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MILK-BORNE DISEASES IN MAN

(A brief review of some fundamental aspects)

by

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MILK-BORNE INFECTIONS

The transmission of pathogens through milk may produce either scattered sporadic cases, without obvious relation to a common source, or localized epidemic outbreaks, which very obviously point to a common source. This is due to fundamental differences in the epidemiological mechanism.

A. The sporadic or non-epidemic type of milk-borne infections

These result from a more or less permanent occurrence in the milk supply of pathogens with a relatively low rate of infectivity and meet with a widespread immunity in the human population. Within areas where tuberculosis or brucellosis are of wide occurrence among the milking herds, a rather permanent exposure to these infections exists, because of the almost permanent spread of bacilli through the market milk from the chronically infected herds. Moreover, when the relatively low rate of infectivity and the immunizing effect of slight exposures are considered, it seems quite natural that the transmission of tubercle bacilli or brucella organisms through the milk, in circumstances such as described, should result in sporadic but ever recurrent cases of the disease rather than in massive epidemic outbreaks.

B. The acute epidemic type of milk-borne infections

These result from the sudden appearance in the milk supply of an infectious agent which possesses a high rate of infectivity which meets with no or only a very slight degree of immunity in the human population. The source of infection in these cases usually has only a very brief contact with the milk supply line, resulting in the spread of pathogenic micro-organisms being of a short duration or of an intermittent character rather than a persistent spread. When the high rate of infectivity is considered together with the absence of widespread immunity, it is obvious that this mechanism should lead to acute epidemic outbreaks.

LIST OF MILK-BORNE INFECTIONS

It is difficult to draw up a complete list of infectious diseases which may be transmitted through milk. Theoretically, any kind of pathogenic micro-organisms may occasionally gain access to the milk supply and consequently milk-borne transmission seems to be a possibility with regard to all types of infectious diseases transmissible by the alimentary route of infection. In some diseases, milk-borne spread have been definitely established since a long time, while in other diseases, the transmission through milk has not yet been established as an accepted fact. In the following table examples are given of both categories.

TABLE

I DISEASES IN WHICH MILK-BORNE TRANSMISSION OCCURS FAIRLY FREQUENTLY

A.	B.
<u>The sporadic, non-epidemic type</u>	<u>The acute, epidemic type</u>
Tuberculosis	Streptococcal angina and scarlet fever
Brucellosis	Diphtheria
	Typhoid fever
	Paratyphoid
	Salmonellosis
	Shigellosis
	Cholera

II DISEASES IN WHICH MILK-BORNE TRANSMISSION IS OF RARE OCCURRENCE OR A NON CONFIRMED POSSIBILITY

Anthrax
Foot and Mouth Disease
Poliomyelitis
Epidemic hepatitis
Leptospirosis
Listeriosis
Q-fever

I DISEASES IN WHICH MILK-BORNE TRANSMISSION OCCURS FAIRLY FREQUENTLY

A. The Sporadic, non-epidemic Milk-borne Infections

1. Tuberculosis

1.1 Bovine tuberculosis in man

The role played by the bovine type of tubercle bacilli in the epidemiology of tuberculosis in man is now fairly well understood. While in earlier days opinions varied, it is now a well established fact that the bovine bacilli equal the human type bacilli regarding virulence and pathogenicity for man. While bovine bacilli in the early days were almost exclusively found in extrapulmonary tuberculosis (cervical glands, joints and bones, meningitis etc), it is now recognized that bovine bacilli may also play an important part in pulmonary tuberculosis. The rural population in areas with a high incidence of tuberculosis in cattle are exposed to a double risk of infection: by mouth through consumption of contaminated milk, and by way of the respiratory tract through inhalation of bovine tubercle bacilli. Out of a total of 3698 cases of pulmonary tuberculosis from all parts of Denmark type-determined up till 1936, 5.35% showed bovine bacilli, whereas the incidence of bovine infection reached as high as 42.5% among rural patients who acquired their pulmonary tuberculosis while living in the south-western part of Jutland, where the percentage of tuberculous herds at that time exceeded 75.

For a correct understanding of bovine tuberculosis in man, it must be noted that exposure to virulent tubercle bacilli does not necessarily result in the development of serious clinical tuberculous disease. In the large majority of cases such exposure is only followed by a sub-clinical infection, causing immunity and a positive tuberculin reaction. This happens regardless of whether the type of infecting bacilli is human or bovine. An encapsulated inactive primary lesion causing immunity, but no serious disease, is produced more frequently, when the bacilli are introduced by the oral route, than when introduced by way of the respiratory tract. Moreover, when primary lesions develop into clinical tuberculous disease, the course of the disease is usually less malignant when the primary lesion is located in the alimentary tract than when it occurs in the respiratory system, especially the lungs. It is therefore very obvious that aerogenic infection and pulmonary lesions are the most dangerous and most predominant causes of morbidity and mortality in tuberculosis of man. Most cases of pulmonary tuberculosis develop from aerogenic infections and primary lesions in the lungs, and as man as a whole (except for special professional groups) lives in closer contact with other human beings than with cattle, it is logical that the majority of pulmonary tuberculosis in man must be of the human type. Most cases of extrapulmonary tuberculosis develop from alimentary infection and primary lesions in the alimentary tract, and as milk, which is the most important source of alimentary tuberculosis infections, is much more exposed to contamination from tuberculous cattle than from man, it is logical that a very large percentage of extrapulmonary tuberculosis in man should be of the bovine type, this being especially so among the younger groups whose diet usually contains more milk.

