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Source: Journal of Wildlife Diseases, 23(3) : 386-390

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-23.3.386

Journal of Wildlife Diseases, 23(3), 1987, pp. 386–390

EPIDEMIOLOGY OF *MYCOBACTERIUM ULCERANS* INFECTION IN KOALAS (*PHASCOLARCTOS CINEREUS*) ON RAYMOND ISLAND, SOUTHEASTERN AUSTRALIA

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ABSTRACT: *Mycobacterium ulcerans* infections were found in 11 koalas (*Phascolarctos cinereus*) between 1980 and 1985, in a population of approximately 200 koalas on Raymond Island in southeastern Australia. Ulcers caused by the infection occurred on the face, forearm, rump, groin and footpads. Seven koalas had multiple ulcers. All the infected animals were mature (age classes 4, 5 and 6), and eight were male. The distribution of ulcers corresponded with the distribution of wounds in a sample of 87 koalas. Many of these wounds were associated with social behaviour.

Key words: *Mycobacterium ulcerans*, skin ulcers, koala, *Phascolarctos cinereus*, social behaviour, epidemiology.

INTRODUCTION

Mycobacterium ulcerans has been identified as a cause of skin ulcers in many countries (Hayman, 1984), usually in people living near rivers or swamps (Uganda Buruli Group, 1971; Barker, 1973; Barker and Carswell, 1973; Oluwasanmi et al., 1976; Hayman, 1985; Hayman and McQueen, 1985). However, the source of infection is not known. Attempts to isolate the organism from soil, water and vegetation have been unsuccessful (Barker et al., 1972; Stanford and Paul, 1973; Radford, 1974; Portaels, 1978). Animals have been considered also as a source of infection. Artificial infections with *M. ulcerans* have produced ulcers in several mammal and one reptile species (Mitchell et al., 1984), but natural infections have been reported only in koalas (*Phascolarctos cinereus*), on Raymond Island in southeastern Australia (Mitchell et al., 1984; McOrist et al., 1985). This paper discusses some epidemiological aspects of *M. ulcerans* infections in these koalas.

MATERIALS AND METHODS

Raymond Island is in the brackish Gippsland Lakes of southeastern Australia. The 750 ha island consists of low-lying *Eucalyptus tereticornis* woodland, higher sandy areas dominated by *E. viminalis* or *E. botryoides*, some salt and fresh-water marshes and some open pastures. The eastern end of the island has a settlement with 100 to 150 permanent residents and many summer visitors. In addition to the native fauna, there are cattle, horses, dogs, cats, foxes, rats and mice on the island. Koalas were introduced in 1953 (Warneke, 1978).

Mycobacterium ulcerans infections were discovered in four koalas on Raymond Island in 1980. In December 1980, the entire island was searched for koalas, using 3 to 5 people for 6.5 days. Adult koalas (>1 year old) were either captured and examined or examined with binoculars for the presence of skin ulcers and wounds. Body weight and wear on the premolar teeth were used to assign captured animals to an age class (Martin, 1981, 1985). Sex was recorded, and the animals were marked with dye to avoid recaptures. Three koalas with *M. ulcerans* infections were found during the survey. The pathology and bacteriology of these three cases and the four original cases were described by Mitchell et al. (1984). Two additional cases were found in 1982 (described by McOrist et al., 1985), one in 1983, and one in 1985.

Wire-mesh cage traps for small mammals were placed in several habitats on the island over 11 nights in December 1980, for a total of 571 trap nights. All captured animals were examined for ulcers. Parts of the island were searched using spotlights one night in January 1981. Animals located with the lights were examined through binoculars. Soil samples were collected from 50 sites on Raymond Island in January 1981 and submitted for bacteriological examination, using methods described in Mitchell et al. (1984).

In the period from January 1980 to August 1985, 30 additional koalas from different parts of the Gippsland region were found sick or dead and were examined for skin ulcers. The prevalence of infection in koalas in different localities in Gippsland was compared with the prevalence of human infections reported in southeastern Australia between 1975 and 1985 (Hayman, 1985; Hayman and McQueen, 1985), using the estimates of populations for each locality obtained from the Land Conservation Council (1982) and shire council staff.

