Dairy Session II

"New Frontiers in Medicine"

Moderator— John Ferry

Salmonellosis: Diagnostic Approach to Disease Control and Epidemiology in the Bovine Animal

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Salmonella Biology and Nomenclature

Nomenclature

The genus *Salmonella* is a member of the *Enterobacteriaceae*. It is named after the American veterinarian Daniel Salmon, a graduate of Cornell University's College of Veterinary Medicine. Salmonella are gram negative rods which possess lipopolysaccharide (LPS), also polysaccharide repeat units (part of the "O" antigen) as part of their cell walls, and with rare exceptions are flagellated (the "H" antigens). The "O" antigens are used to serogroup strains of salmonella (e.g., serogroup B or D) and the combination "O" and the "H" antigens are used to completely serotype strains/isolates of salmonella (e.g., *Salmonella typhimurium* or *S. dublin*). Current taxonomy lists *Salmonella* as having one as having one species called *enterica* and 6 subspecies; previously there had been 3 different species names with the Arizona group classified separately. Today *Salmonella typhimurium* and *S. dublin* (their common or familiar names) would be correctly (and formally) called the following:

Salmonella enterica subsp *enterica* ser Typhimurium
Salmonella enterica subsp *enterica* ser Dublin

However, most diagnostic laboratories still report salmonellae with their more common or familiar names. There are currently over 2200 salmonella serotypes. Some serotypes such as Dublin (cattle), Pullorum/Gallinarum (poultry), and Typhi (human) are called *host-adapted,* while others such as Typhimurium (found in many animal and avian species) are *non host-adapted;* these terms reflect the ranges of hosts in which one usually finds the serotype.[1,2]

Fingerprinting strains for epidemiology

Once a strain of salmonella has been serotyped we often want a further discrimination for epidemiological purposes. Some serotypes have phage typing (PT) schemes; biotyping (BT) schemes; chromosomal DNA may be analyzed with restriction enzymes to produce restriction fragment length polymorphism (RFLP); IS200 sequence variation; 16S ribosomal RNA (rRNA) may be analyzed to produce a ribotype; and if strains have plasmid DNA this may be analyzed for number of plasmids present and their molecular weights, plasmids may be further subdivided with restriction cuts and also may be placed into compatibility groups; antimicrobial susceptibility profiles; outer mebrane protein (OMP) profiles may be compared; fatty acid methyl ester (FAME) profiles may be compared; electrophoretic analysis of allelic variation at enzyme-encoding chromosomal genes (mutilocus enzyme electrophoresis) may be tested.

Environmental survival

Salmonella bacteria have a remarkable ability to survive under adverse conditions. They survive between the pH's of 4 to 8, and can grow between 8 and 45°C. Salmonella are facultative anaerobic bacteria that can survive under low oxygen tension such as in manure slurry pits. Salmonella are known to survive for long

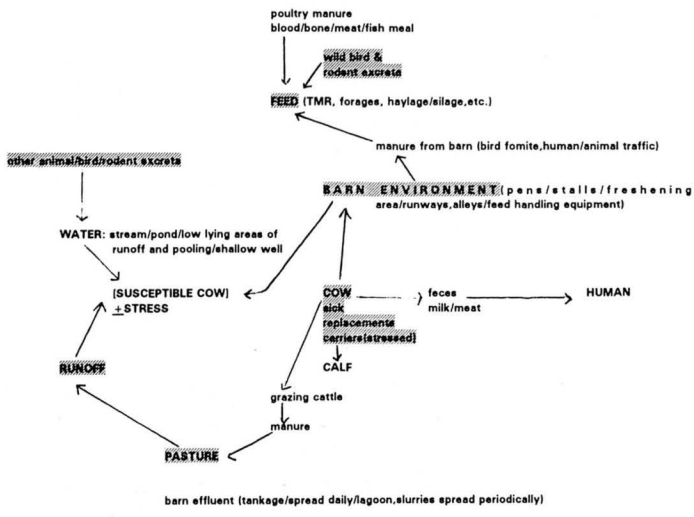
periods in soil and in water. Salmonellae spread onto fields in the form of manure may survive for long periods; it is best to spread the manure onto flat land (to prevent runoff problems) where it is exposed to the drying effects of wind, and the bactericidal effect of UV irradiation from the sun; manure should be spread onto cropland rather than onto pastures for grazing. There has been much recent investigation into the advantages of different manure disposal methods; composting has many advantages from the standpoint of controlling disease. Salmonellae, as gram negative rods, are no more or less sensitive to the effects of commonly used disinfectants than are other gram negatives. Chlorine solutions, iodines, quaternary ammoniums, phenolics, etc., are very good at killing salmonellae on surfaces; however, efficient scraping/dry cleaning is important to get rid of organic matter and bedding, followed by wet cleaning with high pressure hot water/steam and then disinfection. The interval between wet cleaning and disinfection must not be too long or salmonellae can "bloom" in the wet environment. Many strains are relatively resistant to the effects of drying, salting, and smoking of foods. However, salmonellae are very sensitive to beta and gamma irradiation.

Epidemiology

The ubiquity of salmonellae in the environment, carrier animals, birds, etc., means that eradication is unlikely; therefore, efforts must be directed toward understanding epidemiology of infection with the **aim of breaking the cycle(s) of infection.**

Figure 1. Epidemiology of Infection Cycles in Adult Cattle.

- Identify potential sources of infection: clinical case, carriers, feed/water, etc., especially early in an outbreak
- Many avenues of infection for the cow and calf
- Importance of fecal-oral cycling of infection
- Rapid contamination of the environment by clinical case; problem of determining initial source late in an infection.