Thus the role played by bovine tuberculosis in cattle in the epidemiology of tuberculosis in man may be summarized as follows: direct contact between tuberculous cattle affected by tuberculosis of the lungs, and man involves the same risk of aerogenic infection and pulmonary tuberculosis as do human contacts involving persons affected by pulmonary tuberculosis. The spread of bovine tubercle bacilli through milk produced by tuberculous herds results in a widespread distribution of sub-clinical immunizing, alimentary infections plus a certain percentage of clinical cases of extrapulmonary tuberculosis (cervical, glands, abdominal tuberculosis, meningitis, bones and joints etc.) especially among children. The ratio of sub-clinical infections to clinical infections depends upon the intensity of exposure and the incidence of acquired immunity within the exposed groups. Large numbers of bacilli in conjunction with a low resistance may result in fatal cases of miliary tuberculosis (meningitis) as is seen fairly often in infants. Out of a total of about 5,000 cases of human tuberculosis typed in Denmark between 1931 and 1936, 456 cases of extrapulmonary bovine tuberculosis were found. These were predominantly due to milk-borne infection, and although this number is relatively low compared to the total number of individuals exposed to bovine tubercle bacilli from milk within the same period, it is nevertheless sufficiently high to warrant an all-out fight against bovine tubercle bacilli in milk. To this number, moreover, must be added several hundred cases of bovine pulmonary tuberculosis, contracted from direct contact with tuberculous cattle.

Adding everything together it is quite clear that tuberculosis in cattle must be eradicated if a general campaign against tuberculosis in man is to succeed.

These are the general principles as they have emerged from experience gained in Denmark, where bovine tuberculosis has now been successfully eradicated, while as late as 1939, about 55% of a total of about 200,000 heads of cattle were tuberculous. It is obvious, however, that the magnitude and overall importance of the problem will vary from country to country, according to the incidence of the disease in cattle as compared to the incidence of human pulmonary tuberculosis in the population. Certain modifications may also be expected from variations in local conditions with respect to dietary customs (boiling of milk) or to housing conditions for cattle and man.

1.2 Contamination of milk with bovine tubercle bacilli

The transfer of tubercle bacilli to the milk may take place directly through excretion from tuberculous lesions in the udder tissue itself, or indirectly through contamination of the milk during milking with dust and other dirt materials, carrying viable tubercle bacilli originating from infective excreta (sputum, manure, urine, vaginal discharge). The tuberculous lesions within the udder itself represent the most massive source of infection of milk, but even in the absence of cases of udder tuberculosis within a tuberculous herd, the pooled milk from such herds will frequently carry tubercle bacilli if other types of open tuberculosis occur (uterus, lungs, kidney).

1.3 Udder tuberculosis

This localization ordinarily develops as a form of generalization in cows having primary lesions elsewhere. The introduction of contaminated instruments through the teat canal may, however, produce a primary tuberculosis of the udder in tuberculin negative cows. Apart from this, tuberculosis of the udder is mostly found in cows having advanced tuberculous lesions in other organs. It is generally said that 25-30% of cows with generalized tuberculosis will present lesions of the udder, and the average incidence of udder tuberculosis is about 1-2% of the total number of tuberculin reactors. Most cases take on a chronic course with latent or only slight symptoms, the milk retaining a normal appearance for a long time, even when containing large numbers of tubercle bacilli. Hence many cases remain undetected for long periods of time and may give rise to a very extensive contamination of large quantities of milk. It is frequently found that milk from one single case of udder tuberculosis diluted with milk from several thousands of healthy cows is still infective to susceptible experimental animals. On one occasion about 25 tubercle bacilli per ml could be cultivated from market milk originating from a dairy plant with only one case of udder tuberculosis among about 2,000 producing cows.

1.4 Tuberculosis of the genital tract and kidneys, tuberculosis of the lungs

Uterine tuberculosis resulting in abortion and vaginal discharge comes next to udder tuberculosis as a source of tubercle bacilli in milk. The outflow from the vagina is often very rich in bacilli, especially during the first week following abortion, the tail, hindlegs, udder and surroundings become heavily contaminated with tubercle bacilli that easily find their way to the milking pail in handmilking, and also from the surface of the teats into the milking machine. Upon dessication, the material turns into virulent dust. Uterine tuberculosis occurs in 1-2% of the total number of tuberculin reactors. Excretion of tubercle bacilli through the urine also provides possibilities for a widespread transfer of bacilli. The same applies to faecal materials containing tubercle bacilli, as will be the case in animals having open tuberculosis of the lungs and swallowing the expectorate. It is to be noted that tubercle bacilli may remain viable in dust and dirt in dark stables for several months. So pooled milk from tuberculous herds, even without actual cases of udder tuberculosis, will practically always carry viable tubercle bacilli when other types of open tuberculosis are present.

1 1.5 Tubercle bacilli in milk and milk products

Despite the high dilution occurring in market milk when milk from many herds is pooled together, tubercle bacilli may readily and regularly be demonstrated in market milk and milk products produced in countries with a high incidence of tuberculosis in cattle, if the milk has not been pasteurized. The tubercle bacilli are unable to multiply in milk, but they are very resistant and will survive for a considerable length of time and withstand any kind of processing (souring, cheesemaking, buttermaking, drying, freezing) except heating.

1.6 Preventive measures against transmission of tuberculosis through milk

Of course a complete solution to this problem lies only in total eradication of tuberculosis in cattle. Until this can be achieved, certain preventive measures to minimize the danger must be applied.

In fact, the milk control herd inspection service in Denmark was especially created because something had to be done to protect primarily children against milk from tuberculous cows. The organization started about 1901 and for many years the most important achievements of this control system was the detection and elimination from the milk producing herds, of cows with open tuberculosis. The milk of any cow showing clinical signs of tuberculosis (whatever the site of the disease may be) shall be retained and not delivered to any dairy plant or used for human consumption. Cows suspected of udder tuberculosis, genital tuberculosis, intestinal tuberculosis or open tuberculosis of the lungs, shall immediately be isolated and specimens sent for laboratory examination. If the diagnosis is confirmed, the animals must be slaughtered without delay.

As soon as circumstances allow, only tuberculin-negative herds should get a licence for the production of milk for human consumption, and tuberculin testing would have to be repeated regularly once a year as a condition for maintaining the licence.

2. Brucellosis

Animals suffering from brucellosis are nearly always the source of human brucellosis (Febris undulans), as the disease - unlike human tuberculosis - is practically untransmissible from man to man. Transmission from animals to man may take place in two ways· through contaminated foods, primarily milk and milk products, and through direct contact with infected animals.