RESULTS

In December 1980, 36 male and 51 female adult koalas were captured and examined; 23 were in age classes 2 or 3, and 64 were in age classes 4, 5 or 6. Two males and one female had *M. ulcerans* infections. An additional 25 males, 36 females, 24 adult koalas of undetermined sex and 34 juveniles (1 year old) were sighted but not caught. None of these animals appeared to have ulcers, but some were difficult to see clearly.

Of the 11 koalas found with *M. ulcerans* infections between 1980 and 1985, eight were males and all were in the older age classes (age classes 4, 5 and 6). Four of the infected animals had single ulcers (one ulcer each), involving the face (one case), scrotum (one) and forearm between the elbow and carpus (two). Multiple ulcers occurred on the forearm, rump and footpads of the front and hind limbs (one case), the footpads and face (two), the footpads only (three), and the face and forearm (one). Females had ulcers only on the face and footpads (Table 1). Of the six animals with footpad lesions, five had lesions on more than one limb. All footpad lesions were on the volar surface.

Eighteen of the 87 captured koalas had skin wounds. Fourteen were males and 15 were in age classes, 4, 5 or 6. Ten of the 18 animals had face wounds (Table 1), mostly small scars on the ears, eyelids, nose and chin. Only males had wounds on their forearms and groin. The forearm wounds consisted of scars or deep wounds, usually on both the medial and lateral aspects of the elbow. Two males had deep tears on the medial aspects of both thighs. Only two animals had wounds on the footpads; one was a deep tear on the wrist and the other was a torn claw.

TABLE 1. Sites of ulcers caused by *M. ulcerans* and sites of skin wounds in koalas on Raymond Island.

	Males		Females	
	Ulcers	Wounds	Ulcers	Wounds
Number of animals	8 (3)[a]	14	3 (1)	4
Site				
Face	2	8	2 (1)	2
Shoulder	—	1	—	—
Rump	1	—	—	—
Groin and thigh	1 (1)	2	—	—
Forearm and elbow	4 (2)	5	—	—
Hind leg	—	—	—	1
Footpads	4	1	2	1

[a] Number of cases (number of cases with single ulcers).

Trapping for small mammals yielded 18 rats (*Rattus rattus*), two mice (*Mus musculus*), two brushtail possums (*Trichosurus vulpecula*) and 11 lizards (*Tiliqua* spp. and *Egernia* sp.). One rat had a small ulcer on the hind leg; acid-fast organisms were seen on smears, but *M. ulcerans* was not isolated and histological sections were not examined. Mammal spotlighting revealed seven brushtail possums, one ringtail possum (*Pseudocheirus peregrinus*), four swamp wallabies (*Wallabia bicolor*), five foxes (*Vulpes vulpes*) and four domestic cats. Ulcers were not seen on these animals. *Mycobacterium ulcerans* was not isolated from the soil samples from Raymond Island.

The prevalence of human infection was high on Raymond Island (1/150 cases/resident), Loch Sport (3/600), Providence Ponds (1/<100) and Warneet (3/170), compared with Bairnsdale (2/9,400), Lakes Entrance (2/3,020) and other population centres in the region (Fig. 1). Raymond Island, Loch Sport and Warneet have similar environments and koalas living close to residential areas. *Mycobacterium ulcerans* infection was not found in the 30