Classes of animals that shed Salmonella

a. *passive carrier* - this animal is a "living fomite", and is not actually infected. Contaminated feed is passing through its intestinal tract. Many parameters interact to determine if a host animal will become infected including dose of salmonella ingested. Nevertheless such animals serve to contaminate the environment. Passive carriers are also at risk of infection.

b. *incubating (subclinical)-to-clinical case* - part of a spectrum of disease; these animals are truly infected (salmonella have invaded and multiplied within the mucosae); they may be shedding varying numbers of salmonella bacteria.

c. *convalescent carrier* - animals that are recovering from disease may still be shedding salmonella for varying periods of time.

d. *active carrier* - seemingly healthy animals that shed intermittently without apparent stress.

e. *latent carrier* - apparently healthy animals that shed only when stressed. Both active and latent carriers may be subclinical cases or recovering cases.

SPECTRUM OF DISEASE OCCURS WITH SALMONELLOSIS = from inapparent/subclinical disease to mild/moderate/severe clinical case; "stress" factors important

Epidemiology of Samonellosis in the Veal Calf

Cow to calf:	on the farm of origin directly - transplacental; S dublin milk excretion; fecal-udder contamination indirectly - contamination of barn floors, buckets, feed, water by fecal contact
Transportation:	increased exposure in trucks; crowding in sale yards; tendency for calves to suckle each other
Increased susceptibility of the neonate:	questionable immune status - has the calf received colostrum? was it of good quality? too little, too late?
Problems in veal unit:	poor husbandry! stress! diet - is milk replacer of good

quality? problem of denatured milk proteins
crowding - poor ventilation (high humidity; ammonia vapor builds up; effect on respiratory defense mechanisms)
Intercurrent disease - parasitism; colibacillosis; enteric viruses, viral and bacterial pneumonias

In general: in conditions of intensified husbandry with stress factors, a rapid buildup of salmonella and other organisms will occur in the environment. This is in association with a compromised host population of neonatal calves, whose immune status is questionable.

BEWARE of literature you read on salmonellosis, i.e.,

There may be serotype dependent clinical presentations. For example, *Salmonella typhimurium* (mild to severe enteric signs) versus *S. dublin*'s septicemia/meningitis/pneumonia in calves.

Salmonella dublin has emerged as a problem in the Northeast USA; this has tremendous herd and public health significance.

Risk factors, stress and bovine salmonellosis:

a. important to think of salmonellosis in terms of the **"Epidemiological triad of disease",** i.e. Disease agent (salmonella serotype, dose), Host (age, immune status), Environment including stresses, crowding, feed/water changes):
RISK FACTORS FOR BOVINE SALMONELLOSIS
1. salmonella serotype involved (its relative virulence)
2. dose ingested
3. route of exposure
4. age of host (neonate and immature calves at great risk)
5. intercurrent disease
6. prior exposure to salmonella and immunologic status of the host (colostrum deprived calf at great risk; BVD immunosuppressed cow at risk; previous exposure may confer somedegree of immunity)
7. nutritional plane of the host (affects overall well-being of the animal, including the immune system; starvation and feed changes may lower the volatile fatty acids of rumen and large intestine which are a protective factor in the gastrointestinal tract)
8. stress.

b. STRESS FACTORS FOR BOVINE SALMONELLOSIS

1. shipment (crowding, exhaustion, dehydration, starvation)
2. weather extremes (especially sudden changes)
3. parturition
4. surgery and associated procedures (shipment to the hospital, food and water deprivation, antimicrobials, anesthesia)
5. vaccination (MLV-BVD immunosuppression)
6. concurrent disease
7. parasite load
8. poor nutrition (resulting in starvation, indigestion from poor quality feeds, moldy feeds, overheated feed, frosted grain, grain excess, concentrate excess)
9. sudden feed or water deprivation
10. feed changes (especially today with so many additives and custom-made diets; resulting in rumen fatty acid changes and changes in resident microbial flora)
11. contaminated feed (toxic materials: herbicides, mycotoxins, and their effect on the immune system)
12. oral administration of drugs (antimicrobials, ph-altering drugs, and their effect on resident microbial flora)
13. crowding
14. poor ventilation (humidity, ammonia fumes)
15. exposure to newly introduced animals
16. exposure to areas of field run-off such as in exercise lots
17. exposure to animals with diarrhea

Pattern of Disease Seen in Cattle

1. point source outbreaks (contaminated feed, water source)
- potentially large numbers of animals presenting simultaneously with disease (point source outbreaks with secondary spread to contact - see second wave of disease after initial outbreak)
2. individual sporadic cases, e.g., where a "stressed" carrier cow(s) or newly exposed breaks with disease 2-4 days post-parturition, post-shipment, post-feed change, i.e., post stress;
- (outbreak originating from individual case - in these cases the degree of spread is dependent on management practices, e.g., ability to contain spread, isolate animal, type of housing (free stall versus conventional); sporadic cases may have lateral spread and become epidemics!)

- salmonellosis appears to be increasing in our dairy, beef and veal operations. Certainly some man-

agement factors may have contributed to this phenomenon by increasing the chance of spread within a herd, e.g., increase in free stall housing, larger size herds with intensive management, etc. We also have had changes in our distribution of serotypes in the Northeast, i.e., *S. Dublin* has arrived in veal and dairy beef, and we have had new clones of *S. typhimurium* arrive.

Clinical Signs - Cattle

- spectrum of disease (subclinical, clinical case: acute/chronic, carriers)

1. **peracute disease:** colostrum-deprived or -deficient calf most commonly affected; fever (105-107° F); diarrhea (yellow with or without flecks of blood and mucus); rapid dehydration, prostration and death occurring within 24-48 hours due to fulminating septicemia. Mortality high.