In Denmark about 500 - 600 cases of Febris undulans have been reported every year from 1928 to 1940. Since 1942, the yearly average has dropped, and in 1948 it reached only about 50% of the former level. The reason for this change is that since about 1940 milk-borne cases have become very rare, partly due to the introduction of compulsory pasteurization of market milk since that year, and partly due to the introduction of the A.B.R. milk test in milk control whereby milk from infected herds could be segregated from milk from clean herds. What remains of human brucellosis today is mainly contact-infection directly from infected animals. Under the present conditions in Denmark, it has been found that milk-borne cases amount to approximately 50% of the total figure for human brucellosis, and direct contact infections to another 50 per cent.

The further decline of human brucellosis in Denmark since 1948 results mainly from the rapid progress of the eradication campaign against brucellosis in cattle achieved during these years.

Statistics of Febris undulans (human brucellosis) in Denmark

Year	Total cases	Year	Total cases
1928	441	1943	327
1929	525	1944	262
1930	526	1945	284
1931	589	1946	291
1932	510	1947	279
1933	606	1948	224
1934	655	1949	194
1935	513	1950	188
1936	606	1951	153
1937	581	1952	126
1938	585	1953	70
1939	521	1954	35
[illegible]	[illegible]	1955	21

The principal type of brucella in cow's milk is, of course, Brucella abortus bovis. It must, be borne in mind also that Brucella melitensis and Brucella suis may occur in cows. Sheep milk and goat milk are the main vectors of Brucella melitensis.

2.1 Brucella bacteria in milk

The main source of brucella bacteria in milk is no doubt udder infections which are a frequent manifestation of generalized brucellosis. Apart from this, indirect contamination during milking may also occur, especially from vaginal discharges in animals that have aborted.

Brucella infection of the udder is a typical latent infection without clinical symptoms of disease. The milk is apparently normal, and the udder-infected animals can actually only be detected by demonstrating the bacteria in milk samples, either through guinea pig inoculations or through cultivation. The number of bacteria per c.c. of milk from infected animals is usually rather low, varying from some hundreds up to a hundred thousand. The incidence of udder-infected cows in brucellosis herds varies considerably. The highest rate of excretion is found among cows that have aborted, as approximately 80% of all aborting cows excrete brucella bacteria in the milk for a longer or shorter period following abortion. Consequently, the percentage of excreters may approach 80% in herds where the disease is present in its acute form, causing many abortions. In herds where the acute phase of infection has passed and the disease has entered the chronic phase with only a limited number of abortions, 15-20% of the cows are usually found to be excreters. Some udder-infected cows may rid themselves of the udder infection after a few months, or during the dry period, but very often the infection, when once established, will persist from one lactation period to the next for years.

Udder-infected cows will usually develop and maintain high blood titers. Removal from a herd of permanent high reactors, therefore, will clear that herd of udder-infected cows to a very large extent. Cows showing low blood titers that tend to fade out will seldom harbour udder infection. Udder-infected cows will also show antibodies in the milk (positive A.B.R. test or whey agglutination test), but antibodies in the milk is itself no proof of an udder infection being present. Antibodies in the milk foci in the udder tissue itself, but the lining epithelium of the udder is also permeable to antibodies produced elsewhere and brought to the udder through the bloodstream. In general, only about 50% of the cows showing antibodies in the milk are found to be excreters of brucella bacteria.

In pooled milk, market milk or herd milk samples, the correlation between findings of antibodies and brucella bacteria is much higher than in milk from individual cows. Generally speaking, samples of market milk or herd milk showing a negative A.B.R. test can be considered free from brucella bacteria, whereas such milk showing a positive A.B.R. test will certainly contain brucella bacteria.

Brucella bacteria are unable to multiply in milk or milk products but may survive for a considerable length of time, although they are found less resistant than tubercle bacilli.

2.2 Epidemiology of milk-borne brucellosis in man

In countries and areas where brucellosis in animal herds is widespread, unpasteurized market milk constantly contains brucella bacteria. This means that consumers of milk are permanently exposed to brucella infection from this source. As in tuberculosis, only a rather low percentage of the exposed persons develop clinical brucellosis (Febris undulans). Natural resistance to brucella bacteria (especially Brucella abortus bovis) in humans is high, and sub-clinical infections quite often result in immunity as may be seen from the fact that positive blood reactions or positive skin tests are very often found in healthy persons having no history of brucellosis. Jersild in Denmark, made brucellin skin tests on 603 persons, of which 60 were found positive; only 7 out of these had a history of clinical brucellosis. It thus appears that exposure often results in sub-clinical immunizing infections instead of clinical brucellosis. As mentioned earlier, the number of bacteria excreted from the udders of infected cows is usually low, which, of course, is also one of the factors that limit the infectivity of the milk. Cream and its derivatives are more dangerous than whole milk, because the brucella bacteria tend to concentrate in the cream. No doubt this tendency is due to agglutination of the bacteria by the effect of brucella antibodies, in the same way as is seen in positive milk when performing the A.B.R. test. Raw cream taken from the cream layer on top of milk cans in infected herds is thus likely to contain large amounts of brucella bacteria.

2.3 Vaccinated herds

Milk from non-infected, strain 19 vaccinated herds, present hardly any danger of brucella infection as long as the vaccination is restricted to calfhood vaccination. When cows also have been vaccinated, udder infection may result from vaccination. As has been proved by Huddleson in the United States, strain 19 is able to produce Febris undulans in humans. Uncontrolled vaccination, of course, makes it very difficult, or even impossible, to distinguish between infected and non-infected herds and deprives the milk control of an excellent means of diagnosis, which the A.B.R. test on herd milk samples would otherwise be.

2.4 Preventive measures against transmission of brucellosis through milk

Complete eradication of brucellosis from animal herds is, of course, the only measure that will solve the entire problem of human brucellosis. When this goal is reached milk-borne cases, as well as contact cases in humans will disappear.

Milk from cows that have aborted should be retained and not delivered to any dairy plant until discharge from the vagina has ceased. This measure, of course, will not prevent the milk of infected herds from being contaminated with brucella bacteria, but as aborting cows must be considered as especially dangerous sources of contamination, both because excretion of bacilli is greatest during the first weeks after abortion, and because of the danger of contamination presented by the heavily infective vaginal outflow, this measure seems, nevertheless, to be justified.

When circumstances permit, only brucellosis-free herds should get a licence for producing milk for human consumption. Then the A.B.R. test will provide an excellent means of ensuring that herds are kept free from brucellosis.

