeria. The VTH is located on the university campus on Bama Road, while SVH is located by Magaram Road within the township, close to the town's major metropolitan market. The two hospitals are about 6 km apart and serve as training centers for veterinary students in the clinics of the Faculty of Veterinary Medicine at the University of Maiduguri. They have poultry clinics with necropsy services that provide veterinary care to community poultry farmers. The VTH has diagnostic laboratories staffed by trained personnel with capabilities in serological, histopathological, and molecular diagnostic methods. However, laboratory diagnostic capability is poor due to the unavailability of diagnostic reagents and related consumables, resulting from a lack of funding dedicated to laboratory surveillance activities for IBD and other reportable diseases.

Maiduguri (11° N, 13° E) has a land area of about 105.5 km² with an increasing population of educated commercial poultry (chicken) farmers raising broilers for meat and layers for egg production, using an intensive production system. They keep their chickens on deep litter or battery cage systems, with flock sizes ranging from 50 to >100,⁵⁹ and are conscious of avoiding losses due to poor growth, reduced egg production, and mortality. Therefore, the farmers are inclined to report disease or outbreak events on their farms immediately to obtain diagnostic services, veterinary advice, and treatment for the flock.

2.2. Surveillance data collection process

Surveillance data were collected in both VTH and SVH

poultry clinics by experienced veterinarians. There were at least two veterinarians at each clinic, responsible for attending to farmers who reported disease outbreaks on their farms. The workflow leading to syndromic detection and outbreak identification (Figure 1) was reconstructed through direct engagement and interactive interviews with the veterinary staff. Farmers typically reported outbreaks by bringing sick or dead birds to the clinic when they observed clinical signs of disease and mortality on their farms. Occasionally, the clinic's ambulatory unit conducted farm visits to review outbreaks in detail. Farmers were expected to provide information on housing and husbandry practices, flock size and composition, age of birds, feeding, vaccination and medication history, number of deaths and mortality patterns, previous outbreaks, observed clinical signs, biosecurity measures, and other relevant farm history. Sick birds were physically examined for further clinical details, and the carcasses were sent for postmortem examination by veterinarians. Lesions were identified, described, and grouped into a specific disease syndrome as part of preliminary syndromic classification before any laboratory testing, with specimens collected when possible. Laboratory resources at both VTH and SVH were limited and generally insufficient for disease confirmation. Syndromic diagnoses based on clinical and postmortem examinations were recorded in the clinic logbook.

2.3. Syndromic lesion indicators and disease categorization

The syndromic detection of acute IBD was based on recognition of gross lesions in affected organs, including the BF; thigh, leg, and pectoral (breast) muscles; intestines; the proventriculus–ventriculus junction (PVJ); and kidneys (Figure 2). The lesion indicators were primarily used in the syndromic detection of the disease. The BF lesions were described as swollen/enlarged, hemorrhagic with luminal exudates, or any combination of the three descriptive features. Occasionally, BF lesions co-existed with hemorrhages in the thigh, leg, and/or pectoral muscles, hemorrhage at PVJ, inflammatory lesions in the intestine (enteritis), and kidney lesions with or without urate deposit.

An IBD outbreak complicated by a secondary disease syndrome was defined at necropsy as the co-occurrence of IBD lesion patterns with additional lesions specifically indicative of another concurrent disease. Secondary complications identified in the postmortem records (Figure 3) included Newcastle disease (ND), indicated by hemorrhages on the proventricular glands and cecal tonsils; colibacillosis (COL), presenting with fibrinous perihepatitis, pericarditis, and peritonitis; coccidiosis (COC) causing hemorrhagic enteritis; and necrotic

