c. cooking
d. treatment with lime, formalin or chlorine
e. pasteurisation

6. Acute salmonellosis in calves is most commonly seen at:
   a. 2 – 6 weeks of age.
   b. 1 – 2 days of age.
   c. 6 – 10 weeks of age.
   d. 5 – 10 days of age.
   e. 3 months and older.

7. Affected calves may develop pathological lesions in the following:
   i. Intestine (mucohaemorrhagic enteritis).
   ii. Mesenteric lymph nodes (oedema, congestion, enlarged).
   iii. Liver (necrotic foc).
   iv. Joints (serofibrinous).
   v. Brain (meningoecephalitis).
      a. Only (i).
      b. Only (ii).
      c. Only (iii).
      d. None of the above.
      e. All of the above.

8. A diagnosis of salmonellosis in dead animals is usually confirmed by means of:
   a. Culture only.
   b. Histopathology only.
   c. PCR screening of faeces.
   d. Serology only.
   e. Combination of (a) and (b).

9. Which of the following statements best describes the author's view on antimicrobial resistance of Salmonella sp in South Africa?
   a. Resistance is seen mostly in S.Dublin serotypes.
   b. Resistance is seen in most S.Typhimurium serotypes.
   c. Very few cases of antimicrobial resistance has been identified.
   d. Serotyping of cultures are not always done and resistance patterns has not been followed for a prolonged period of time.
   e. None of the above.

10. Which of the following statements is true about the diagnosis of carrier animals?
    a. It is a relative uncomplicated procedure.
    b. Animals shed bacteria intermittently requiring frequent attempts of isolation.
    c. S. Dublin latent carriers always yield positive faecal culture results.
    d. In dead animals culturing the udder is of no use.
    e. In dead animals culturing the gall bladder is of no use.

Please note that this electronic CPD system is different from the SAVA CDP system. If you registered on the SAVA system, you will have to register again to utilise this system. Registration is free.

It is possible to interact with the CPD Solutions system in one of two ways.

**WEBSITE**
The first method is via our website: www.onlinevets.co.za Go to www.onlinevets.co.za and follow the instructions. You will have to sign up – a link will be sent to your email inbox, click on the link – this will take you back to web where you can now log in as user. Click on Articles and Multiple choice test, this will take you to a page where you will select Online vets. Now you can view the selection available and choose the test you want to complete.

**SMS**
The other is by constructing and sending a SMS message to our SMS gateway. Go to www.cpd SOLUTIONS.co.za/Help/help.php and download instructions or phone 012 346 1590. Code for sms system for this article is a66038.

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since 1971. During this period, S. Dublin has remained fully susceptible to the antimicrobials used for sensitivity testing (Wray, 1997).

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>2007 % Isolates Sensitive</th>
<th>2008 % Isolates Sensitive</th>
<th>2009 % Isolates Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampicillin</td>
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<td>91</td>
<td>88</td>
</tr>
<tr>
<td>Cefotaxim</td>
<td>100</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>Co-Trimoxazole</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>97</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Florfenicol</td>
<td>94</td>
<td>96</td>
<td>88</td>
</tr>
<tr>
<td>Penicillin</td>
<td>19</td>
<td>52</td>
<td>29</td>
</tr>
<tr>
<td>Streptomycin</td>
<td>100</td>
<td>91</td>
<td>38</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>97</td>
<td>91</td>
<td>75</td>
</tr>
<tr>
<td>Tilmicosin</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Sensitivity of bovine Salmonella isolates from 2007-2009**

Cultures from Vetdiagnostix have indicated a drift in resistance during the period from 2007-2009. Multiple antibiotic resistance in the UK is usually associated with a small number of phage types of S. Typhimurium e.g. PT29 (Anderson, 1968), DT204c (Wray et al., 1987b) and more recently DT104 (Evans and Davies, 1996; Wray and Davies, 1996). In The Netherlands, multiple resistant phage types were 201, 193, 202 and, more recently, 206 (van Leeuwen et al., 1984; W. J. van Leeuwen, personal communication). However, in the USA most S. Typhimurium from cattle are multiply resistant.

**CONCLUSION**

In South Africa Salmonella infections in animals is a potentially significant erosive disease and has serious zoonotic implications. It would be useful to have more emphasis placed on routine screening of production animals with serotyping of cultures and defining their antibiotic resistance patterns.