B. The Acute epidemic Milk-borne Infections

1. Streptococcal infections: Angina - Scarlatina

Streptococcal Angina is an acute inflammation of the tonsilla and adjoining pharyngeal mucosa, caused by Streptococcus pyogenes humanus (Lancefields serological group A.). All milk-borne epidemics of angina have so far proved to have been streptococcal angina.

Scarlatina is a closely related infectious disease, which is also caused by Streptococcus pyogenes humanus. It may be described as streptococcal angina accompanied by a typical exanthema of the skin probably a toxic allergic reaction. Exposure to milk, carrying Streptococcus pyogenes humanus, regularly results in the development of both angina and scarlatina cases. Adults usually react by developing angina while children largely develop scarlatina. This is an indication that differences in resistance play some part in determining whether persons exposed to group A. streptococci respond to the infection by developing angina or the more severe condition known as scarlatina. The ratio of angina to scarlatina in an angina-scarlatina milk epidemic will, however, vary from one outbreak to another, indicating also that specific characteristics of the infecting strain or type of streptococci may play a role.

Streptococcus pyogenes humanus is a typical hemolytic streptococcus. Serologically it belongs to Lancefields' group A., but within this group, approximately 30 different types have been differentiated by means of an agglutination technique; each type contains, besides the mutual group antigen, a specific type antigen located in the surface of the bacterial cell.

Group A. streptococci differ from the usual animal types of hemolytic streptococci in biochemical properties and in possessing a specific enzyme, which dissolves human fibrine. Thereby it is characterized as a specific human pathogen, and it is considered by far the most important pathogenic streptococcus in human pathology. Apart from being the cause of angina and scarlatina in man, this streptococcus is also found in a variety of other diseases of man, otitis media, erysipelas, puerperal fever, pyogenic inflammations of various kinds, abscesses and - of special importance regarding contamination of milk - very often in the common suppurative finger phlegmones, panaritium. This important streptococcus, however, is also pathogenic for cattle, as transmission from human infections to the udder of the cow may produce mastitis. In fact this has been the epidemiological mechanism in most angina-scarlatina milk epidemics. Fortunately group A. streptococcal mastitis in cows only occur occasionally. In humans, group A. streptococcal infections are widespread, both active clinical cases and carriers. In Denmark Ernst found group A. streptococci in pharynx and tonsillas in 3.9% of a large number of healthy persons examined. Among people living in close contact with clinical streptococcal cases, the percentage of carriers is much higher, and clinical recovery from angina or scarlatina is often followed by a long period of latent pharyngeal or tonsillar infection.

1.1 Epidemiology of angina and scarlatina

The transmission and spread of angina and scarlatina may occur either through direct contact from clinical cases or carriers in the form of a droplet infection by coughing or sneezing, or through consumption of contaminated milk. The contamination of milk can be effected in two ways

1) By direct contamination from persons suffering from streptococcal disease (angina, scarlatina, panaritium, otitis media, erysipelas, infected wounds, pustulous eczema);

2) Indirectly with a cow's udder acting as an intermediate link when persons suffering from streptococcal disease during milking and handling of cows transmit the infection to the udder of a cow via the teat duct.

1.2 Direct contamination from humans

Considering the widespread occurrence of streptococcal disease in man, this must be a rather common happening, but usually such contact does not result in a large enough contamination of the milk to cause epidemics, because group A. streptococci are unable to multiply in milk under ordinary circumstances. In special cases, where the milk has been very heavily contaminated, such direct contact may be sufficient to cause an epidemic spread of disease. So far in Denmark only one such occasion has been reported where direct contamination of the milk supply from a human source produced a large epidemic spread. This was in 1937, when a milker suffering from an otitis media with a heavy purulent discharge from her ear, succeeded in transferring enough infective pus to the milk she was handling so that about 118 cases of scarlatina and 50 cases of angina developed among the consumers of the milk within three to four days (Angina-Scarlatina milk epidemic in Vejle 1937). Moreover, there have been one or two occasions where direct contamination of milk from panaritium and angina cases among workers at a milk bottling plant produced a few scattered cases of angina-scarlatina among milk consumers within the area. That group A. streptococci in low numbers may occasionally be found in milk is also seen from the findings of P.A. Bruhn, who carried out a type determination of 345 strains of hemolytic streptococci, selected at random from samples of raw producers milk. The majority of strains were group B. and other specific animal pathogens, but one strain proved to be of group A. occurring in a milk sample containing only about 100 hemolytic streptococci per cc. Bruhn's results are shown below.

Type determination of 345 strains of hemolytic streptococci isolated from producers milk samples

Group	A.	1	=	0.3%
"	B.	278	=	80.6%
"	C.	19	=	5.5%
"	D.	4	=	1.2%
"	E.	21	=	6.1%
"	L.	22	=	6.4%

1.3 Indirect contamination - human - cows udder - milk

In most of the large milk-borne angina-scarlatina epidemics that have been investigated, the source of the outbreak was found in a case of mastitis in cow caused by group A. streptococci transmitted to the cow from an infection in humans. The typical epidemic outbreak is only likely to occur when the milk happens to become heavily contaminated, so that the milk supply still carries infective doses of streptococci, even after dilution with clean milk from other sources.

Therefore the active multiplication of the streptococci within the udder of a cow is essential, as the streptococci, as already mentioned, are unable to multiply in milk outside the udder glands.