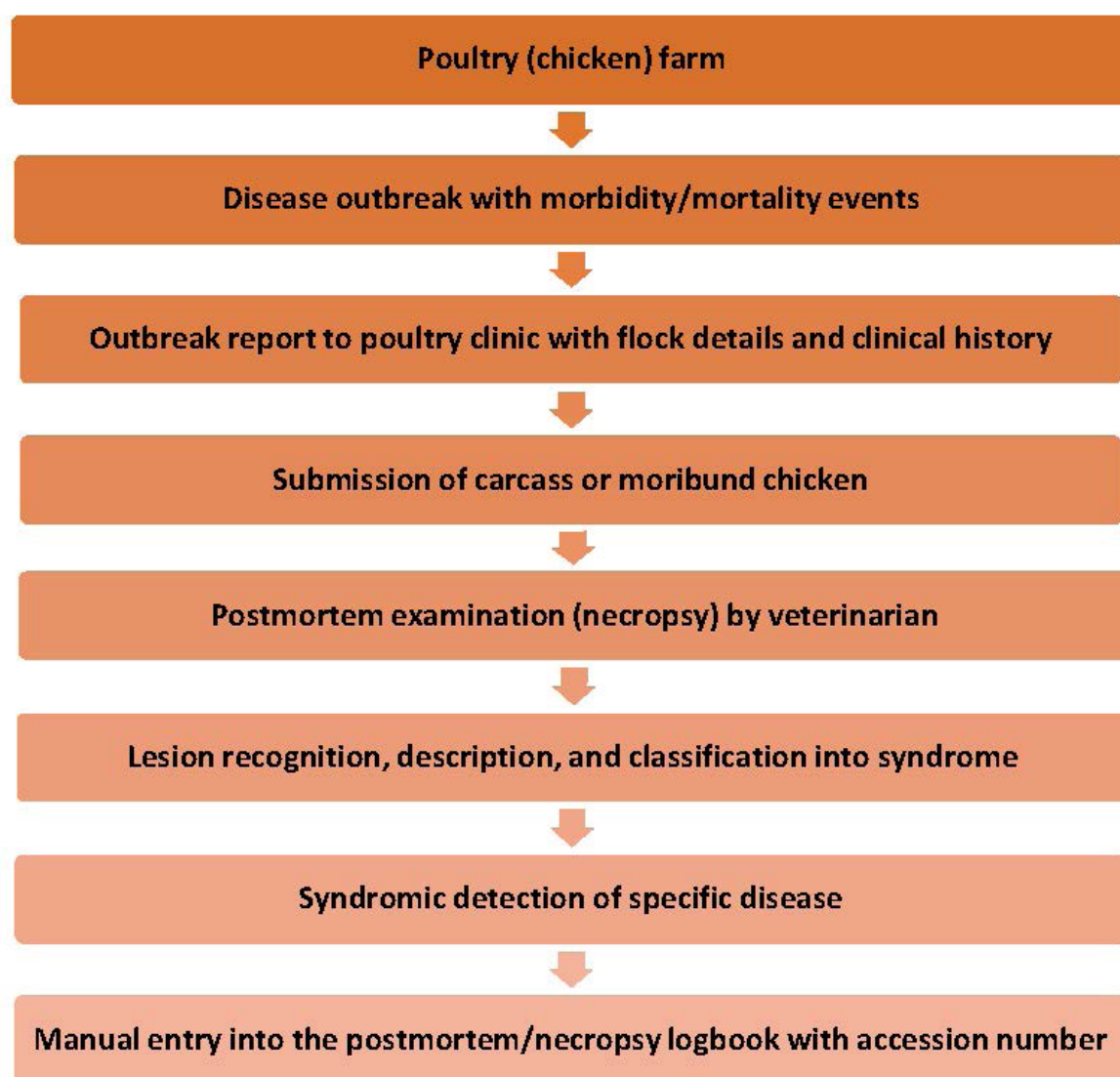


Figure 1. Workflow of syndromic detection of disease at the poultry clinic

enteritis (NE) associated with intestinal croupous pseudomembranes on the mucosa.

2.4. Data extraction from postmortem logbooks

The postmortem logbooks were obtained from VTH and SVH after obtaining official permission. The postmortem records for 2008–2018 were examined and validated for accuracy, with each record bearing the signature of an attending veterinarian. The records were handwritten on a ruled spreadsheet with column headings for the entries. The manually extracted records included details of acute IBD outbreaks among all recorded disease outbreaks detected by postmortem examination using lesion indicators.

Eligible outbreak records were manually entered into a spreadsheet if the corresponding logbook entries were completed, consistent with the lesion descriptions, and validated by the pathologists extracting the records. A focus group meeting of poultry disease experts involved in the study was convened to critically appraise the clinic records through a seminar-style discussion. Consensus was reached to adopt the data for summarization, with guidance on its potential utility in a national syndromic surveillance plan for Nigeria. Records that were inconsistent—particularly regarding vaccination history and seasonality—were deemed inadequate for meaningful analysis and were excluded after extraction.

Part of organ	• Lesion description
Bursa of Fabricius	• Swollen • Hemorrhagic • Luminal exudate
Thigh, leg, and pectoral muscles	• Petechial, ecchymotic and/or paint-brush hemorrhages
Proventriculus–ventriculus junction	• Hemorrhage
Intestine	• Diarrhea caused by the inflammation of the intestine
Kidney	• Swollen with or without urate (white) deposit in the ureter

Figure 2. Lesion descriptions of infectious bursal disease during syndromic surveillance

2.5. Data summary and analysis

The outbreak records were tabulated annually to include all available details from postmortem records, such as lesions described for disease detection, chicken type, age at the time of the outbreak, farm flock size, and mortality. Annual outbreak counts and percentages were collated, and year-specific prevalence rates of IBD outbreaks were calculated. Trend lines were fitted using the least squares method in Microsoft Excel. The IBD outbreaks, with or without complications, were counted, and corresponding percentages were calculated. The frequency of each secondary complication among IBD outbreaks was also calculated. Chicken type-specific prevalence was estimated as the proportion of IBD outbreaks relative to

the total number of disease outbreaks for each chicken type. Age distributions of chickens affected by IBD were grouped annually to calculate age-specific prevalence, with the modal and mean ages ($\pm$ standard deviation) estimated from frequency tables. Flock sizes and mortality records (2015–2018, the period for which these data were available) were used to calculate annual and overall mortality rates. Outbreak prevalence was expressed as a proportion with 95% confidence interval (CI), calculated using normal approximations (<https://epitools.ausvet.com.au/ciproportion>). Total frequencies of lesions in organs across IBD outbreaks were also determined. Variations in proportions and associations were analyzed using the chi-square test in GraphPad software (version 13.05), and significant variations and associations were at $p < 0.05$.