**REFERENCES**


**MULTIPLE CHOICE QUESTIONS**

1. The most important serovars in cattle are:
   a. **S. abortusovis** and **S. derby**.
   b. **S. cholerasuis** and **S. typhi**.
   c. **S. Typhimurium** and **S. Dublin**.
   d. **S. enteritidis** and **S. brandenburg**.
   e. **S. bovismorbillicans** and **S. hindmarsh**.

2. The most important/common route of infection seems to be:
   a. Percutanous
   b. Via artificial insemination.
   c. Transplacentally.
   d. Insect transmitted.
   e. Faecal - oral.

3. Which of the following statements is false?
   a. S. Dublin is a cattle-specific serovar.
   b. Pigs may be a significant carrier of salmonellas.
   c. S. Typhimurium is less host specific.
   d. S. Dublin does not create a carrier state in cattle.
   e. Aerosol transmission of Salmonella sp may also be possible.

4. Which of the following statements is true?
   a. Infection may be localized in lymph nodes and tonsils.
   b. Mixing of young susceptible calves is ineffective in spreading of disease.
   c. Stress does not exacerbate clinical disease.
   d. Concurrent BVDV infection prevents salmonellosis.
   e. The normal intestinal flora promotes intestinal colonization by Salmonella sp.

5. Slurry contaminated with Salmonella sp can be disinfected by means of:
   a. sterilization
   b. freezing
swabs or preferably freshly voided faeces. In animals with severe acute diarrhoea, rectal biopsies may be a more suitable sample than faeces as it may more easily yield the adherent and invasive organisms.

The identification of carrier animals may be more difficult, as carriers may shed bacteria intermittently. It may be necessary to submit multiple specimens taken at a number of occasions before a positive culture is obtained. The identification of latent S. Dublin carriers is particularly problematic, as faecal culture and serology are usually negative. Since parturition may activate latent infection, swabs or faeces and vaginal discharges should be cultured. To diagnose latent infection in a dead animal, attempts should be made to isolate Salmonella from the gall bladder, ileocaecal lymph nodes, tonsils, female genital tract, supramammary lymph nodes and udder.

In aborted foetuses salmonellas can be isolated from organs (liver, spleen, lungs) and the abomasal contents whilst placenta and vaginal mucus of cows that abort would be suitable for bacterial isolation.

Results of a study by Van Kessel et al suggests that milk filters may be an effective method for monitoring shedding prevalence at the herd level. In-line filter testing is a sensitive measure of Salmonella, and perhaps other pathogens, in raw milk.

**LABORATORY CULTURE RESULTS**

Samples submitted to Vetdiagnostix laboratories over the period 2007 - 2009 have yielded 82 positive cultures for Salmonella of which 11 (13%) were from group B, and 66 (80%) from group D, to which the serovars S. Typhimurium and S. Dublin belong respectively. Samples were collected from animals either with clinical signs or post mortem lesions suspicious of salmonellosis. In a large number of cases typical macroscopic and histological lesions of salmonellosis were seen. It is, however, not possible to ascertain from this data whether all these isolates were the primary or secondary causes of disease, or whether they were part of a multifactorial problem. In most cases culture was also attempted in order to confirm the diagnosis and rarely to identify carrier animals.

Due to financial constraints in many cases, serotyping was not performed in all the cases and therefore results can only be reported accordingly to the groups. Significant pathogens in the groups would include:

- **Group B** - *Salmonella Typhimurium* and *Salmonella paratyphi-B*.
- **Group C** - *Salmonella bovismorificans*, *Salmonella choleraesuis* and *Salmonella typhisuis*.
- **Group D** - *Salmonella Dublin*, *Salmonella typhi* and *Salmonella enteritidis*.

**Culture results according to sample type and age**

<table>
<thead>
<tr>
<th>ISOLATE</th>
<th>SAMPLE</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>Abomasal fluid</td>
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<td></td>
</tr>
<tr>
<td>Brain</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Faeces</td>
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<td></td>
</tr>
<tr>
<td>Intestine</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Lung</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Rectal swab</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Organs</td>
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<td></td>
</tr>
<tr>
<td>Muscle</td>
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</tr>
<tr>
<td><strong>Group B Total</strong></td>
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<td></td>
</tr>
<tr>
<td>Abomasal fluid</td>
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</tr>
<tr>
<td>Placenta</td>
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<td>Intestine</td>
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<tr>
<td><strong>Group C Total</strong></td>
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<tr>
<td>Abomasal fluid</td>
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<td></td>
</tr>
<tr>
<td>Faeces</td>
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</tr>
<tr>
<td>Gut swab</td>
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<tr>
<td>Intestine</td>
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<tr>
<td>Kidney</td>
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<tr>
<td>Liver</td>
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<td>Liver and intestine</td>
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<tr>
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<tr>
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<tr>
<td>Swab</td>
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<td><strong>Group D Total</strong></td>
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<tr>
<td><strong>Grand Total</strong></td>
<td><strong>82</strong></td>
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</table>