The first streptococcal milk-borne epidemic of this type to be reported was a large epidemic which occurred in Chicago in 1911. In Denmark several such epidemics have occurred, the most severe in recent years being the so-called Gladsaxe epidemic of 1941 totalling 2400 human cases with 24 deaths. The history of this epidemic, which may be considered as quite typical, was as follows: On 19 November 1941 a physician in the town of Gladsaxe reported to the municipal veterinary officer in charge of milk control, that he had that same day, diagnosed six severe cases of angina under circumstances pointing to a milk-borne infection from the Gladsaxe dairy. The district medical officer was approached, but at that time he had no reports of an angina epidemic within his district. The veterinary officer immediately collected samples of raw bottled milk from the cooling rooms of the Gladsaxe dairy plant and planted the milk on to blood agar to investigate the presence of hemolytic streptococci. Early in the morning of 20 November, moreover, samples were taken for cultural examination in blood agar from all producers' cans at the receiving platform of the dairy plant. The market milk from 19 November was found, when the cultures were examined after incubation overnight, to contain about 0.5 mill. hemolytic streptococci per cc. Further distribution of milk from the plant was then stopped. Next day the cultures of milk from the producing farms were examined and the milk from one farm was found to contain more than 5 mill. hemolytic streptococci per cc. An inspection of the farm was immediately made; there were only five cows in the barn, and one was suffering from an acute mastitis in the right hindquarter. The gland showed oedematous swelling and the secretion was purulent. From the secretion of the inflamed quarter 1700 mill. hemolytic streptococci per cc. were cultivated. All strains isolated from milk were determined as group A., and proved identical with strains isolated from throat swabs of the human patients. A milker on the farm was found to be suffering from a panaritium caused by the same type of streptococci. During milking he had transmitted the infection to the cow, and, against the rules, the milk from the diseased cow had not been retained but delivered to the dairy plant, despite severe acute symptoms of mastitis.

The average incubation period in this epidemic was 18-20 hours. Of the reported cases, 2300 were angina cases, only 100 scarlatina cases.

The incident showed that by applying a simple bacteriological examination of the milk for hemolytic streptococci, the source of the epidemic could be traced down with great certainty within three days of suspicion first being aroused and while the epidemic was still developing. The same technique of epidemiological investigation has also been successfully used on some later occasions.

2. Group A. streptococcal mastitis in cows

The clinical picture in group A. mastitis has proved in most cases to be quite different from the usual picture of bovine streptococcal mastitis. Whereas the usual bovine streptococcal mastitis produced by group B. streptococci is a chronic disease with a protracted course and long periods of latens interrupted by active flare-ups, the group A. mastitis is an acute form of mastitis. Immediately following introduction of the infection, a severe reaction is seen with an acute swelling of the affected udder and purulent secretions, and in a few weeks the affected gland becomes dry and atrophic. Consequently when investigating the source of a streptococcal milk epidemic, recent cases of acute mastitis with a severe inflammatory reaction,should especially be considered. In 1945, however, we discovered one case of group A. mastitis which had obviously behaved as a typical chronic sub-clinical mastitis. When discovered, the case had persisted for more than a year, altogether causing about 12 sporadic cases of scarlatina in persons that happened to take milk from that cow; mostly visitors to the farm who stayed for dinner. The milk had a normal appearance, and there were only very slight symptoms of induration of the gland, but the milk contained about 10,000 group A. streptococci per cc.

This case did not give rise to a large explosive outbreak, but only a few sporadic cases over a longer period, because the milk from the farm was delivered to a creamery only producing pasteurized butter. It had no connection with the distribution of liquid milk, and only people living on the farm or visiting the farm were exposed when milk for the kitchen was taken from a can containing the milk of that particular cow. (Tilsted endemic scarlatina originating from a cow with a chronic group A. infection of the udder, 1946).

Human streptococcal infections from which transmission to the udder of cows are known to have taken place include cases of panaritium, angina, scarlatina, otitis media. In spite of the numerous daily occasions for contact between cows and such conditions in milkers, only a limited number of group A. mastitis cases result from such contacts, and when cases become established, no spread from one cow to another within the herd is seen, despite the fact that streptococcal udder infections in cows will ordinarily spread rather easily. Obviously, cows are rather resistant towards group A. streptococci. The explanation for this is found partly in the fact that normal cows' milk contains a bacteriostatic factor, which is very active against group A. streptococci but not against the ordinary bovine type streptococci belonging to Lancefields serological group B. Streptococcus agalactiae. This perhaps means that special circumstances are necessary before exposure of the orifice of the teat canal to group A. streptococci results in the establishment of a persistent udder infection.

3. Diphtheria

Milk-borne epidemics of diphtheria are always caused by direct contamination of the milk supply from human carriers of Corynebacterium diphtheriae. They may be either clinical cases or carrier cases. Not only people having suffered from diphtheria become carriers, the same happens when immune persons are exposed to infection from active cases.

Transmission may take place from nasal discharges or from droplets produced by sneezing or coughing. Diphtheria patients may also harbour the bacilli in ulcerative finger lesions. Corynebacterium diphtheria is able to multiply in milk kept at a temperature above 15°C. so that even a slight primary contamination may develop into a large infection. It should be borne in mind that diphtheria bacilli have been demonstrated in sores and skin lesions of the teats of cows milked by persons suffering from diphtheria, so a clinical examination of the teats of cows in herds where human cases of diphtheria among milkers have occurred is useful.

4. Gastro-Intestinal Infections

4.1 Typhoid - Paratyphoid

The micro-organisms causing typhoid and paratyphoid in man, Salmonella typhi and Salmonella paratyphi A, B, C, are specific human pathogens. Infections in animals generally do not occur. Contamination of milk with these bacteria originate from human cases being in contact with the milk supply, either clinical cases or carriers. Infected humans excrete the bacilli through faeces, and sometimes through urine. It is very common that people who recover from attacks of typhoid or paratyphoid continue to carry the infection in the intestinal tract or in the gall bladder or the bile ducts for a long time after. 3-5% continue to be carriers for more than three months after the clinical symptoms have subsided, and many of these will continue for years. There are also carriers who have never had a clinical attack of the disease. When immune persons are exposed to infection, no clinical disease will develop, but sometimes a sub-clinical carrier infection will result from such exposure, just the same as in the case of diphtheria. Transfer of typhoid or paratyphoid bacilli from humans to milk takes place through direct or indirect contamination of the milk with human faecal material. Contact with unclean hands, not properly washed after use of the lavatory, is one important source. Another is sewage-polluted water supply being utilized for washing and cleaning milk utensils, or pollution of the cowshed or field crops with human faeces because of lack of proper lavatory facilities. Typhoid and paratyphoid bacilli are able to multiply readily in milk at temperatures down to 15°C. Also deposits and milk films in dirty milking utensils provide a suitable medium for growth. This, of course, means that even a very slight inoculation may result in a heavy contamination, when suitable conditions of growth exist, because of improper cooling or otherwise. Salmonella typhi and Salmonella paratyphi may survive in milk and milk products for several weeks, and at low temperatures they may survive souring of the milk in the manufacture of butter and cheese. The same applies to other types of salmonella bacteria.

