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THE EPIDEMIOLOGY OF SUMMER MASTITIS; A SURVEY OF CLINICAL CASES

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SUMMARY

Details of 252 suspected cases of summer mastitis among dry cows and heifers in England in 1983 and 1984 were gathered by questionnaire. Samples of secretion were obtained from 242 of these cases and examined bacteriologically using both aerobic and anaerobic culture.

The majority of cases (202) appeared to be summer mastitis, usually involving *Corynebacterium pyogenes*, and occurred predominantly in late gestation.

Most cases affected only a single quarter, usually a front one and were more frequent in older, but not elderly cows.

Only 3% of cases occurred within three weeks of cows receiving dry cow therapy, but 50% occurred within six weeks of therapy. At least 60% of cattle infected with summer mastitis were culled.

Other types of udder infection were also found, particularly in pregnant cattle.

INTRODUCTION

The term summer mastitis is often used to describe cases of clinical mastitis in non-lactating cows and heifers in the summer months. Such cases include infections from which *Corynebacterium pyogenes* can be isolated as well as other pathogens. Marshall (1981) however, did not consider the isolation of *C. pyogenes* a pre-requisite for the diagnosis of summer mastitis. Tolle & Reichmuth (1985) concluded that summer mastitis was an infection from which at least two bacterial species from the group of *C. pyogenes, Peptococcus indolicus, Streptococcus dysgalactiae, Bacteroides* spp. or unclassified microaerophilic cocci were isolated. This definition appears over-rigorous since *C. pyogenes* is often isolated in pure culture (Sorensen, 1974; Schwan & Holmberg, 1979). We consider summer mastitis (or *C. pyogenes* syndrome) to be an infection of non-lactating or newly calved cattle from which *C. pyogenes* is isolated alone or in combination with other pathogens. Occasionally, cases that resemble summer mastitis yield only one of the strict anaerobic bacteria, and these probably should be included within the definition.

Various reports on the aetiology and epidemiology of summer mastitis in northern Europe have been published, but there has been little consistency in case selection or the methodology used for bacteriological examination. Only Stuart *et al.* (1951), Sorensen

(1974), and Schwan & Holmberg (1979) have cultured material under both aerobic and anaerobic conditions reporting similar results.

Little epidemiological data have been reported on summer mastitis other than its seasonal occurrence, the possible involvement of the fly *Hydrotaea irritans* (Sorensen, 1974) and the prophylactic benefits of dry cow therapy (Edmunds & Welsh, 1979).

This paper reports the main findings from an epidemiological and bacteriological survey of 252 suspected cases of summer mastitis in England during 1983 and 1984.

MATERIALS AND METHODS

Mastitis cases among dry cows or heifers, mostly dairy cattle, were identified by the authors or by one of thirty co-operating veterinary practices in the summers of 1983 and 1984. Where possible, affected quarters and sometimes all quarters were sampled aseptically prior to therapy. Secretions were delivered, usually by post, to the National Institute for Research in Dairying (NIRD) or co-operating Veterinary Investigation Centres (VIC) at Bristol, Reading, Gloucester, Starcross, Winchester, Wye, Penrith and Thirsk for bacteriological examination. Details of each infected animal, information about the husbandry of the herd, clinical signs and treatment given were recorded on a standard questionnaire.

Secretion samples were cultured, aerobically and anaerobically, on aesculin blood agar (Bramley *et al.*, 1985). The identity of bacterial pathogens was confirmed, following sub-culturing, by standard morphological and biochemical criteria (Bramley *et al.*, 1985; Cowan & Steel, 1974; Higgs & Bramley, 1981). Identification of *C. pyogenes* was substantiated by Grams staining and liquefaction of inspissated serum (Loefflers serum agar, Oxoid Ltd., Basingstoke). *P. indolicus* was identified using an anaerobe identification kit (API 20A-API, Montalieu Vercieu, France) aided by Grams staining and Ehrlich's reaction (Schwan, 1979). Microaerophilic cocci were detected as small white colonies after aerobic or anaerobic culture often showing satelletism and become haemolytic on continued incubation. Confirmatory tests included Grams staining, coagulase and catalase reactions and occasional examination using API 50CH tests (API, Montalieu Vercieu, France). Reactions were consistent with those reported by Schwan & Holmberg (1979). Cross-checks were used with standard cultures for final confirmation.