Secondary complication	• Lesion description
Newcastle disease	• Hemorrhages on the proventricular glands and cecal tonsils
Colibacillosis	• Fibrinous perihepatitis, pericarditis, and peritonitis showing fibrin debris on the liver, pericardium, and peritoneum
Coccidiosis	• Hemorrhagic enteritis showing hemorrhage on the mucosa and in the intestinal lumen
Necrotic enteritis	• Fibrinous enteritis with croupous pseudomembranes of fibrin on the mucous membrane of the intestine

Figure 3. Lesion descriptions of concurrent secondary complications during syndromic surveillance

3. Results

3.1. Overall and year-specific prevalence of infectious bursal disease outbreaks

The overall prevalence of IBD outbreaks in chicken farms was 7.6% (95% CI: 7.0–8.3%), based on 493 IBD outbreaks among 6,486 reported outbreaks of various poultry diseases in Maiduguri from 2008 to 2018 (Table 1). The year-specific prevalence ranged from 1.6% (95% CI: 0.9–2.3%) to 17.3% (95% CI: 12.9–21.7%) and showed a significant ($p < 0.001$) association. The yearly prevalence was higher ($p < 0.05$) in 2008–2011 (13.1–17.3%) than in 2012–2018 (1.6–8.9%). The year-specific prevalence showed a significant ($p < 0.01$) linear trend ($r = -0.73$), indicating a declining yearly prevalence of IBD outbreaks (Figure 4).

3.2. Chicken type-specific prevalence of infectious bursal disease outbreaks

The prevalence of IBD outbreaks varied significantly ($p < 0.05$) among the types of chicken during the period (Table 2). Chicken type-specific prevalence ranged from 7.1% to 25.0%. The Noiler chicken (a dual-purpose breed) had the highest prevalence (25.0%), followed by exotic cockerels (17.5%), local chickens (9.1%), broilers (7.2%), and layers (7.1%). Exotic cockerels had a significantly higher outbreak prevalence ($p < 0.05$) than broilers, layers, and local chickens.

3.3. Age-specific prevalence of infectious bursal disease outbreaks

The age-specific prevalence of IBD outbreaks among the 475 (96.3%) IBD outbreaks in chicken flocks with recorded age data in Maiduguri from 2008 to 2018 is presented in Table 3. The IBD outbreaks occurred in chickens aged 2–27 weeks, with a modal age of 4–5 weeks, and a mean age of 5.0 ± 1.7 weeks. The frequency of outbreaks increased from 18.3% at 2–3 weeks to 53.9% at 4–5 weeks, after which it declined to 17.9%, 7.4%, and 2.5% at 6–7, 8–9, and 10–27 weeks, respectively. The majority of outbreaks (>90%) occurred in birds aged nine weeks or younger, whereas only 2.5% occurred in those aged 10 weeks or older.

3.4. Mortality rates in infectious bursal disease outbreaks

Data on IBD outbreaks from 2015 to 2018, including flock size and mortality records, are summarized in Table 4. The total flock size for the period was 38,485, with 4,842 (12.6%) deaths (95% CI: 12.3–12.9). The year-specific mortality rates were 11.6%, 13.9%, 6.4%, and 12.2% in 2015, 2016, 2017, and 2018, respectively. The mortality rates did not vary significantly in 2015, 2016, and 2018 ($p > 0.05$). However, the mortality rates in 2015, 2016, and 2018 were significantly higher than in 2017 ($p < 0.05$). The yearly mortality trend flattened for three years, with an inverted middle parabola (U-shape).