In Norway, several outbreaks of gastro-enteritis salmonellosa in man have been caused by salmonella-infected sour cheese, produced in farms where salmonellosis in cattle occurred.

A very good illustration of the epidemiological mechanism of a milk-borne epidemic of typhoid is found in a case which occurred in a Danish town in 1946. 12 cases of typhoid occurred simultaneously in a group of people, all of whom had participated in a dinner party at which whipped cream had been served. The whipped cream was bought from a milk shop in a house where a female typhoid carrier was living. Although she had been instructed to always use a separate toilet, she had, on that particular day, used another lavatory in the house, which had afterwards been used by the milk dealer, immediately before she weighed and handed out whipped cream to the customer in whose house the infected meal was served. The milk dealer admitted that she had not washed her hands in between. In another family which had bought whipped cream from the same supply, only a short while after the first-mentioned family bought its cream, 3 or 4 cases of typhoid also developed, whereas the customers coming later escaped the infection. Although the milk dealer herself was not a typhoid carrier, she obviously had been able to pick up on her hands enough typhoid bacilli from the polluted lavatory to transmit infective doses to the first two portions of whipped cream she afterwards handled. Later, however, her hands must have become sufficiently clean so that further contamination stopped.

An American statistics of the source of infection in 373 milk-borne tyhpoid epidemics shows the picture given below.

Source of infection in 373 milk-borne epidemics of typhoid

Typhoid carriers in dairy farms or dairy plants	:	162	outbreaks
Active typhoid cases	:	134	"
Contamination of milk bottles returned from	:	37	"
houses with typhoid cases	:	37	"
Polluted water used for cleaning milk utensils	:	28	"
Contamination of cows from polluted water	:	4	"
Various sources	:	8	"

4.2 Gastro-enteritis salmonellosa

Within the salmonella group a large number of species are pathogenic to man as well as to animals, Salmonella typhi murium, Salmonella enteritidis, Salmonella dublin, S. Cholerae suis, a.o. In medical bacteriology these bacteria are often described as the gastro-enteritis group of salmonella, because they produce in man with a distinct clinical picture, different from that of typhoid and paratyphoid. In typhoid and paratyphoid the incubation period is 2-3 weeks, and the disease is characterized by more or less severe symptoms of sepsis. The duration of symptoms is 3-4 weeks, and after that a carrier state often develops. In the acute gastro-enteritis (gastro-enteritis salmonellosa), caused by bacilli of the gastro-enteritis group, the incubation period is short, about 24 hours, and the predominant symptoms are those of an acute gastro-enteritis without general sepsis. The duration of the disease is generally only about 3-4 days and a carrier state only develops in a minority of cases.

In animals, these bacilli may produce an acute septic gastro-enteritis, usually in younger animals, and carriers are common. In some countries salmonellosis in calves is widespread and when calves and cows are kept together in the same barn, the danger of contamination of the milk from the faeces of diseased calves exists. Occasionally cases of acute salmonellosis are seen in adult cattle, and when milking cows are involved, a milk-borne epidemic of gastro-enteritis salmonellosa may result from this source.

One such epidemic was studied in Denmark in 1922, 95 persons in a hospital being taken ill. The milk was delivered to the hospital from a particular herd in which a cow had died from an acute septic enteritis with severe diarrhoea. Salmonella dublin was isolated from spleen and udder tissue of the cow and the same strain was found in the stools of patients at the hospital. Like typhoid and paratyphoid bacilli, bacilli of the gastro-enteritis group grow in milk at temperatures down to 15°C.

Milk from cows suffering from salmonellosis must be retained and not delivered to any dairy plant. The same applies to animals that are shown to be carriers. The infected animals must be removed from the cowshed and bacteriological examination of samples of faeces should be carried out to trace carriers. The milk from cows affected with febrile enteritis accompanied by systemic disturbances (septic enteritis) should be handled in the same way as milk from salmonellosis cases, even though the diagnosis of salmonellosis is not yet established. If salmonellosis occurs among calves housed together with the milking cows, the infected calves must be removed from the cowshed, and necessary cleaning and disinfection of the stable should follow.

4.3 Dysentery (Dysenteria bacillaris)

This is an infectious ulcerative colitis in man caused by bacteria of the shigella group. Shigella are gram-negative non-motile, non-lactose fermenting rods, differentiated serologically into several types: Shigella dysenteriae (Shiga-Kruse), Shigella sonnei, Shigella flexneri, Shigella smithi. Dysentery behaves as a localized intestinal infection without sepsis and the bacteria do not spread outside the intestinal tract. The incubation period is 2-5 days and the symptoms are fever, gastric pains and diarrhoea with slimy and often bloody stools. The duration of typical cases is about one week, but chronic cases with very slight symptoms are of frequent occurrence as are carrier cases. Shigella are specific human pathogens and the source of milk-borne epidemics is consequently to be found among persons - chronic cases or carrier cases - dealing with milk. Transmission takes place through faecal contamination, directly or indirectly, as described for typhoid and paratyphoid. Shigella organisms will multiply readily in milk and dirty milk utensils at temperatures down to 15°C.

Dysenteria bacillaris is a typical food-borne infection all over the world. The incidence of dysentery is generally considered to reflect fairly accurately the prevailing standards of food hygiene of a country. In Denmark about 2-300 cases a year is the normal figure. During World War II, when hygienic standards deteriorated by force of events, this figure rose 5-6 times. After the war it returned to "normal". Similar experiences are common in many other countries. Milk-borne outbreaks have been reported rather frequently. Some have been traced to properly pasteurized milk which was recontaminated at the dairy plant after pasteurization by carriers that had transmitted the infection to unclean pipelines, storage tanks and bottle-fillers in the dairy plant. The bacilli obviously were able to establish themselves in the sediment and dirt films in unclean utensils in the same way as is seen with coliform bacilli. Only a thorough disinfection which clears the pasteurized milk of coliform organisms stopped the contamination.

5. Growth of various pathogenic bacteria in milk

The following results from the investigations by Cohn and Malling Olsen in Denmark are illustrative.