**Table 1: Culture results according to sample type**

<table>
<thead>
<tr>
<th>Age (Months)</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Total</th>
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<td>10</td>
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<td>2</td>
<td>-</td>
<td>10</td>
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<td>-</td>
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<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Calf</td>
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<tr>
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<td>2</td>
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<tr>
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<tr>
<td><strong>Total</strong></td>
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<td>5</td>
<td>66</td>
<td>82</td>
</tr>
</tbody>
</table>

**Table 2: Culture results according to age group**

Groups are shown below in tables 1 and 2 respectively:

**ANTIMICROBIAL RESISTANCE**

Antimicrobial resistance has been monitored in *Salmonella* isolated from cattle in England and Wales.
prognosis, even without treatment, is quite good, although complete recovery takes about 2 months. In some instances, variations in the clinical disease arise from the fact that illness is not due to recently acquired infection but to activation of a latent infection by some other disease or stress. Such cases may show a wide gradation in the severity of clinical signs and it may be difficult to determine whether disease is caused primarily by Salmonella or whether Salmonella are playing a secondary role.

It has become apparent that cows may abort from S. Dublin infection without showing clinical signs.

Calves
In calves, the clinical disease is more common after the first week of life and clinical signs are often seen at 2-6 weeks of age. The clinical picture in calves is variable and may include respiratory infections, but the enteric form of the disease is most frequent. The typical clinical case is characterized by fever, dullness and loss of appetite, followed by brown diarrhoea, with foetid offensive faeces, which may contain blood or mucus. Affected calves quickly lose condition and become dehydrated, weak and emaciated. With S. Dublin, bacteraemia and respiratory signs often predominate and the calves are frequently older than those affected with other serovars.

Some calves may suffer septicaemia and collapse with no diarrhoea. Affected animals show profound depression, dullness, prostration, high fever (40.5 - 42°C) and death may occur within 24 - 48 hours. Because the infection also commonly causes pneumonia, evidence of this may be present. Jaundice is a feature in some cases and nervous signs due to encephalomenigitis may be seen in other cases. Polyarthritides and oesalitis have also been described and in some cases of enteric salmonellosis dry gangrene of the extremities, including ear tips, tail tip and the limbs from the fetlock down has been described.

The severity and duration of clinical signs are often related to the standard of husbandry and hygiene. On poorly run farms, 80% or more calves may develop clinical signs, with mortality rates of 10-50%. Contributory factors are important in determining the occurrence and severity of clinical disease. Concurrent viral diseases, such as BVDV infection, have been shown to be of importance.

PATHOLOGY
Calves
The intestine may not be the sole portal of entry for Salmonella, and infection of oesophagostomized calves with S. Typhimurium, reported by De Jong and Ekdahl, 1965, resulted in haematogenously spread via the tonsil to the intestine. Most experimental studies, however, have been made with oral challenge, where the organism gains entry to the tissues predominately in the lower small intestine. Here the bacteria invade the intestinal mucosa via both M-cells, which overlie the lymphoid follicles and the enterocytes. The bacterial infection results in distinct typical pathological changes: the villi become oedematous and shortened and there is an abnormal extrusion of enterocytes. Seagall and Lindberg (1991) showed that S. Dublin had a specific affinity for columnar enterocytes of the terminal jejunum and ileum, the follicle associated epithelium over the Peyer’s patches and glandular tissues in the duodenum, tonsillar area and lungs.

Animals dying of acute septicaemia show extensive submucosal and suberosal petechial haemorrhages. More prolonged cases are characterized by poor bodily condition, usually with evidence of foetid diarrhoea. The small intestine typically shows diffuse mucoid or mucohaemorrhagic enteritis and the mesenteric lymph nodes are oedematous, congested and greatly enlarged. Severe haemorrhagic and diphtheric enteritis has been seen in some cases of S. Typhimurium infection. The liver commonly shows jaundice, with thick turbid bile and many reports refer to the presence of necrotic foci in the liver and kidneys. Gibson (1965) commented that, although such liver lesions were commonly reported in mainland Europe, they were uncommon in his experience. Sharply defined areas of pneumonia may be present in the anterior lobes of the lungs. When joints are affected, the joint cavities and adjacent tendon sheaths contain a gelatinous or serofibrinous fluid. Skeletal lesions of epiphyseal separation, osteopeniortitis and rarefying osteomyelitis of the distal limb bones were described in calves suffering from chronic S. Dublin infection (Gitter et al., 1978). Meningo-encephalitis may also develop.