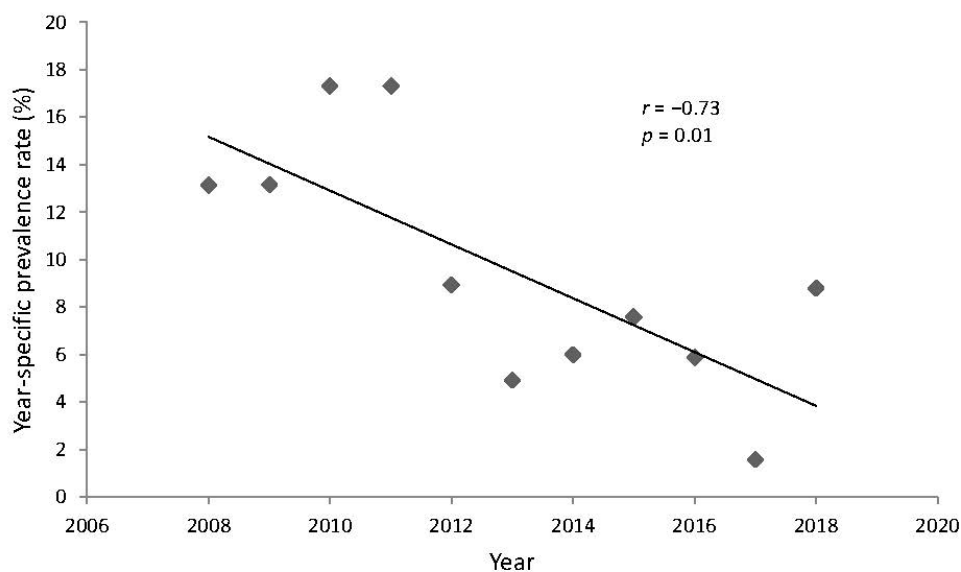


Figure 4. Trend of infectious bursal disease outbreaks in Maiduguri from 2008 to 2018

Table 1. Prevalence of outbreaks of infectious bursal disease in chickens in Maiduguri, Nigeria (2008–2018)

Year	Number of outbreaks of diseases	Outbreaks of infectious bursal disease		
		Number	Prevalence (%)	95% confidence interval
2008	160	21	13.1 ^a	7.9–18.4
2009	357	47	13.2 ^a	9.7–16.7
2010	306	53	17.3 ^a	13.1–21.6
2011	283	49	17.3 ^a	12.9–21.7
2012	459	41	8.9 ^b	6.3–11.5
2013	548	27	4.9 ^b	3.1–6.7
2014	50	3	6.0 ^b	0.0–12.6
2015	316	24	7.6 ^b	4.7–10.5
2016	1,446	85	5.9 ^b	4.7–7.1
2017	1,140	18	1.6 ^b	0.9–2.3
2018	1,421	125	8.8 ^b	7.3–10.3
Total	6,486	493	7.6	7.0–8.3

Notes: ^{a,b}Statistically significant differences between yearly prevalence values. Values sharing the same letter are not significantly different ($p \geq 0.05$). Values with different letters are significantly different ($p < 0.05$).

Table 2. Chicken type-specific prevalence of infectious bursal disease in Maiduguri, Nigeria (2008–2018)

Type of poultry	Number of outbreaks of diseases	Outbreaks of infectious bursal disease		
		Number	Prevalence (%)	95% confidence interval
Broiler	5,342	386	7.2 ^a	6.5–7.9
Layer	663	47	7.1 ^a	5.1–9.0
Exotic cockerel	229	40	17.5 ^b	12.6–22.4
Noiler	20	5	25.0 ^b	6.0–44.0
Local chicken	11	1	9.1 ^a	0.0–26.1
Unidentified and others	221	14	6.3 ^a	3.1–9.6

Notes: ^{a,b}Statistically significant differences between chicken type-specific prevalence. Values sharing the same letter are not significantly different ($p \geq 0.05$). Values with different letters are significantly different ($p < 0.05$).

Table 3. Age-specific prevalence based on the proportion of total outbreaks of infectious bursal disease in chickens of different ages

Age of chicken during outbreak (week)	Outbreaks of infectious bursal disease		
	Number	Prevalence (%)	95% confidence interval
2–3	87	18.3 ^a	14.8–21.8
4–5	256	53.9 ^b	49.4–58.4
6–7	85	17.9 ^a	14.5–21.3
8–9	35	7.4 ^c	5.0–9.7
10–27	12	2.5 ^d	1.1–3.9
Total	475	100	-

Notes: A total of 493 IBD outbreaks were recorded in Tables 1 and 2; however, age at the time of outbreak was available for only 475 outbreaks. Thus, the age-specific prevalence estimates presented in Table 3 are based on these 475 outbreaks, representing 96.3% of all IBD outbreaks recorded from 2008 to 2018. ^{a, b, c, d}Statistically significant differences between age-specific prevalence. Values sharing the same letter are not significantly different ($p \geq 0.05$). Values with different letters are significantly different ($p < 0.05$).

3.5. Occurrence of gross lesion indicators in infectious bursal disease syndromic detection

The occurrence of gross lesions of IBD, on which presumptive diagnosis was based, involved the BF (90.9%), followed by the muscles (72.2%), proventriculus and intestine (49.1%), and kidneys 7.7%) (Tables 5 and 6). The acute bursal lesion, presenting as BF swelling, was the most common (90.9%), but the absence of bursal swelling was not common (9.1%) and was associated with hemorrhagic

muscle lesions. It was uncommon (1.0%) to observe IBD lesions in all of the organs analyzed. Cloacal bursitis, as the only lesion, was also not frequent (3.0%). The concurrence of lesions in the BF with the muscle, proventriculus, and intestine, or both, was recorded in 36.9%, 23.1%, or 20.9%. Swollen BF (42.0%) and bursal swelling with evidence of hemorrhages (42.4%) were the most frequent (84.4%) presentations of bursal lesions. Luminal exudate with swollen BF, without (3.7%) or with (2.8%) hemorrhages,