	Initial inoculation	Count after 24 hours at 15°C	
Shigella dysenteriae			
Raw milk	6,100	740,000	120X
Pasteurized milk	1,700	550,000	320X
Shigella sonnei			
Raw milk	10,200	640,000	65X
Pasteurized milk	11,000	830,000	80X
Salmonella typhi murium			
Raw milk	13,900	521,000	40X
Pasteurized milk	14,500	1,960,000	130X
Corynebacterium diphtheria			
Raw milk	16,900	32,500	1.9X
Pasteurized milk	9,200	47,500	5.3X

Similar results have been found with Salmonella typhi and Salmonella paratyphi, whereas Streptococcus pyogenes humanus (group A.) only grows to any appreciable extent in sterilized milk.

The general rule is that pasteurized milk is a better medium for growth than raw milk, because the bacteriostatic agent, present in raw milk, is destroyed by heat. This bacteriostatic compound is especially active against the human type streptococci, but also - although much less - against the pathogenic intestinal bacteria. It must be stressed that a proper protection of pasteurized milk against recontamination by pathogenic intestinal bacteria is a highly important function of dairy plant sanitation.

II DISEASES IN WHICH MILK-BORNE TRANSMISSION IS OF RARE OCCURRENCE OR A NON-CONFIRMED POSSIBILITY

1. Anthrax

The occurrence of anthrax in a milking herd needs to be considered from the point of view of the resulting risk of transmission of the infection to man through the milk. Bacillus anthracis is a spore-bearing bacillus, and spores will survive any form of pasteurization. Only boiling for 5-10 minutes will kill the spores. Contamination of milk with bacilli or spores of anthrax may take place either indirectly from infective faecal material, or directly through the excretion of bacilli may also be localized in the glandular tissue of the udder. In most cases the disease has an acute or peracute course with early death, leaving little time for the production of contaminated milk by the affected animals. However, a few cases of chronic anthrax have been reported, where the animal survived, but had a persistent localization of the infection in the udder, showing symptoms of a chronic catarrhalic mastitis. In one such case the condition remained unchanged for about a year and the milk contained as many as 40-100 millions of anthrax bacilli per cc.

Observations of milk-borne transmission of anthrax to man are very few, but one fatal case has been reported. As anthrax in man must always be considered as a severe disease, drastic precautions to protect contamination of the milk supply seem justified whenever outbreaks of the disease occur in milking herds.

The Danish instructions for veterinarians in the milk control herd inspection service state: The milk of the diseased cows must not be used as food for man or animals. Milk from healthy cows in the herd may be delivered, provided not more than two cases have occurred in the herd and the sick animals were removed from the herd immediately. Disinfection measures must be carried out. If the disease is spreading within the herd, the milk must be retained from the whole herd 14 days after the last case has been disposed of and disinfection of the barn has been undertaken.

2. Foot and Mouth Disease

Milk from cows affected by foot and mouth disease carries virus for a period of 10-12 days from the onset of disease. This of course involves a considerable risk of spread of the disease to other herds by transport routes collecting milk from several farms. It also involves a certain risk to milk consumers insofar as foot and mouth disease virus has been reported as causing disease in man. The majority of these cases, however, have been transmitted through direct contact to milkers handling diseased cows, and in any case the infectivity of the virus for humans is apparently very low. Even when large epidemics among cattle develop, only a few scattered cases of what is thought to be human foot and mouth disease are seen, despite ample opportunities of human contact with the virus. The symptoms in man are described as follows:

it starts with fever (39°- 40°C) and general symptoms of disease - headache, pains in the throat and sometimes diarrhoea. After a couple of days vesicules erupt on hands, fingers and sometimes also in the mouth and on the soles of the feet. Following the eruption of the vesicular exanthema, the temperature drops. The vesicules will rupture in a few days leaving superficial erosions. The duration of the disease is about a week.

The contamination of the milk with foot and mouth disease virus in the first few days of disease is due to excretion of virus through the udder. Later, virus will drop into the milk from vesicules on the teats, rupturing during the process of milking.

Much more important - from a milk hygienic view - than the presence of virus in the milk, is the influence of the disease upon udder function and the wave of mastitis which usually follows an attack of foot and mouth disease.

The relationship between foot and mouth disease and mastitis has been studied in detail by the Danish foot and mouth disease station at Lindholm. The main findings were: the excretion of virus through the udder during the generalization period in the early days of the disease may cause a pathological reaction of the udder tissue in both bacteriologically negative glands and in glands harbouring a chronic infection of streptococci or staphylococci.

This reaction occurs after 2-3 days of disease, and is considered to be an effect of the virus upon the glandular tissue. Later, after 6-8 days, another and more severe reaction follows due to the introduction of bacteria through the teat canal, which is practically unavoidable in teats having erosions on the tip following rupture of vesicules. Similar reactions also occur in glands already carrying a bacterial infection.

Severe losses in milk production follow from these attacks, and pathological milk appears in large quantities, making milk from herds affected by foot and mouth disease a very inferior product with regard to its hygienic quality.

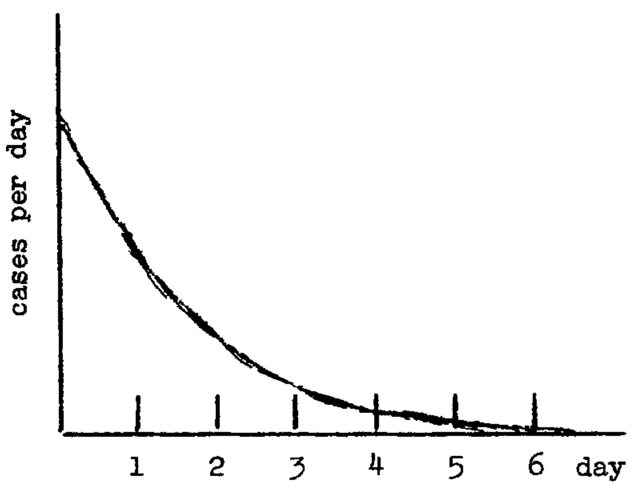
3. Other milk-borne infections

It is obvious that the list of diseases that have a milk-borne epidemiology is not limited to the diseases already mentioned. These are only examples of diseases where transmission through milk is actually known. There remain several more diseases where milk-borne spread is more or less likely to occur. Thus milk-borne cholera epidemics have been reported e.g. from India, and other infectious agents occurring in human faecal material, sewage, and polluted water may also, of course, occasionally find their way to milk supply: poliomyelitis virus, hepatitis epidemica virus. Leptospira of various types from human and animal leptospirosis is another possibility. The same applies in the case of rickettsia, causing Queensland-fever. In California, for instance, it has been found that many cows show positive serological reactions of Q-fever and excrete the rickettsia organisms through the milk. These organisms are remarkably resistant to heat and may survive pasteurization. The epidemiological significance of these findings for Q-fever in man, however, is not yet understood. The same applies to the presence of leptospira in milk from cows suffering from apparent or latent leptospira infections. So there are still new fields to be explored within the theme of milk-borne human disease.