   NOTE: many veal calves and dairy beef have a different presentation when infected with *Salmonella dublin* - 8 to 10 week old calves go off feed, have fevers, show clinical signs of pneumonia/septicemia, diarrhea may or may not be present. Morbidity in affected units is high as is mortality in untreated calves.

2. **acute enteritis:** most common form in adult cattle and many times is precipitated by some stress factor(s). Affected cattle rapidly contaminate their environment. Clinical signs include: fever (104-106° F) followed by anorexia, depression and a foul-smelling diarrhea with varying amounts of blood, mucus, fibrinous casts, and shreds of intestinal mucosa. In milking animals there is a severe drop in milk production. Abortion sequels are not uncommon. Dehydration varies with the severity of disease. Temperatures rise 24 hours before the onset of diarrhea and may drop off again with the onset of diarrhea. Mortality rates vary depending on the serotype of salmonella involved. The time course of clinical infection is usually 7-10 days with recovery in 2 to 3 weeks. Some animals may never resume full production. Acute cases that recover may become carriers that shed Salmonella for varying periods of time (e.g., *S. typhimurium* from 3 to 6+ months versus *S. dublin* = lifelong carriers).

3. **chronic cases:** preceded by the acute form of disease. Fever (103-104° F) is intermittent and watery diarrhea persists resulting in progressive dehydration and weight loss. Recovery may be slow and mortality rates are difficult to predict; cattle are often culled due to unthriftiness and poor condition.

Diagnostic Approach to Salmonella Problems in the Bovine

We usually first get involved with a case of bovine salmonellosis after we have performed bacterial cultures on case material from the herd in question. We usually get minimal history of diarrhea and a fecal swab intransport medium or in a tied off rectal examination glove or a 4 oz specimen container. After we have made a salmonella isolation and serogrouped it, the referring veterinarian is contacted by telephone to discuss the case.

Differential diagnosis and herd histories

Salmonellosis in calves or adult cattle may present with a spectrum of clinical signs. In approaching the problem of diagnosing salmonella infections, the first step is the formulation of the differential diagnosis during the course of getting both the herd history and the individual animal history.

Differential Diagnosis of Calfhood Diarrhea (Morse, et al, Radostits)

Escherichia coli/colibacillosis
rotavirus type A, B, C
Coronavirus
Cryptosporidium parvum
BVD
other enterovirus, small round viruses (calici, astro, parvo, Bredavirus?
Clostridium perfringens
salmonellae
Campylobacter spp.?
Yersinia enterocolitica?
Yersinia pseudotuberculosis?
coccidia

other calf problems (non-infectious)
metabolic disorders
nutrition
chemicals/drugs

Differential Diagnosis of Adult Diarrhea in the Cow

acute diarrhea (Petrie L.)	**chronic diarrhea** (Whitlock RH)
salmonellosis	parasitism
winter dysentery	Johne's disease
overeating acidosis	salmonellosis
malignant catarrhal fever	BVD
plant poisonings	abdominal fat necrosis
arsenic poisoning	chronic peritonitis
BVD	thrombosis of posterior vena cava
	renal amyloidosis
	right-heart failure

abdominal neoplasia
mycotoxicosis
copper deficiency
blue tongue
ascites
foreign material
magnesium excess

1. First I take a herd history via a quick telephone questionnaire and/or via a mailed out questionnaire. During this history taking I establish the following points which helps to interpret the severity of disease on the farm and also risk factors for cattle salmonellosis: case definition; morbidity and mortality; the index case(s) details of clinical signs, location in herd, duration of clinical signs, treatments given; I also try to establish the presence of any obvious risk factors for salmonellosis in the index case(s) (see list above); try to establish the epidemic curve for the herd (patterns of spread, too); the referring veterinarian's differential diagnosis; herd demographics (size, type of housing, exercise areas, freshening areas, lay of the land, calf protocols); areas where water run-off/pooling can occur; location of all water sources on the farm; manure disposal protocol; is this an open or closed herd; how recent were any herd additions; general herd health problems for the last 3 month period (especially diarrhea, DA's, ketosis; abortions; drop in herd production); vaccination program and most recent vaccinations; feeding program including location of all feedstuffs on the farm; rodent and/or bird problems on the farm; other animal species on the farm; any high risk groups of humans on the farm (elderly, infant, immunosuppressed, corticosteroid-antacid-antibiotic users) and their access to animals and raw milk; determine whether any other herds in the area have had diarrhea problems.

2. With the above information and the clues it offers us, we can establish:

a. number of cases (few or outbreak; if outbreak think of point source contamination of feed and/or water)
b. how fast has the disease been spreading (from the epidemic curve); from the location of cattle and feedstores and exercise areas are there any clues to disease spread via traffic patterns or management practices; are any one group of animals ill or affected first? such as the high producing milkers/ recently fresh cows, dry group, calves?
c. run-off problems as from barn or manure storage area effluents that may have contaminated the water source(s) for cattle; from the farm physical plant setting and exercise areas of cattle, are the cattle exposed to contaminated run-off, stagnant pools of water?; has there been any recent heavy rainfall correlated with the problem?
d. were there any Risk Factors present for the cases, e.g., recently fresh (stressed carrier cow that broke with salmonella, or uninfected cows that were exposed to salmonella in a "dirty" freshening stall?; recent herd additions with the stress of adjustment and shipment; recent visits to fairs or to a veterinary hospital for medical/surgical treatment?; any recent feed changes ("new" forages, protein supplements) or frozen feed and water that might have stressed a carrier or brought in salmonella; recent antimicrobials used; weather extremes.