Table 4. Mortality rates in chicken flocks with outbreaks of infectious bursal disease in Maiduguri (2015–2018)

Year	Total flock size	Outbreaks of infectious bursal disease		
		Number of deaths	Mortality rate (%)	95% confidence interval
2015	1,280	149	11.6 ^a	9.9–13.4
2016	14,980	2,074	13.9 ^a	13.3–14.4
2017	1,660	106	6.4 ^b	5.2–7.6
2018	20,565	2,513	12.2 ^a	11.8–12.7
Total	38,485	4,842	12.6	12.3–12.9

Notes: ^{a,b}Statistically significant differences between mortality rates. Values sharing the same letter are not significantly different ($p \geq 0.05$). Values with different letters are significantly different ($p < 0.05$).

was not common (6.5%). Muscle hemorrhage in the leg, thigh, and breast muscles was more frequent (48.1%) than in breast muscles alone (2.4%) or leg and thigh muscles alone (15.0%). Hemorrhages at the PVJ occurred alone (16.6%) or with enteritis (8.3%), whereas 24.5% of enteritis occurred alone without PVJ lesions. The kidneys were swollen with (4.9%) or without (3.3%) urate deposits.

3.6. Occurrence of concurrent gross lesion indicators of secondary complications

The postmortem reports showed concurrent secondary complications of ND, COL, COC, and NE in the IBD outbreaks (Table 7). Out of the 493 IBD outbreaks, 88 (17.9%) had secondary complications. The presence of concurrent lesions did not vary significantly across outbreaks ($p > 0.05$). The lesions associated with ND occurred ($p < 0.05$) more frequently (87.5%) than lesions of other diseases (1.1–5.7%). Secondary complication patterns occurred singly alongside IBD in nearly all outbreaks, except for one case in which two concurrent conditions—ND and COL—were identified.

4. Discussion

A syndromic surveillance system, established to report IBD and other disease outbreaks in chickens using lesion indicators during postmortem examination, was facilitated by data collection and a repository in veterinary clinics located in Maiduguri, northeastern Nigeria. Insights from the data summary and analysis of disease events provided a critical assessment of the status and trend of

the IBD burden, along with other diseases identified in the surveillance. These findings highlighted that IBD monitoring via syndromic IBD detection could support sustained epidemiological evaluation of IBD endemic outbreaks in the surveillance area. The highest year-specific prevalence rates were in 2010 and 2011. There was a downward trend in IBD outbreaks between 2008 and 2018, which might be attributable to improvements in the poultry management system by farmers⁴⁴ through the adoption of biosecurity and adequate immunization against the disease, probably driven by improved awareness and acceptance of better veterinary services among chicken farmers.^{32,60} Previous reports of IBD outbreak prevalence among disease outbreaks in Maiduguri were 6.6% in 1997–2001⁴² and 16.4% in 2004–2012.⁴⁵ The endemicity of IBD among viral diseases of chickens in Maiduguri (with ND) in 1995–2000 was previously reported.⁴¹ The acute outbreak prevalence of IBD in Maiduguri in this study was lower than previously reported rates in Kaduna (24.5%),³⁸ Zaria (12.0–12.5%),^{39,40,44} and Sokoto (32.9%).⁴³ The observations from our data are similar to the acute IBD outbreak prevalence rates of 7.8–31.7% in Bangladesh,^{52,61–63} 7.8–15.1% in India,^{64–67} and 7.1% in China.⁶⁸

Our data showed that IBD outbreaks occurred more frequently among Noiler chickens and exotic cockerels than among broilers, layers, or local chickens, indicating that chicken type significantly affected outbreak prevalence. The lighter breeds of chicken were reported to be more susceptible to IBD than the heavier breeds; layers are affected more than broilers.^{69,70} However, the

Table 5. Occurrence of gross lesions in organs of chickens during outbreaks of infectious bursal disease in Maiduguri

Lesion location	Number	%
Total occurrence in the organ		
BF	448	90.9
Muscles	356	72.2
Proventriculus and intestine	242	49.1
Kidney	38	7.7
A combination of organs in occurrences		
BF + muscle	182	36.9
BF + proventriculus-intestine	114	23.1
BF + muscle + proventriculus and intestine	103	20.9
BF + muscle + kidney	19	3.9
BF only	15	3.0
BF + muscle + proventriculus and intestine + kidney	7	1.4
BF + proventriculus-intestine + kidney	5	1.0
BF + kidney	3	0.6
Muscle only	28	5.7
Muscle + proventriculus and intestine	13	2.6
Muscle + kidney	4	0.8

Abbreviation: BF: Bursa of Fabricius.