Results from the questionnaire were tabulated using a DEC VAX 751 computer and statistical tests performed using the Minitab package on the VAX computer.

RESULTS

Bacteriology

Two hundred and fifty two suspected cases of summer mastitis were reported of which 234 were from dairy cattle. Questionnaires were completed for all cases, but only 242 samples from affected quarter(s) were received. Twenty of these samples (8%) yielded no bacteria of pathogenic significance.

Twenty three different combinations of pathogenic bacteria were found in the 222 samples from which pathogenic bacteria were cultured (Table I). Forty of the samples (16%) yielded only *Str. dysgalactiae, Streptococcus uberis, Staphylococcus aureus, Pasteurella haemolytica, Escherichia coli* or combinations of these pathogens. Although these occurred in non-lactating animals, there was no evidence that the infection involved *C. pyogenes* and hence they have not been classified as 'summer mastitis' infections.

C. pyogenes was found in 154 of the remaining 182 samples (84·6%) in 11 different permutations of pathogens (Tables I and II). Most frequently *C. pyogenes* was isolated alone or in combination with *P. indolicus* (50%). In a further 28 cases it was inferred from the clinical severity of the infection and its bacterial complexity that *C. pyogenes* may have

Table I
Species and combinations of pathogenic bacteria isolated from 222 samples collected from suspected summer mastitis cases

Pathogen(s)	*Number of cases*	*% summer mastitis cases*
C. pyogenes (C)	39	21·4
P. indolicus (P)	4	2·2
Microaerophilic coccus (M)	7	3·8
Str. dysgalactiae (SD)	24	
Str. uberis (SU)	6	
S. aureus	7	
Others	3	
C+SD	8	4·4
C+P	54	29·4
C+M	7	3·8
P+M	4	2·2
SD+P	10	6·0
SD+M	2	1·1
C+SU	2	1·1
C+O	3	1·6
C+P+SD	14	7·7
C+SD+M	3	1·6
C+P+M	15	8·2
C+P+SU	4	2·2
C+SD+SU	1	0·5
SD+P+M	1	0·5
C+P+SD+M	4	2·2

Table II
Recoveries of the summer mastitis associated organisms from clinical cases in this and other studies

	This survey		*Stuart* et al. *(1951)*		*Sorensen (1974)*	
Pathogen	*No.*	*%*	*No.*	*%*	*No.*	*%*
C. pyogenes	154	84·6	64	80	182	73·1
P. indolicus	113	62·1	48	65	211	84·7
Str. dysgalactiae	43	23·6	34	49	41	16·5
Microaerophilic coccus	40	22·0	32	45	184	73·9

been implicated but was not isolated either for technical reasons or because it was no longer viable in the secretion. *P. indolicus* was isolated from all but two of these 28 samples.

The recovery rates of *C. pyogenes* and *P. indolicus* were very similar to those reported from other surveys (Table II). The isolation rate of *Str. dysgalactiae* and microaerophilic cocci were lower than previously reported in the UK (Table II).

Infected animals—pregnancy

A small proportion (10%) of the cases of suspected summer mastitis submitted were found in newly calved cattle but bacteriological examination revealed that half of these were of differing aetiology, usually *Staphylococcus aureus* or *Str. dysgalactiae.* The remainder of the non-summer mastitis infections occurred in non-lactating cattle (Table III). Of cases in pregnant cattle, 14% and only one case in non-pregnant cattle, fell into this classification.

Table III
Distribution of mastitis cases with pathogen species, classification of cattle and pregnancy

	Number of cases					
Infection	*Dry cows*	*In-calf heifers*	*Newly calved cattle*	*Calves*	*Non-pregnant heifers*	*Barren cows*
Summer mastitis						
—with *C. pyogenes*	71	31	11	10	27	4
—no *C. pyogenes*	16	4	1	0	7	0
Str. dysgalactiae	6	9	5	0	1	0
Str. uberis	3	1	1	0	0	0
S. aureus	3	3	4	0	0	0
Others	2	2	0	0	0	0
Total	101	50	22	10	35	4

The relationship between summer mastitis cases and season is illustrated in Fig. 1. Almost all cases were reported in July, August, September and October including those for in-calf heifers in months 3, 4 and 5 of pregnancy. Four cases in non-pregnant animals and three in newly-calved cows were reported over the winter of 1983–1984.