HACCP Approach to Prevention and Control of Bovine Salmonellosis

Currently there is a national effort in many animal industries to control salmonella in the food chain. We hear the terms **Hazard Analysis Critical Control Point (HACCP), Best Management Methods approaches, Pre- and Post-Harvest Food Safety, Pathogen Reduction Programs.** <u>All of these efforts are attempting to prevent the establishment or spread of salmonella bacterial infection at multiple levels of the food chain, thus assuring food safety.</u> The Salmonella Committee of the United States Animal Health Association (USAHA) has already written Best Management Methods for controlling salmonellosis in the poultry/turkey industries and is actively pursuing the same goal in cattle. **The discussion below details the hazards (or risk areas) and the critical control points (CCP) for salmonellosis in cattle; this will include only the preharvest section of the program i.e., on the farm CCP's.**

3. Attempt to find source of infection and the degree of environmental contamination:

a. recommend **<u>bacterial culture</u>** of 5-10 well but "at risk" animals, recently ill suspect animals in order to determine the extent of salmonella shedding in the herd. There is also the possibility now to perform serology on suspect animals to ascertain infection status. For culture we may ask for any of the following:
feces (in rectal exam glove or Amies transport medium w/charcoal or 4 oz specimen container)
blood cultures (in conventional blood culture bottles)
milk cultures (sent in on ice packs)
joint tap (in Amies, usually from a calf)
aborted fetuses (using our Bovine Abortion Kit)
necropsy material from calf or adult cases (heart blood, bone marrow, mesenteric LNs, tied off loop of jejunum/ileo-cecal area, lung, joint swabs) or submission of entire animal to our necropsy ser-

vice at the College of Veterinary Medicine.

b. also culture of **feedstuffs**; protein supplements, forages/silage/haylage (40 grams in a whirl pack bag)
c. culture **water** (3-4 liters) from different sources
d. culture of **birds/rodent droppings** on the farm (usually found in the feed bunks/silos/rafters)
e. use a Moore swab to culture the **drains or manure storage areas** to ascertain extent of salmonella in the environment; also use the poultry "drag swab" to culture the environment.

4. Collect and save feed and water samples for possible future workup for mycotoxins, toxicology analysis.

5. Perform your diagnostic workup, supportive treatment and isolation of cases early.

6. Keep good records of clinical signs, animal movement, feed sources, location of animals on premises, dates of onset of clinical signs . . . this will aid in the development of epidemic curves, etc.

7. Take temperatures twice a day of at risk animals; any fever can be an early marker of infection.

8. Collect serum from representative number of cases and well animals for BVD titers/virus isolation and for salmonella serology (obtain a paired serum later).

9. Restrict movement of animals and personnel handling cattle so as to prevent spread of disease.

10. Isolate sick animals as much as is possible because they are shedding large numbers of Salmonella bacteria.

11. Increased awareness and management changes for better hygiene: i.e., wash and disinfect boots often; after leaving barns, change barn clothes and/or coveralls often, remove manure more frequently from barns so as to prevent buildup of infection.

12. Potential use of bacterins or gram negative core-antigen vaccines (or someday live attenuated mutant salmonella vaccines) in at risk groups of animals.

13. Careful carcass disposal so as to prevent further spread of disease in the food chain of animals and humans.

14. Cleaning and disinfection of milking parlors, freshening stalls, runways with an approved product.

15. LONG TERM CONSIDERATIONS:

- improve management where appropriate
- prompt attention to new cases especially in stressed animals
- stop giving raw milk to calves, especially from acute cases that are being treated and from recovering cases
- use feeds from dealers that provide a salmonella-free product; store the feed in a dry, vermin-free environment; use loading equipment (different buckets at least) that has not been used to handle manure or dead animals.
- give prompt attention and diagnostic workup to abortions
- submit feces, aborted fetuses and placentas from animals with fevers and/or diarrhea
- stop drinking raw milk by humans from the bulk tank
- dispose of manure often to crop rather than grazing pastures; onto flat versus hilly areas, so as to minimize runoff and maximize exposure to UV radiation.
- water supplies should come from a deep well, or from a chlorinated source, not from streams, ponds; consider fencing off ponds and streams at least during the grazing season following a salmonella outbreak.
- control rodents and birds on the premises so as to protect feeds from contamination.
- isolate newly purchased animals, perform salmonella serology, and salmonella culture
- Salmonella vaccination program for the dry cows and springing heifers (specific for the salmonella serotype in the herd)
- followup culture of cases so as to detect chronic carriers
- clean calving pens between animals
- do not allow rendering trucks near the barn or feed animals so as to prevent spread on potentially infectious material

Bibliography

Salmonella Bacteriology and Nomenclature.

1. Ewing, W.H. 1986. Edwards and Ewing's Identification of the Eneterobacteriaceae. 4th Edition. Elsever, New York. 2. World Health Organization Collaborating Centre for Reference and Research on Salmonella. Antigenic Formulae of the *Salmonella*, publication number BD/72.1 Rev. 3 (1980). WHO, Geneva, Switzerland.

Fingerprinting strains for epidemiology.