Table 6. Occurrence of various described lesions in organs of chickens in infectious bursal disease outbreaks in Maiduguri

Described lesions	Number	%
Lesions in the bursa of Fabricius		
Swollen	207	42.0
Swollen and hemorrhagic	209	42.4
Swollen with luminal exudate	18	3.7
Swollen and hemorrhagic with luminal exudate	14	2.8
Lesions in the leg, thigh, and breast muscles		
Hemorrhages in the breast muscle	12	2.4
Hemorrhages in the leg and thigh muscles	73	15.0
Hemorrhages in the leg, thigh, and breast muscles	237	48.1
Lesions in the proventriculus and intestine		
Enteritis	121	24.5
Enteritis and hemorrhage at PVJ	41	8.3
Hemorrhage at PVJ	82	16.6

(Cont'd...)

Table 6. Continued

Described lesions	Number	%
Lesions in the kidney		
Swollen	16	3.3
Swollen and the presence of urate deposits	24	4.9

Abbreviation: PVJ: Mucosa of the proventriculus-ventriculus junction.

Table 7. Occurrence of lesions associated with other secondary complications ($n = 88$) during outbreaks of infectious bursal disease in Maiduguri

Secondary complication	Number	%
Newcastle disease	77	87.5 ^a
Colibacillosis	5	5.7 ^b
Coccidiosis	3	3.4 ^{bc}
Necrotic enteritis	2	2.3 ^{bc}
Newcastle disease and colibacillosis	1	1.1 ^c

Notes: ^{a,b,c}Statistically significant differences between the occurrence of lesions associated with other secondary complications. Values sharing the same letter are not significantly different ($p \geq 0.05$). Values with different letters are significantly different ($p < 0.05$).

prevalence of IBD outbreaks was comparable between layers and broilers in this report. Tong *et al.*³⁹ reported that susceptibility to IBD was higher in broilers than in layers in Kaduna, whereas Mbuko *et al.*⁴⁴ reported the lowest specific prevalence in layers among all chicken types and the highest rate of 25.8%, followed by cockerels and layers kept together with cockerels (16.7%). The highest specific prevalence in this report was observed in dual-purpose Noiler chickens, indicating that this presumably hardy breed^{71,72} could be susceptible to IBDV when exposed. There was no previous report of IBD in Noilers.⁴⁴ The local chickens are susceptible to IBDV, and outbreaks of the disease have been reported in local flocks after exposure.^{12,69,73} The variations in outbreak frequency may be linked to biosecurity or biosafety measures,⁶⁰ vaccination practices,³² or genetic differences among chicken types associated with susceptibility to infection due to viral receptor preponderance, extent of immune responsiveness, level of innate resistance during viral exposure, and presence of husbandry stressors.^{74–77}

The IBD outbreaks in the chickens started at two weeks of age and occurred in birds aged up to 27 weeks, with most occurring at 4–5 weeks. The disease rarely occurs before two weeks of age,^{44,63,78} as the chickens are protected

by maternal antibodies against IBDV. However, a lack of maternal antibodies may lower the age at which chickens become susceptible to IBD. This contrasts with the typical peak susceptibility at 4–5 weeks of age, when maternally derived antibodies—present from day-old chicks—have declined over time.⁷⁹ Most IBD outbreaks were reported at 3–5 weeks,⁴⁴ 3–4 weeks,^{63,66,79} or 3–6 weeks.⁶⁴ The age at which chickens experience IBD outbreaks is influenced by the developmental stage of the BF, when it is highly active and contains abundant lymphocytes that serve as targets for the virus,^{80,81} and susceptibility may extend until the BF undergoes complete involution, typically at 24–26 weeks of age.⁸² Outbreaks of acute IBD have been reported to occur in older chickens aged 11–14 weeks,^{27,83,84} 15–20 weeks^{3,7,10,83} and 24 weeks.²⁹ In this report, the outbreak in chickens at 27 weeks of age might have arisen from an infection before complete BF involution, and BF might not have played a prominent role in the disease at the time. In the absence of an active BF, the virus may still be infectious; however, lesions are predominantly observed in the muscles and intestines.⁸⁵

The pooled mortality rate (12.6%) in IBD outbreaks could have a negative impact on production. Mortality from IBD has been reported to be higher in younger

chickens (less than eight weeks of age) than in older chickens,⁶² consistent with our finding that >90% of outbreaks occurred in birds younger than nine weeks. In other longitudinal studies, mortality rates in IBD were reported as 2.61%⁷⁸ in India, 5.3%⁶⁸ and 7.8%⁶³ in Bangladesh (2010–2011 and 2012–2013, respectively), and 2.4%⁶⁸ in China (2010–2011). However, flock-specific mortality rate in specific-pathogen-free chickens exposed to virulent IBDV ranged from 0–100%, depending on the strength of protective immunity after vaccination.^{86–88} Nigerian isolates of virulent IBDV were reported to cause flock-specific mortality of 43.3–95.8%,²⁴ 75%,⁸⁹ and 9.3–87.2%.⁴⁴ Similarly, outbreaks of acute IBD by virulent IBDV also resulted in flock-specific mortality of 26–34%⁸⁴ and 3–76%.⁹⁰ Mortality in flocks with IBD outbreaks could be greatly reduced by effective immunization.⁸⁹ In contrast, exposure to virulent IBDV in flocks with inadequate immunity often leads to outbreaks associated with high mortality.^{24,27,33}