Most summer mastitis cases in dry cows occurred in the last two months of pregnancy (Table IV); this result might be expected since dairy cows are rarely dry other than at this stage but a similar trend was also observed for cases in pregnant heifers, although infections were reported at most stages of pregnancy for these animals (Table IV). This predominance of summer mastitis in the final trimester of pregnancy probably reflects the calving pattern of the national dairy herd. The occurrence of non-summer mastitis infections, especially in heifers, is probably an indicator of the susceptibility of the udder at this developmental stage to infection.

Many more summer mastitis infections were reported from pregnant dry cattle (134 cases) than from non-pregnant dry cattle (48 cases), although the latter are at least as common in the national dairy herd if calves and maiden heifers are included.

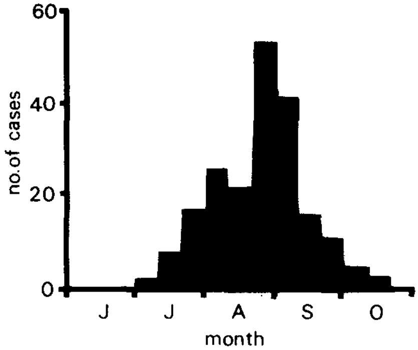

Fig. 1. The number of clinical cases confirmed as summer mastitis by bacteriological examination in 10 day periods over the summer months of 1983 and 1984.

Table IV
Stage of gestation of pregnant heifers and pregnant dry cows at time of mastitis diagnosis including some cows dried off early in pregnancy

	Number of cases					
Month of	*All*		*Summer mastitis*		*Other infections*	
pregnancy	*cows*	*heifers*	*cows*	*heifers*	*cows*	*heifers*
1–3	0	3	0	2	0	0
4	1	6	0	6	0	0
5	3	2	2	2	0	0
6	8	3	6	0	1	2
7	11	7	5	1	2	1
8	21	18	17	9	3	4
9	63	22	50	16	7	6
unknown	10	1	7	0	1	1

Table V
Relationship between lactation age of dry cows and susceptibility to summer mastitis

Lactation interval	*Number of cases*	*% cases*	*% cows in* population*	*Susceptibility** index*
1–2	3	4	26	0·16
2–3	9	12	20	0·61
3–4	22	30	17	1·75
4–5	14	19	12	1·58
5–6	15	20	9	2·25
6–7	5	7	6	1·13
7–8	3	4	4	1·01
8–9	2	3	3	0·90
9–10	1	1	3	0·45

*% cows in population is the age structure of the national herd.
**Susceptibility index is % cases age X/% cows in national herd age X.

Infected animals—age

In dry cows, prevalence of summer mastitis increased with age. This was shown most clearly when the number of cases reported for each lactation interval was weighted according to the probable proportion of cows of that age in the average dairy herd. The index calculated shows that susceptibility increased 14-fold to a maximum in the dry period between the fifth and sixth lactations (Table V). The lower incidence in the oldest cows, if not an artefact because of the small numbers of animals included, may identify cattle much less susceptible to summer mastitis.

Distribution of quarters affected by summer mastitis

For each infected animal the frequencies with which one or more quarters were found infected are shown in Table VI. If quarter infections are independent these frequencies should fit a probability model of independent events where the likelihood of infection in a quarter is p. The likelihood of a quarter not being infected is $q=(1-p)$. As an approximation p can be assumed to be the national incidence rate, say 2% (O'Rourke *et al.*, 1984). On this basis the frequencies of infection found differ significantly ($\chi^2=714$) from the predicted values (Table VI). Thus the presence of an infection in a quarter significantly increases the risk of subsequent quarters becoming infected.

Sixteen animals were reported as having two quarters infected, most commonly on the same side of the udder (Table VII). This relationship between infected quarters supports the results in Table VI.

Infections in one quarter were unevenly distributed with quarter position ($P<0\cdot05$) (Table VIII). Fewer infections were found in the right hind quarter. Despite this, there was no difference in which side of the udder was affected although significantly more cases were reported for front than hind quarters (Table VIII). This latter result might be biased by the low incidence of infections in the right hind quarter. A similar trend, however, occurred for infection in the left side of the udder (Table VIII) although this difference was not statistically significant.