1. Aho, M.O.C.F.T., L. Nuotio, E. Nurmi, and T. Kiiskinen. 1994. Competitive exclusion of campylobacters from poultry with k-bacteria and broilact. Int J Food Microbiol, Amsterdam:. Elsevier Science Publisher, B.V. Mar/Apr 1992. volum:volume 15-volume 275. 2. Alonso. R., A. Echeita, and M.A. Usera. 1994. [Subtyping of Salmonella enteritidis using a new phage typing protocol]. *Enferm. Infecc. Microbiol. Clin.* 12:197-199. 3. Baquar, N., E.J. Threlfall, B. Rowe, and J. Stanley. 1994. Phage type 193 of Salmonella typhimurium contains different chromosomal genotypes and multiple IS200 profiles. No Journal Found. 4. Chowdry, N., E.J. Threlfall, B. Rowe, and J. Stanley. 1993. Genotype analysis of faecal and blood isolates of Salmonella dublin from humans in England and Wales. *Epidemiol. Infect.* 110:217-225. 5. Christensen, J.P., J.E. Olsen, and M. Bisgaard. 1993. Ribotypes of salmonella enterica serovar gallinarum biovars gallinarum and pullorum. *Avian. Pathology.* 22: 725-738. 6. Dorn, C.R., R. Silapanuntakul, E.J. Angrick, and L.D. Shipman. 1992 Plasmid analysis and epidemiology of salmonella-enteritidis infection in

three commercial layer flocks. *Avian. Dis.* 36:844-851. 7. Harrington, C.S., J.A. Lanser, P.A. Manning and C.J. Murray. 1991. Epidemiology of Salmonella sofia in Australia. *Appl. Environ. Microbiol.* 47:223-227. 8. Heilesen, A.M. and P.H. Christensen. 1994. Abscess of the submandibular gland caused by Salmonella typhimurium biotype 10. *Scand. J. Infect. Dis.* 26:223-224. 9. Kaura, Y.K., J. Singh, R.K. Kaushik, R.C. Kulshrestha, Minakshi, and G. C. Chaturvedi. 1990. Salmonella-gallinarum-var-duisburg an emerging biotype causing heavy mortality in poultry birds in northern India. *Indian J. Anim. Sci.* 60:127-130. 10. Lammerding, A.M., M.M. Garcia, E.D. Mann, Y. Robinson. W.J. Dorward, R.B. Truscott, and F. Tittiger. 1988. Prevalence of salmonella and thermophilic campylobacter in fresh pork, beef, veal and poultry in Canada. *J. Food Prot.* 51:47-52. 11. Lammerding, A.M., M.M. Garcia, E.D. Mann, Y. Robinson, W.J. Dorward, R.B. Truscott, and F. Tittiger. 1994. Prevalence of salmonella and thermophilic campylobacter in fresh pork, beef, veal and poultry in Canada. *J. Food Prot.*, Ames, Iowa: International Association of Milk, Food and Environmental Sanita: Volume 51-52, xx ch. 12. Li, J., N.H. Smith, K. Nelson, P.B. Crichton, D.C. Old, T.S. Whittam, and R.K. Selander. 1993. Evolutionary origin and radiation of the avian-adapted non-motile samonellae. *J. Med. Microbiol.* 38: 129-139. 13. McDonough, P.L., J.F. Timoney, R.H. Jacobson, and R. Khakhria. 1989. Clonal groups of salmonella-typhimurium in New York State, USA *J. Clin. Microbiol.* 27:622-627. 14. Nastasi, A., C. Mammina, and M.R. Villafrate. 1993. Epidemiology of salmonella-typhimurium ribosomal DNA analysis of strains from human and animal sources. *Epidemiol. Infect.* 110:553-565. 15. Nastasi, A., M.R. Villafrate, and C. Mammina. 1990. Characterization of strains of Salmonella enterica subsp. enterica serovar Wien isolated in Italy: an epidemiological evaluation. *Microbiologica.* 13:317-321. 16. Opal, S.M., K.H. Mayer, F. Roland, J. Brondum, J. Heelan, and L. Lyhte. 1989. Investigation of food-borne outbreak of salmonellosis among hospital employees. *Am. J. Infect. Control.* 17:141-147. 17. Pohl, P., P. Lintermans, G. Ghysels, M.L. Chasseur Libotte, and C. Schlicker. 1994. Salmonella from animals, meet and meals in 1980. Serotypes, biotypes and resistances (includes feed contamination). Ann. Med. Vet., Bruxelles. Personnel, Enseignant. et. Scientifique. de. la. Faculte de Medecine. 18. Pohl, P., P. Lintermans, M. Marin, L.M.L. Chasseur, and G. Ghysels. 1986. Salmonella strains from animals meat and feedstuffs isolated in Belgium during the year 1985 serotypes biotypes and resistances. *Ann. Med. Vet.* 130:109-117. 19. Pohl, P., P. Lintermans, C. Schlicker, L.M.L. Chasseur, and G. Ghysels. 1985. Salmonella strains from animals meat and feedstuffs isolated in Belgium during the year 1984 serotypes, biotypes and resistances. *Ann. Med. Vet* 129:121-129. 20. Pohl, P., P. Lintermans, C. Schlicker, G. Ghysels, and M.L. Chasseur Libotte. 1994. Salmonella from animals, meat and feed-stuffs: 1981. Serotypes, biotypes and resistance (Belgium). *Ann. Med. Vet. Bruxelles.*, Corps. enseignant. de. la. faculte. de. medicine. veterinaire, Univers. 21. Sergevnin, V.I., E.A. Pegushina, N.D. Pozdeeva, and O.G. Pegushina. 1993. Epidemiological markers of salmonella enteritidis. Zhurnal, Mikrobiologii. *Epidemiologii. i. Immunobiologii.* 49-50. 22. Usera, M.A., T. Popovic, C.A. Bopp and N. A. Strockbine. 1994. Moecular subtyping of salmonella enteritidis phage type 8 strains from the United States. Washington. American Society for Microbiology, Jan. 1994 v. 32 (1) *Journal of Clinical Microbiol.* 23. Wachsmuth, I.K.C., D.C., J.A. Kiehlbauch, C.A. Bopp, D.N. Cameron, N.A. Strockbine. J.G. Wells, and P.A. Blake. 1994. The use of plasmid profiles and nucelic acid probes in epidemiologic investigations of foodborne, diarrheal diseases. *Int. J. Food. Microbiol.*, Amsterdam: Elsevier. Science Publishers., B.V., Jan. 1991. Volume 12 iss:volume 12-vol 90, ill.