The postmortem diagnosis of IBD was based on the recognition of typical lesions. The lesions are usually characterized by tissue necrosis, hemorrhage, and acute inflammation. Acute inflammatory swelling or enlargement of the BF would occur within a few days of the outbreak²⁵ and was observed in the majority (90.9%) of outbreaks. Swollen or enlarged BF is characterized by increased weight due to congestion, exudation of fluid into the interfollicular tissues, accumulation of fluid in the necrotized lymphoid follicles forming cysts, and presence of mucous, caseous, or gelatinous exudate on mucosal folds lining the inside of the bursal lumen.^{25,91} A few of the outbreaks that were not associated with enlarged BF at postmortem might have occurred later in the outbreak, when the inflammation had receded, and BF atrophy was setting in due to lymphocytic depletion from necrosis and apoptosis. Reduction in BF size to normal or less than normal is considered a consequence of the resolution of acute inflammation in the transition to sub-acute and chronic inflammation, which involves the clearance of inflammatory exudates after the diminution of the actions of virus-induced pro-inflammatory cytokines and the onset of fibroplasia in the interstices.^{25,36}

The hemorrhages in the muscles arise from minute endothelial injuries in small blood vessels, which lead to diapedesis into the extravascular spaces of the muscles. These are active muscles in chickens, prone to strain from strenuous activities such as supporting body weight during locomotion and flapping the wings. This muscular activity could enhance diapedesis and hemorrhage by increasing capillary pressure. The hemorrhages were reported to be associated with thrombocytopenia and clotting

abnormalities, which might be elicited by depletion of blood coagulation factors.^{92–95} The enteritis in IBD was reported to be associated with infiltration of heterophils, lymphocytes, and macrophages in the intestinal mucosa and destruction of the gut-associated lymphoid tissues.⁹⁶ These lesions trigger the passage of diarrheic feces due to exudation of fluid from the mucosa through damaged epithelium and increased gastrointestinal propulsion of digesta. This would lead to fluid loss and dehydration, a factor that enhances urinary lesions and urate deposition in the urinary system. The frequency of kidney lesions was the lowest among all lesions, consistent with earlier reports.⁹⁷ The kidney lesions were previously demonstrated to be caused by acute glomerulonephritis, glomerulonecrosis, nephrotubular necrosis with epithelial desquamation, and tissue debris in the tubular lumina.^{97,98} Urate precipitation and deposition could result from stasis of glomerular filtrate and urine due to decreased glomerular function associated with glomerulonephritis, and from severe dehydration caused by reduced water intake and fluid loss from diarrhea. The supersaturation of concentrated urine in the collecting tubules and ureter, and the presence of tubular tissue debris generated by nephrosis and the accumulation of promoting inorganic solutes, could predispose to urate urolithiasis and kidney swelling.^{97,98}

Infectious bursal disease outbreaks detected through characteristic gross lesions were considered valid even without laboratory confirmation, due to the consistent association of these syndromic indicators with subsequent molecular diagnoses in reported clinical outbreaks. In all cases, BF exhibiting typical lesions yielded IBDV amplicons in 100% of outbreaks.^{30,34,35,90} When the BF from a suspected clinical outbreak tested negative for IBDV by molecular methods, it was presumed that the assay failed to detect the virus due to genomic mutations, reassortment, or recombination in the field strain.⁹⁹ Acute IBD is the only known disease of chickens that causes grossly visible acute exudative inflammatory swelling of the BF with hemorrhage. Atrophic BF with some evidence of inflammatory cytokine expression may be associated with subclinical and convalescent IBDV infections and other viral diseases such as ND, Marek's disease, infectious bronchitis, and chicken infectious anemia.^{100–103} Selenium and methionine deficiencies, as well as chemical toxicities from lead and ammonia, have also been reported to elicit lymphoid depletion and some level of inflammatory change in the BF.^{104–107} Neoplastic, non-inflammatory enlargement of the BF may occur in lymphoid leukosis and reticuloendotheliosis.¹⁰⁸ These pathologic conditions should be considered in the differential diagnosis of IBD in syndromic surveillance to study the epidemiology of IBD in the locality.