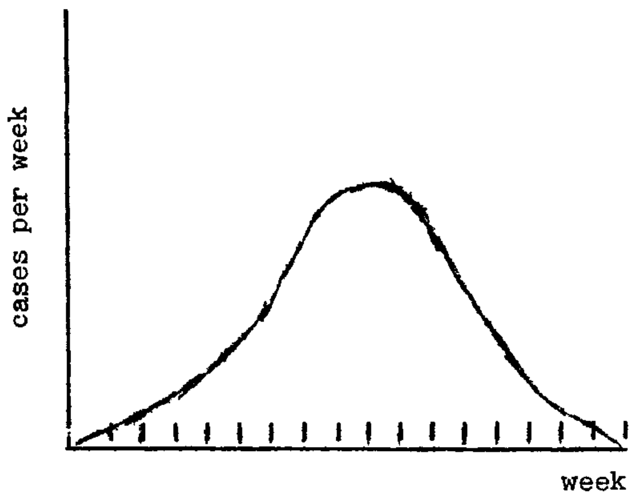
III GENERAL CHARACTERISTICS OF MILK-BORNE EPIDEMICS

When the milk supply within a certain milk distribution area suddenly becomes contaminated with the germs of some acute epidemic disease, a large number of people are exposed to the infection at one time. Through the distribution of infected milk, a whole lot of the infectious agent is immediately carried around to all the families receiving their daily milk supply from that source. Consequently, as exposure to infection occurred to a great many people simultaneously, the outbreak of disease will also occur simultaneously in great numbers following the expiration of the average incubation period. Milk-borne epidemics, therefore start very suddenly, the number of cases being high on the very first day of the epidemic, and then falling off rapidly. This picture is quite different from the picture seen in epidemics where transmission of disease takes place through contact from one person to another. In epidemics spreading through contact, the number of cases per day is low during the beginning of the epidemics and then gradually increases until half of the susceptible individuals have been immunized through an attack of the disease, whereafter the rate of infection falls off following a curve which is symmetrical with the curve of increase. A graphic representation of cases per day in an epidemic transmitted through contact will thus be a symmetric curve with its peak coinciding with the point when half of the susceptible population has been taken ill, whereas a graphic representation of cases per day in a food-borne epidemic will be an asymmetric curve.

Milk-borne epidemic



Epidemic transmitted through contact



For this reason a simple analysis of data reveals the epidemiological mechanism of an epidemic.

Further characteristics of milk-borne epidemics are that they are strictly confined to a certain topographical area following the routes and districts of milk distribution and usually, moreover, several cases occur simultaneously in each of the affected families because all members taking milk were exposed to infection at the same time.

IV PUBLIC HEALTH ASPECTS

In many developing countries milk-borne infections up till now played an astonishingly small role in spite of the primitive system of marketing - by street vendors and individual dairy farmers - of loose raw milk which undoubtedly carries an almost universal infectious contamination. This is due to the fact that consumers in such areas adhere to the practice of boiling the milk prior to use. The poor keeping quality makes immediate boiling upon receipt the only means of preserving the milk fit for use and so the population - from necessity and tradition - has come to consider raw milk unfit for human consumption.

This situation may change completely with the introduction of modern market milk schemes.

To change the milk supply to marketing of bottled pasteurized milk when the necessary conditions are lacking with regard to disease control in dairy herds, milk hygiene and milk control in general incur great risks, because the public due to the improved keeping quality of the pasteurized bottled milk over the raw loose milk to which it has been accustomed, will abandon the practice of boiling the milk. Then the public is left at the mercy of the safety of the pasteurized milk and from all experience we know it takes a highly developed hygienic organization to produce pasteurized bottled milk which is safe and free from recontamination. Hence it is to be expected that such change over of the milk supply system will make the problem of milk-borne epidemics of current interest within areas where this problem did not exist up till now. It is hoped that such countries will be able to learn with less delay than did Europe and North America how to command the centralized dairy plant operation's risk, the milk-borne epidemics. In Denmark the era of milk-borne epidemics only came to an end about 1945.

To some people pasteurization is synonymous with milk hygiene and that is all there is to it. It is correct, of course, that public health hazards of milk, for instance the risk of transmission of bovine tuberculosis, brucellosis and streptococcal infection from animal to man, can be counteracted by efficient methods of milk pasteurization, but as long as diseases of this type are persisting within the milking herds and no system at all of hygienic precautions against pathogenic contamination is functioning, the day by day protection of the milk-consuming public depends upon efficiency of pasteurization only. With the risk of human and mechanical failures in mind, this situation in the long run must be deemed unsatisfactory for safe operation of a milk industry. With chronically infected herds, billions of pathogenic organisms are invading the dairy plant daily, and the safety of the outgoing milk flow is determined accordingly at all times by the efficient operation of the pasteurizers. A satisfactory and lasting state of safety can be established only when the dangerous animal diseases and sources of pathogenic contamination of milk have been eradicated, and when pasteurization no longer represents the ultimate distinction between safe and unsafe milk supply, but acts as an extra safeguarding insurance against unforeseeable events. Thus a satisfactory milk hygiene services involves·

1) Disease control and control of hygiene in the dairy farms to safeguard the raw milk supply.

2) Efficient pasteurization.

3) Hygienic control of dairy plant operations and milk marketing to protect the pasteurized milk against recontamination.