Epidemiology of Infection.

1. 1986. Communicable disease report. April to June 1986. PHLS Communicable Disease Surveillance Centre. Community. Med. 8:356-360. 2. Bernardo, F.M.A. and J.C.C. Machado. 1990. Salmonella in Portugal, A Slaughterhouse Survey. *Rev. Port. Cienc. Vet.* 85:94-102. 3. Bruner, D.W. 1985. Salmonellosis: a continual threat to New York State's cattle and horses. *Cornell. Vet.* 75:93-96. 4. Daniels, E.K., N.E. Woollen, J.S. Dickson, and E.T. Littledike. 1993. Beef cattle salmonellosis: a study of oral s. typhimurium and topical s. newport inoculations. *Bovine Practitioner.* 168-170. 5. Eld, K., A. Gunnarsson, T.. Holmberg, B. Hurvell, and M. Wierup. 1991. Salmonella isolated from animals and feedstuffs in Sweden during 1983-1987. *Acta. Vet. Scand.* 32:261-277. 6. Frost, A., J., D.O'Boyle, and J.L. Samuel. 1988. The isolation of Salmonella spp from feed lot cattle managed under different conditions before slaughter. *Aust. Vet. J.* 65:224-225. 7. Gay, J.M. and M.E. Hunsaker. 1993. Isolation of multiple Salmonella serovars from a dairy two years after a clinical salmonellosis outbreak. *J. Am. Vet. Med. Assoc.* 203:1314-1320. 8. Haneef, W., G.A. Khan, and M. Siddique. 1990. Pathology of mesenteric lymph nodes of buffaloes and cattle with special reference to salmonellosis. *Arch. Roum. Pathol. Exp. Microbiol.* 49:229-232. 9. Helmuth, R. and A. Seiler. 1986. Epidemiology and chromosomal location of genes encoding multiresistance in salmonella-dublin. Joint. Meeting on Evolution, Ecology and Epidemiology of Antibiotic. RESISTANCE, BONN, WE:179-182. 10. Johnston, W.S., G.F. Hopkins, G.K. Maclachlan, and J.C. Sharp. 1986. Salmonella in sewage effluent and the relationship to animal and human disease in the north of Scotland. *Vet. Rec.* 119:201-203. 11. Jorgensen, S.T. 1986. Antibiotic resistance profiles and molecular epidemiology of salmonella-typhimurium and salmonella-dublin mainly from cattle. Joint. Meeting on Evolution, Ecology and Epidemiology. Of Antibiotic. RESISTANCE, BONN, WE:183-188. 12. Lance, S.E., G.Y. Miller, D.D. Hancock, P.C. Bartlett and L.E. Heider. 1992. Salmonella infections in neonatal dairy calves. *J. Am. Vet. Med. Assoc.* 201:864-868. 13. McDonough, P.L., S.J. Shin, and J.F. Timoney. 1986. Salmonella serotypes from animals in New York State, 1978-1983. *Cornell Vet.* 76:30-37. 13a. McDonough, P.L. 1986. Epidemiology of Bovine Salmonellosis. In: *The Proceedings of the 18th Annual Convention of the Am Assoc of Bovine Pract.* pp 169-173. 14. McDonough, P.L., J.F. Timoney, R.H. Jacobson, and R. Khakhria. 1989. Clonal groups of salmonella-typhimurium in New York State USA. *J. Clin . Microbiol.* 27:622-627. 15. McEwen, S.A., S.W. Martin, R.C. Clarke, S.E. Tamblyn and J.J. McDermott. 1988. The prevalence, incidence, geographical distribution, antimicrobial sensitivity patterns and plasmid profiles of milk filter Salmonella isolates from Ontario dairy farms. *Can. J. Vet. Res.* 52:18-22. 16. Milch, H., V.G. Laszlo, and E.S. Csorian. 1985. Epidemiological analysis of Salmonella typhi-murium infections on the basis of laboratory methods. I. Distribution of phage types and biotypes of Salmonella typhimurium isolated in Hungary in the period 1960 to 1981. *Acta. Microbiol. Hung.* 32:75-86. 17. Minga, U.M., H.H. Licht, and J. Shlundt. 1985. Four outbreaks of salmonellosis due to Salmonella typhimurium among cattle in one district in Denmark: case reports. *Br. Vet. J.* 141:490-497. 18. Morisse, J.P. and J.P. Cotte. 1994. Evaluation of some risk factors in bovine salmonellosis. *Vet Res.* 25:185-191. 19. Nastasi, A., C. Mammina, and M.R. Villafrate. 1993. Epidemiology of salmonella-typhimurium ribosomal DNA analysis of strains from human and animal sources. *Epidemiol. Infect.* 110:553-565. 20. Nastasi, A., M.R. Villafrate, C. Mammina, M.F. Massenti, D. Oliva, and G. Scarlata. 1987. Molecular relationship among Salmonella dublin isolates identified at the Center for Enterobacteriaceae of Palermo during the years 1971-85. *Epidemiol. Infect.* 99:283-290. 21. Ngoma, M., A. Suzuki, I. Takashima, and G. Sato. 1993. Antibiotic resistance of escherichia coli and Salmonella from apparently healthy slaughtered cattle and pigs, and diseased animals in Zambia. Jpn. *J. Vet. Res.* 41:1-10. 22. Oosterom, J. 1991. Epidemiological studies and proposed preventive measures in the fight against human salmonellosis *Int. J. Food. Microbiol.* 12:41-51. 23. Pacer, R.E., J.S. Spika, M.C. Thurmond, N. Hargrett-Bean, and M.E. Potter. 1989. Prevalence of Salmonella and multiple antimicrobial-resistant Salmonella in California dairies. *J. Am. Vet. Med. Assoc.* 195:59-63. 24. Papadopoulou, C. and O. Papadopoulos. 1989. Salmonella-spp and other enterobacteriaceae from nosocomial patients, animals, feedstuffs and abattoir sewage in Ioannina, Greece. *Acta. Microbiol. Hell.* 34:611-618. 25. Pelzer, K.D. 1989. Salmonellosis. *J. Am. Vet.*