Adult Cattle
While there have been numerous studies of experimental Salmonella infections in calves, these have been very much less frequent in adult cattle. The post mortem findings of a typical case reveal an acute mucoid or necrotic enteritis, especially of the ileum and large intestine. The wall is thickened and covered with yellow-gray necrotic material overlying a red, granular surface. The mesenteric lymph nodes and spleen may be enlarged. These lesions, however, are insufficient to confirm the diagnosis and bacteriological confirmation is necessary.

DIAGNOSIS OF SALMONELLA INFECTIONS
Typical macroscopic lesions as described above will give an indication of the diagnosis, which may then be confirmed by bacterial isolation and typical histopathological lesions. Samples from inflamed areas of the intestines and other organs such as liver, spleen, mesenteric lymph nodes and lungs should be submitted to the laboratory. In the live animal, confirmation of clinical salmonellosis is performed by culture of rectal
ADDITIONAL FACTORS IN THE AETIOLOGY OF DISEASE

Through the years extensive investigations have been carried out into the epidemiology of disease by authors such as Wray, Davies and Jones.

- Many factors, conveniently labeled as 'stress', may either exacerbate the disease or increase the susceptibility of cattle to Salmonella infections.
- Fasciola hepatica infection and bovine viral diarrhoea virus (BVDV) infection have been associated with more severe infections than when Salmonella alone is present.
- It is known that the normal flora of the alimentary tract is inhibitory to colonization by Salmonella, probably most dependent on the volatile fatty acid content and pH of rumen fluid and a change in feed may precipitate disease.
- An important aspect of the epidemiology of Salmonella infection in cattle is the persistence of organisms in animal accommodation after depopulation. S. Typhimurium DT204c has been shown by plasmid-profile analysis to persist in calf units for periods ranging from 4 months to 2 years (mean 14 months). In laboratory experiments, S. Dublin survived for almost 6 years on faeces on different building materials.
- Salmonella have been shown to survive for up to 286 days in slurry, but this is a function of the initial number of organisms, storage temperature and Salmonella serovar. Survival is greatest at temperatures below 10°C and in slurries containing more than 5% solids. Although Salmonella die rapidly in slurry during storage, there are occasions when disinfection may be necessary. Aeration of slurry is an effective method of reducing Salmonella and chemicals such as lime, formalin and chlorine have been recommended.
- Salmonella may survive for long periods on pastures in infected faeces, where their survival is dependent on a number of factors, especially climatic conditions. In moist unheated faeces, survival up to 3-4 months has been reported and S. Dublin survived for at least 72 days in faeces on pasture in winter and 119 days in summer. Properly composted faeces heats up rapidly and Salmonella numbers are reduced quickly. S. Dublin survived for 13-24 weeks when spread in slurry on pasture. Salmonella survival has been estimated to be from less than 30 days to 1 year in soil, from 200 to 259 days in soil contaminated with animal faeces, from 57 to 300 days in soil contaminated with cattle slurry and from 11 days to 9 months in soil containing sewage sludge (Jones, 1992). Davies and Wray (1996) found that when calf carcasses contaminated with S. Typhimurium were placed in either a decomposition pit or a deep burial pit, Salmonella were isolated from the soil around the pit for 27 weeks and for 15 weeks around the burial site. Salmonella reappeared in soil samples during the cold weather after an apparent 9-week absence. Spread to a nearby drainage ditch occurred and wild birds became contaminated from eating Salmonella infected maggots.
- Sewage sludge is used as a fertilizer and examination of 822 samples of settled sewage sludges and final effluent from eight sewage treatment works found that 68% of the samples were positive for Salmonella (Jones et al., 1980). An investigation of 26 outbreaks of salmonellosis in animals found that the attributed sources of infection were sewage effluent.
- Water-borne infection: There are many reports on the isolation of Salmonella from rivers and streams and, once a water supply is contaminated, rapid spread of infection may occur.
- Rats and mice may acquire S. Dublin infection but available evidence suggests that they do not play a major role in the spread of S. Typhimurium infection. Evans and Davies found that wild birds and cats were possible vectors of DT104 particularly if they had access to feed stores. A high population density of cats around the farm and evidence of access to feed stores by wild birds were both associated with an increased risk of disease. Cats have also been shown to be infected with S. Typhimurium DT104. The presence of infection was also detected in mice, rats and to lesser extent dogs, foxes, and badgers. Contamination of feed grain stores and bedding by their faeces was common (Davies, 1997).
- Feedstuffs such as meat and bone meal, fishmeal and finished feeds have been found to be contaminated with Salmonella, as have vegetable proteins such as soya, rapeseed meal and cottonseed.