Quarter position did not significantly affect the susceptibility to the non-summer mastitis infections.

Table VI
Frequency with which multiple quarters were affected by summer mastitis

	Number of cases	*%*	*Probability of infection*	*Predicted* %*
1 quarter infected	148	88·6	pq^3	97·96
2 quarters infected	16	9·6	p^2q^2	2·00
3 quarters infected	1	0·6	p^3q	0·04
4 quarters infected	2	1·2	p^4	0
unknown	16			

*The predicted % was calculated from probability theory of independent events based on a national incidence rate of 2·0%

$\chi^2 = 714$, 3 df, a significant difference between the proportions found and those predicted by the model.

Table VII
Distribution of pairs of infected quarters from cases of summer mastitis with 2 infected quarters

Pair of quarters	*Number of cases*
RF,RH	8
LF,LH	3
RF,LF	2
RH,LH	2
RF,LH	1
LF,RH	0
Sides	11
Front/hind	4
Diagonals	1

$\chi^2 = 9 \cdot 9$, 2 df, $P < 0 \cdot 01$, shows that when 2 quarters are infected these are most likely on the same side of the udder.

Table VIII
Position of affected quarters for summer mastitis cases involving only one quarter

Quarter	*Number of cases*	χ^2	*df*	*Significance*
RF	48			
RH	24			
LF	42			
LH	34	8·756	3	$P < 0 \cdot 05$
RF+RH	72			
LF+LH	76	0·108	1	N.S.
RF+LF	90			
RH+LH	58	6·918	1	$P < 0 \cdot 01$

Use of dry cow therapy

Ninety three of the 112 dry cows (83%) developing summer mastitis had received dry cow therapy. The dates of application of dry cow therapy and diagnosis of infection were available for 80 of these cases. Whilst less than 7% of cases occurred within three weeks of administration of dry cow therapy, over 50% had occurred within six weeks of administration (Table IX). Too little information was available to draw any conclusions on the comparative duration of effective prophylaxis with individual dry cow products.

Fate of infected animals

At the time of sampling, indications as to the fate of infected animals were obtained. These showed that culling was proposed for 60% of summer mastitis infected animals (Table X).

Table IX
Interval between the administration of dry cow therapy (DCT) and the diagnosis of summer mastitis

Interval since DCT (weeks)		*No. of cases (n=80)*
<1		0
1–2		2
2–3		3
	6% of cases	
3–4		13
4–5		14
5–6		11
	50% cases	
6–7		4
7–8		8
8–9		4
9–10		8
>11		13

Table X
Proposed fate of cattle affected by summer mastitis, determined at time of diagnosis

Fate	*No.*
Death	0
Cull later	10
Immediate cull	72
Join herd if possible	54

DISCUSSION

The frequencies of isolation of *C. pyogenes* and *P. indolicus* were comparable with those from the much smaller survey in England by Stuart *et al.* (1951) and a similar Danish survey by Sorensen (1974). Schwan & Holmberg (1979) found a much lower incidence of *C. pyogenes* and *P. indolicus* in Sweden.

In the UK, Weaver (1955) and Stone (1956) isolated *C. pyogenes* from less than 50% of suspected cases of summer mastitis but they did not use anaerobic culturing which we have found to be advantageous in the isolation of *C. pyogenes*. Low recoveries of *C. pyogenes* were also reported by Yeoman & Warren (1984) who cultured anaerobically, but surprisingly obtained only single isolations of *P. indolicus* and of microaerophilic cocci from 126 suspected summer mastitis cases. Furthermore, pathogens were not isolated from 20% of cases sampled in that survey.

Close examination of our results shows variations in the patterns of pathogen isolation between laboratories. The microaerophilic coccus was found only once by Veterinary Investigation (VI) Centre laboratories, but in 38 samples examined at NIRD yet, still less frequently than found in Denmark (Sorensen, 1974). *P. indolicus* was less frequently found by VI Centres, but they reported *Pasteurella haemolytica*, not found at NIRD.