Med. Assoc. 195:456-463. 26. Pohl, P., Y. Glupczynski, M. Marin, G. Van Robaeys, P. Lintermans, and M. Couturier. 1993. Replicon typing characterization of plasmids encoding resistance to genatamicin and apramycin in escherichia coli and salmonella typhimurium isolated from human and animal sources in Belgium. *Epidemiology and Infection* 111:229-238. 27. Popovic, S., D. Jovanovic, Z. Milosevic, N. Kalinovic, and L. Milosevic. 1991. Salmonella-sp bacteria in the organs of clinically healthy animals. *Vet. Glas.* 45:265-268. 28. Reilly, W.J., D.C. Old, D.S. Munro, and J.C. Sharp. 1985. An epidemiological study of Salmonella montevideo by biotyping. *J. Hyg.* (Lond). 95:23-28. 29. Rumschlag, H.S. and J.R. Boyce 1987. Plasmid profile analysis of salmonellae in a large-animal hospital. *Vet. Microbiol.* 13:301-311. 30. Threlfall, E.J., J.A. Frost, L.R. Ward, and B. Rowe. 1990. Plasmid profile typing can be used to subdivide phage-type 49 of Salmonella typhimurium in outbreak investigations. *Epidemiol. Infect.* 104:243-251. 31. Threlfall, E.J., B Rowe, and L.R. Ward. 1993. A comparison of multiple drug resistance in salmonella from humans and food animals in England and Wales. 1981 and 1990. *Epidemiology and Infect.* 111:189-197. 32. Visser. I.J. 1994. [An outbreak of Salmonella dublin]. *Tijdschr. Diergeneeskd.* 119-101. 33. Weber, A., C. Bernt, K. Bauer, and A. Mayr. 1993. [The control of bovine salmonellosis under field conditions using herd-specific vaccines]. *Tierarztl. Prax.* 21:511-516. 34. West, A.M., S.W. Martin, S.A. McEwen, R.C. Clarke, and S.E. Tamblyn. 1988. Factors associated with the presence of Salmonella spp. in dairy farm families in southwestern Ontario. *Can. J. Public Health.* 79:119-123. 35. Wray. C. 1985. Is salmonellosis still a serious problem in veterinary practice? *Vet. Rec.* 116:485-489. 36. Wray, C. 1994. Salmonella dublin infection of cattle in England and Wales: its epidemiology and control. Proceedings of the International Symposium on Salmonella, New Orleans, Louisiana, USA,J:Snoeyenbos-Sn181, ill. 37. Wray, C., N. Todd, I. McLaren, Y. Beedell, and B. Rowe. 1990. The epidemiology of Salmonella infection of calves: the role of dealers. *Epidemiol. Infect.* 105:295-305. 38. Wray, C., N. Todd, I.M. Mclaren, and Y.E. Beedell. 1991. The epidemiology of Salmonella in calves: the role of markets and vehicles. *Epidemiol. Infect.* 107:521-525. 39. Wray, C., Q.C. Wadsworth, D.W. Richards, and J.H. Morgan. 1989. A three-year study of Salmonella dublin infection in a closed dairy herd. *Vet. Rec.* 124:532-537.

Differential Diagnosis of Calfhood Diarrhea

1. Morse, E.V., M.A. Duncan, J.S. Baker, H.E. Amstutz, E.D. Myhrom, K.A. Gossett. 1975. Prevalence, Clinical Aspects, Treatment and Control of Bovine Salmonellosis. In: *Proceedings of the 17th Annual Convention of the Am. Assoc. of Bovine Pract.* pp 17-20. 2. Radostits, O.M. 1985. Neonatal Diarrhea in Ruminants (calves, lambs and kids). Session #109, In: *Proceedings of the Annual Conference for Veterinarians,* Cornell University, College of Veterinary Medicine. Ithaca, NY.

Differential Diagnosis of Adult Bovine Diarrhea

1. Petrie, L. 1987. Differential Diagnosis of Diarrhea in Adult Cattle. In *Practice,* Mar 1987, pp 50-57. 2. Whitlock, R.H. 1987. Chronic Diarrhea in Cattle: Differential Diagnosis. *Irish Vet J* 41:216-222.