CLINICAL SIGNS

Adult Cattle

Acute and subacute forms of disease are recognized in adult cattle of all ages and infections caused by the different Salmonella serovars show no significant differences.

In acute salmonellosis, the onset is sudden, with fever, dullness, loss of appetite and depressed milk yield. The fever often drops with the onset of severe diarrhoea, which may vary from watery green - brown to foetid watery faeces containing blood, mucus and shreds of casts of necrotic bowel lining. Pregnant animals may abort. In untreated cases the case fatality rate may reach 75% and death is most frequently 4-7 days from onset of clinical signs while treatment may reduce the fatality rate to 10%. In all cases the animals show signs of toxaeamia, dehydration and associated weight loss, with the faeces remaining liquid for 10-14 days and complete recovery may take up to 2 months.

Subacute salmonellosis is less dramatic. Fever varies or is absent and the other signs are less severe. The
Salmonella Infections in Cattle

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INTRODUCTION
Salmonella infections are an important cause of mortality and morbidity in cattle and subclinically infected cattle occur frequently thus constituting an important reservoir for transmission to animals and for human infections. Salmonellosis occurs in animals in most countries of the world. There are many different strains (serovars) of differing pathogenicity and the most significant ones transmit between different animals and man and recently have been associated with significant antibiotic resistance. Salmonella Typhimurium and Salmonella Dublin appear to be the most common serovars isolated from cattle and the distribution of these two serovars may differ between countries. S. Dublin is considered to be serovar specific to cattle, rarely affecting other species and humans. In contrast S. Typhimurium is a less host specific serovar and, similar to most of the other serovars, transmission between different species is more commonly seen. Pigs may be a significant carrier of Salmonella but are not dealt with in this article.

EPIDEMIOLOGY
Infection is usually by the oral route and the results of experimental infections are more consistent and the clinical signs more acute with the higher challenge doses. These doses are likely to be higher than those encountered under natural conditions, where concurrent disease and stress contribute to the course of the disease. It has been suggested that aerosol transmission may also be a means by which Salmonella is transmitted.

Most infection is introduced into Salmonella free herds by the purchase of infected cattle, either as calves for intensive rearing or adult cattle for replacements. A case control study of S. Typhimurium DT104 (an antibiotic resistant phage type) infection in cattle showed that the introduction of newly purchased cattle to a farm increased the risk of disease and that the period of highest risk was the first 4 weeks after purchase. Some adult cattle that recover from Salmonella infection, especially in the case of S. Dublin, may become active carriers, and excrete the organism continuously or intermittently in their faeces for years, if not life.

In contrast, animals recovering from S. Typhimurium infection may continue to excrete the organism in their faeces but this period is usually limited to a few weeks or months after recovery. Evans and Davies (1996) in their investigation of S. Typhimurium DT104 infection commented that, while the disease outbreak was of short duration, subclinical infection in the herd could persist for up to 18 months and that recurrences of infection may occur in some herds 2-3 years after the original infection.

Some animals in a herd may harbor localized infection in lymph nodes, gut associated lymphoid tissues, rumenal fluid, gall bladder, tonsils and udders, especially following S. Dublin infection, without excreting the organism in their faeces. Such animals may be termed latent carriers, which are of importance in the epidemiology of S. Dublin infection and the persistence of the organism on farms. A number of studies have shown that Salmonella infection may be present on farms in the absence of clinical disease.

The mixing of young susceptible calves and their subsequent transport is an effective means for the rapid dissemination of Salmonella, especially S. Typhimurium.

Studies by Wray et al. 1987, showed that the infection rate for S. Typhimurium increases during the first week to reach a peak at 14 – 21 days, although the spread of S. Dublin appears to be slower, with a peak at 4-5 weeks. Salmonella Typhimurium DT 104 infected herds may be a significant risk to herds located within the same geographic area through factors like person contacts, sharing of equipment and contaminated slurry.