These differences might be technical, although similar techniques of isolation and identification were employed, but may also reflect regional differences in the prevalence of pathogens. Other anaerobes, particularly *Bacteroides* spp., have been frequently identified from summer mastitis secretion samples in Denmark (Sorensen, 1978) and W. Germany (Tolle *et al.*, 1983). At NIRD *Bacteroides melanogenicus* was found only once and *Fusibacterium necrophorum* twice—hence there may be regional differences in the frequency of occurrences of these other anaerobes as suggested by Schwan & Holmberg (1979). It is probable however that in this study the mode of collection and carriage of the samples and methodology for anaerobic culturing, especially use of postal samples, were inadequate for reliable isolation of anaerobes more fastidious than *P. indolicus.*

Some variations are apparent in the recovery of *Str. dysgalactiae* in different surveys (Table II). Again regional differences may be important, but the differences are more likely to be due to the much lower incidence of *Str. dysgalactiae* infections as a consequence of the recent widespread application of mastitis control methods (Dodd & Neave, 1970).

C. pyogenes infections are infrequent in lactating cows other than at parturition. Experimental infection of the lactating mammary gland with *C. pyogenes* is often rapidly eliminated (J. E. Hillerton, unpublished observations), and cases arising in lactating cows are often preceded by teat trauma.

The lower incidence of *C. pyogenes* infection among non-pregnant cattle suggests that susceptibility of the mammary gland to *C. pyogenes* infection might increase sometime following conception. Although most cases of summer mastitis occurred in late gestation animals a significant number of cases were reported in heifers in early pregnancy. This may indicate that the stage of gestation is relatively unimportant and that it is the developing non-lactating gland which is fundamentally more susceptible to infection. This is supported by the observation that outbreaks of *C. pyogenes* mastitis can affect young calves (Bramley *et al.*, 1977). Most cases occur in the summer because of the predominant autumn calving pattern allied to the probable role of *H. irritans* in transmission of incidental infections over the summer months (Sorensen, 1974; Bramley *et al.*, 1985). The increased occurrence of infection in pregnant animals may be related to the ability of the pathogens to penetrate or colonize the teat duct as this tissue develops before parturition.

The identification of an increased susceptibility of the older cows, but not the oldest, to summer mastitis is novel but not surprising. A similar increased susceptibility also occurs for coliform mastitis infections (Bramley, 1974) and these must reflect either an increased ease of entry of pathogens to the gland or lowered defences of the gland. If it is the former this would suggest that entry of these pathogens occurs via the teat duct. For *E. coli* mastitis evidence suggests that changes in the ability of the teat duct to prevent entry of the bacteria are crucial (Bramley *et al.*, 1981).

Cows which survive for several lactations/dry periods without contracting a 'summer mastitis' infection or other acute disorder might well be considered to possess some inherent resistance. Breeding from such cows using multi-ovulation techniques and surrogate cows might be of advantage in reducing the likelihood of infections such as summer mastitis especially as such cows have often been free of other infections and metabolic disorders (A. M. Russell, personal comunication).

Most cases of summer mastitis affected only one quarter, usually a front quarter. Contrastingly mastitis in the lactating cow is more likely to develop in a hind quarter (Kingwill *et al.*, 1970). There is no evidence to support the view that there is a difference in the susceptibility of front and hind quarters to infection and the non-summer mastitis infections showed no fore/hind difference. The greater incidence of infections in hind quarters of lactating cows can be attributed to the action of the milking machine (Griffin *et al.*, 1983). A simple hypothesis to explain the greater prevalence of summer mastitis in fore quarters is that flies are more readily attracted to front teats or more easily dislodged from hind teats, perhaps by the tail, and hence exposure to pathogens is greater on front teats. Where two quarters were infected it might be assumed that a front quarter was infected first and that the hind quarter on the same side became infected subsequently. There is no evidence to predict the mechanism of infection of the second quarter.

Dry cow therapy has been shown to be of considerable value in reducing the incidence of summer mastitis (Pearson, 1950 and 1951). However, some 3% of dry cows still become infected (O'Rourke *et al.*, 1984) when only one infusion is used. The evidence here suggests that efficacy of dry cow therapy decreases markedly three weeks after infusion and, effectively, there is no protection after six weeks. This supports the findings of Edmunds & Welsh (1979) who showed that frequent re-infusions were necessary to give reduced incidence of *C. pyogenes* mastitis in dry cows and heifers over the summer months in high risk areas.

The prediction at the time of diagnosis that at least 60% of affected cattle would be culled immediately reflects the farmers' antipathy towards this particular form of mastitis and alone justifies further research.

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