Disease in Cattle

1. Aitken, M.M., P.W. Jones, and D.J. Burden. 1994. Experimental concurrent infection of cattle with ostertagia ostertagi and salmonella dublin. *Res. Vet. Sci.*, London, British Veterinary Association, May, 1984, Volume 36, issue 3, page 3. 2. Choo, P.Y. 1989. Observations on salmonella-dublin abortions in cattle. *J. Vet. Malays* 1:35-39. 3. Clegg, F.G., S.N. Chiejina, A.L. Duncan, R.N. Day and C. Wray. 1994. Outbreaks of salmonella newport infection in dairy herds and their relationship to management and contamination of the environment (cattle, grasses, soil). *Vet. Rec.*, London, British Veterinary Association June, 18, 1983., Volume 112, Issue 25. 4. Clegg, F.G., C Wray, A.L. Duncan and W.T. Appleyard. 1986. Salmonellosis in two dairy herds associated with a sewage farm and water reclamation plant. *J. Hyg.* 97:237-246. 5. Deutrich, V. and G. Pioch. 1991. Risk of infection to man and animals by cattle slurry stored over years. *Monatsh. Veterinaermed.* 46:651-655. 6. Firth, E.C., A.W. Kersjes, K.J. Dik, and F.M. Hagens. 1986. Hematogenous osteomyelitis in cattle. *Vet. Rec.* 120:148-152. 7. House, J.K., B.P. Smith, G.W. Dilling, and L. Roden. 1994. Enzyme-linked immunosorbent assay for serologic detection of salmonella dublin carriers on a large dairy. Schaumburg, Ill., American Veterinary Medical Association. September 1993. v. 54 American jour:54 Americ-54 Am1399. 8. Johnston, W.S., G.F. Hopkins, G.K. Maclachlan, and J.C. Sharp. 1986. Salmonella in sewage effluent and the relationship to animal and human disease in the north of Scotland. *Vet. Rec.* 119:201-203. 9. Lacey, R.U., 1994. Scares and the British Food System: problems and policies in relation to food-related health issues. *Br. Food. J.*, Bradford, Mcb. University Press., 1992 Volume 94, Issue 7, pages 26-30. 10. Meyer, H and G. Steinbach. 1994. Concept for control of salmonella dublin infection of cattle. Monatsh Veterinarmed, Jena, Gustav Fischer Verlag. July 1, 1983, Volume 38, Issue 13. 11. Morisse, J.P. and J.P. Cotte. 1994. Evaluation of some risk factors in bovine salmonellosis. *Vet. Res.* 25:185-191. 12. Nakamura, M., S. Sato, S. Suzuki, Y. Tamura, O Itoh, T. Koeda, and S. Ikeda. 1988. Virulence and immunogenicity of plasmid-cured salmonella serovar enteritidis al 1192 against cattle. *Jpn J Vet Sci* 50:706-713. 13. Oberoi, M.S. and M.S. Kwatra. 1994. Preliminary trials on the serodiagnosis of salmonella (1,9,12,: -) infection in cattle and buffaloes. *Indian Vet J*, Madras, Indian Veterinary Association, Nov. 1983, Volume 60, Issue 14. Segall, T. and A.A.. Lindberg. 1991. Salmonella dublin experimental infection in calves: protection after oral immunization with an auxotrophic aroA live vaccine. *Zentralbl. Veterinarmed.* [B] 38:142-160. 15. Sharp, J.C.M., W.J. Reilly, K.A. Linklater, D.M. Inglis, and W.S. Johnston. 1994. Salmonella montevideo infection in sheep and cattle in Scotland. 1970-81. *J Hyg,* Cambridge, Cambridge University Press, Apr. 1983. Volume 90, Issue 2, pages 225-2: 16. Smith, B.P., D.G. Oliver, P. Singh. G Dilling, P.A. Martin, B.P. Ram, L.S. Jang, N. Sharkov, J.S. Orsborn, P.A.M. Marvin, and et al. 1989. Detection of Salmonella dublin mammary gland infection in carrier cows, using an enzyme-linked immunosorbent assay for antibody in milk or serum [published erratum appears in Am J Vet Res 1989 Oct;50(10):1799]. *Am. J. Vet. Res.* 50:1352-1360. 17. Spier, S.J., B. P. Smith, J.S. Cullor, H.J. Olander, L.D. Roden and G.W. Dilling. 1991. Persistent experimental Salmonella dublin intramammary infection in dairy cows. *J. Vet. Intern. Med.* 5:341-350. 18. Steinbach, G., U. Dinjus, J. Gottschaldt, B. Kreutzer, and C. Staak. 1993. Course of infection and humoral immune reaction in calves infected orally with different salmonella serovars. *Journal of Veterinary Medicine.* Series B, 40:515-121. 19. Visser, I.J.R., W. Wouda, and G. Zimmer. 1990. Increasing incidence of salmonella-dublin infection in dairy farms. *Tijdschr. Diergeneeskd.* 115:738-739. 20. Weber, A., C. Bernt, K. Bauer, and A. Mayr. 1993. [The control of bovine salmonellosis under field conditions using herd-specific vaccines]. *Tierarztl. Prax.* 21:511-516. 21. Woollen, N.E., E.K. Daniels, and E.T. Litledike. 1992. Salmonellosis in beef cattle. 92nd. General Meeting of the American Society for Microbiology, New Orleans, LA, :395. 22. Wray, C. 1985. Is salmonellosis still a serious problem in veterinary practice? *Vet. Rec.* 116:485-489. 23. Wray, C. 1994. Salmonella dublin infection of cattle in England and Wales: its epidemiology and control. Proceedings of the International Symposium on Salmonella, New Orleans, LA, USA, J:Snoeyenbos-Sn 181, ill. 24. Wray, C. and R.J. Callow. 1989. The detection of salmonella infection in calves by the fluorescent antibody test. *Vet. Microbiol.* 19:85-89. 25. Wray. C., N. Todd, I. McLaren, Y. Beedell and B. Rowe. 1990. The epidemiology of Salmonella infection of calves: the role of dealers. *Epidemiol. Infect.* 105:295-305. 26. Wray. C., Q.C. Wadsworth, D.W. Richards, and J.H. Morgan. 1989. A three-year study of Salmonella dublin infection in a closed dairy herd. *Vet. Rec.* 124:532-537. 27. Zwahlen, R.D. and D.R. Roth. 1990. Chemotactic competence of neutrophils from neonatal calves functional comparison with neutrophils from adult cattle. *Inflammation.* 14:109-124.