The present study revealed that IBD outbreaks were complicated by concurrent lesions associated with ND, COL, COC, and NE, with ND lesions as the most common secondary complication. Outbreaks of IBD in association with bacterial^{3,4} and parasitic¹⁰⁹ diseases, as well as hydropericardium syndrome,²¹ have been reported in chickens. In clinical surveys of avian infectious diseases, multiple pathogens may be present in a single outbreak, and individual cases can be diagnosed with mixed infections.⁵¹ Mixed infections, involving the simultaneous occurrence of 2–5 pathogens in a single outbreak, have been reported in diseased chicken flocks.^{3,4,110,111} The local chicks in Maiduguri often had mixed viral infections with IBD and ND viruses.¹¹² The likelihood of increased susceptibility to enteric infections causing COL, NE, and COC could be increased in IBD outbreaks by altered intestinal microbiota and damaged mucosal lymphoid organs.⁹⁶ As an immunosuppressive disease, IBD could trigger the establishment of lesions of other diseases whenever the causative agent co-exists with IBDV.

5. Conclusion

Syndromic surveillance demonstrated that acute IBD in chickens was endemic, with a temporal trend in outbreak prevalence, suggesting that contemporary factors, including risks and control measures, might be important in efforts to reduce or eliminate the disease burden.⁵⁵ Given the reported prevalence and mortality rates, IBD outbreaks have the potential to reduce the profitability of chicken production, particularly in hardy local and dual-purpose breeds, which are typically raised in rural backyard systems with poor management, inadequate biosecurity, and incomplete vaccination against IBDV. Other concurrent clinical diseases shown by lesion indicators during IBD outbreaks could exacerbate losses through deaths. The postmortem lesions identified in the BF and muscle could serve as syndromic indicators or lesion patterns for IBD detection and provide the basis for an expanded nationwide integrated syndromic surveillance system, with subsequent strategic and aggregated laboratory surveillance. This study provided insights into IBD case and syndrome definitions and classifications, supporting the design of a national syndromic surveillance system and enabling the expansion of data collection needed to develop effective IBD preventive measures. The lack of credible vaccination records associated with the outbreaks was a limitation during data collection and documentation, but their availability would have provided background on the outbreaks and statistical evidence to assess vaccine coverage and preventive strategies in the surveillance area. The required laboratory diagnosis to

confirm the nature of the virus involved was not available at the surveillance centers. However, surveillance officers within the animal disease monitoring system could have been tasked with collecting and preserving specimens for confirmatory diagnosis, to be stored in a specimen archive. These archived specimens could be useful for laboratory investigation when syndromic indicators suggest an epidemiological crisis in vaccine-preventable IBD outbreaks driven by vaccine failures. Massive laboratory investigations using archived specimens may commence with strategic funding interventions, such as Regional Disease Surveillance Systems Enhancement, or expanded support for laboratory capacity, or during a nationally sponsored emergency program to forestall an IBD epidemic breaking through control measures established by the national agency for disease control. Furthermore, our data were not amenable to spatial analysis because the data source lacked spatial information. Multicenter data collation of reported IBD outbreaks nationwide was not accessible for spatio-temporal analysis within the country. A recent study revealed gross underreporting of IBD and the potential for near-future outbreaks, based on spatial mapping of IBD outbreaks using World Animal Health Information System data.⁵⁶ To date, no spatial analysis of IBD outbreaks has been reported using national records from the former Animal Disease Reporting System, now the National Animal Disease Information System.¹¹³ Gaps exist in the reporting system due to breaches in the reporting cascade, which begins with farm-initiated reports to veterinarians in private and public clinics, who then forward the information to the State Director of Veterinary Services for entry into the National Animal Disease Information System. The current local spatial data scarcity may arise from the low priority given to the IBD outbreak reporting, as the disease is not zoonotic; nonetheless, it is an economically relevant transboundary disease under international surveillance.⁵⁶ The challenge of preserving and perpetuating the available data in a paper-based system is also a problem that could be solved by transitioning to the National Animal Disease Information System's web-based information system, with a mobile-enabled application, and by deploying a geographic information system with spatial information output. Therefore, developing a syndromic surveillance system for IBD outbreaks in Nigeria could build on the strengths and address the limitations of the surveillance data presented in this report. Such a system, coordinated by the State Director of Veterinary Services, would aim to provide timely, seamless, and complete reporting, with the necessary data inputs, to support disease monitoring and intelligence for IBD and evidence-based disease prevention and control.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Ethics approval and consent to participate

The research was approved by the Postgraduate Committee on Research (University of Maiduguri; approval no.: PGA/16/11/04/09900), and the institutional Ethics Committee confirmed that no ethical approval was required after permission to obtain data was granted.

Consent for publication

Not applicable.

Availability of data

The raw data for the study are available upon request, subject to permission from the veterinary hospitals that maintain the passive surveillance data.

Further disclosure

Findings of this study have been uploaded as preprint versions on Research Square:

- (i) Badau SJ, Igbokwe IO, Hassan SU, El-Yuguda AD. Outbreaks of acute infectious bursal disease

of chickens in Maiduguri, Nigeria (2008-2018): retrospective survey, 23 February 2023, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-2305788/v1]

- (ii) Badau SJ, Hassan SU, El-Yuguda AD, Igbokwe IO. Syndromic surveillance using lesion indicators for infectious bursal disease in chickens: insight from data summary and analysis from clinic records (2008-2018), 07 September 2025, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-5200288/v1]

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