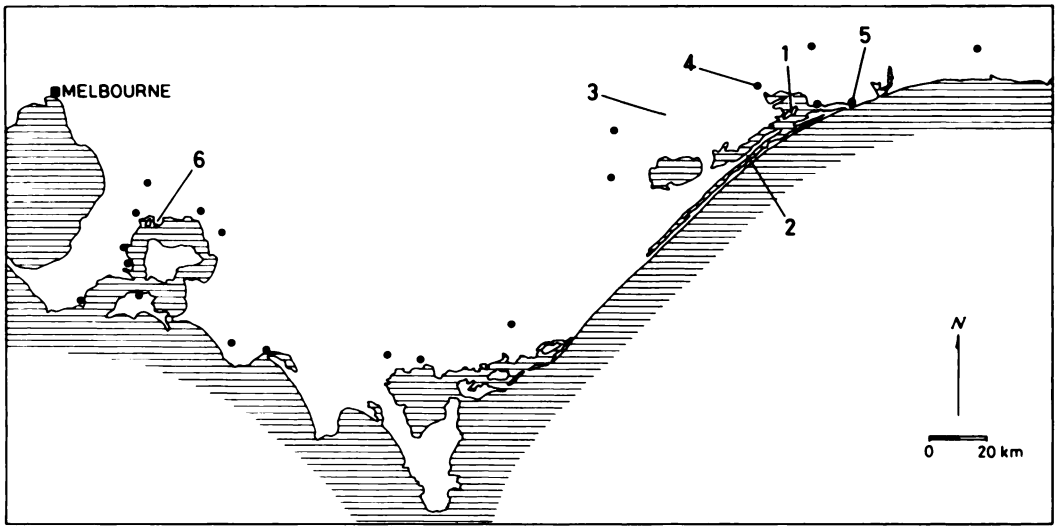

FIGURE 1. Map of the Gippsland region of southeastern Australia, showing the locations of human cases of *M. ulcerans* infection from 1975 to 1985. The locations are: 1, Raymond Island; 2, Loch Sport; 3, Providence Ponds; 4, Bairnsdale; 5, Lakes Entrance; 6, Warneet. Closed circles represent towns near the coast with more than 500 residents.

additional koalas examined between 1980 and 1985. Eight of these animals came from Raymond Island, two from Loch Sport, six from other areas near the Gippsland Lakes and 16 from other parts of Gippsland.

DISCUSSION

In humans, ulcers caused by *M. ulcerans* usually occur on the limbs, at sites that are often exposed to soil and vegetation (MacCallum et al., 1948; Uganda Buruli Group, 1971; Radford, 1975; Oluwasanmi et al., 1976; Hayman, 1985; Hayman and McQueen, 1985). Furthermore, ulcers occur frequently at the sites of wounds (MacCallum et al., 1948; Forbes et al., 1954; Meyers et al., 1974). This suggests that *M. ulcerans* survives in soil or vegetation, as do many other nontuberculous mycobacteria (Wolinsky, 1979), and that ulcers result from the infection of wounds.

Fighting between mature male koalas could result in injuries such as those found on the head, forearm and elbow, and groin of some males, while mating activities might result in facial injuries to males and females (Smith, 1980a, b; P. J. Mitchell, unpubl. data). On Raymond Island, these injury sites corresponded with the sites of many of the ulcers in the koalas, including all the single ulcers.

Climbing accidents have been observed (P. J. Mitchell, unpubl. data), and this could explain the wounds on the footpads. However, the number of animals with ulcers on the footpads (six) was greater than the number with wounds on the footpads (two), and five animals had multiple ulcers on the footpads. Multiple ulcers occur in up to 25% of human cases, following either haematogenous or transcutaneous dissemination from a primary lesion (Janssens, 1972; Oluwasanmi et al., 1976). Experimentally infected mice and rats developed multiple tail, foot and scrotal ulcers. These are sites where the subcutaneous temperature is less than core body temperature and closer to the optimal temperature (30–33 C) for the growth of *M. ulcerans* on artificial media (MacCallum et al., 1948; Fenner, 1956; Feldman et al., 1957). These

secondary lesions must have resulted from haematogenous spread, since the animals were initially infected by intravenous, intracranial or intraperitoneal injection. In the koalas with *M. ulcerans* infections, there was no evidence of a bacteraemia (Mitchell et al., 1984; McOrist et al., 1985). Also, localization following haematogenous spread of the infection would be expected to produce lesions on both the dorsal and volar surfaces of the distal extremities. Only the volar surfaces were affected in the koalas. Transcutaneous spread through small abrasions on the footpads would also explain the distribution of multiple ulcers in the koalas. This spread could occur during grooming or contact with contaminated surfaces.

The prevalence of *M. ulcerans* infections in koalas on Raymond Island (11 koalas in 6 yr, 7 cases in the first yr, in a population of approximately 200 animals) was much higher than the prevalence in humans on the island (1 case in 10 yr in a population of 100 to 150). Koalas may have a low resistance to mycobacteria. This was suggested, but not clearly demonstrated, for another marsupial, the brushtail possum (Moriarty and Thomas, 1983). In this case, infections would be expected in other koala populations. Koalas are conspicuous animals. They are commonly seen in southeastern Australia, including places where human cases of *M. ulcerans* infection occur, and sick and injured koalas are reported often. Despite this, cases of *M. ulcerans* infection in koalas have not been reported from any location other than Raymond Island.

Perhaps koalas are more frequently exposed to an environmental source of infection with *M. ulcerans*. However, koalas are arboreal, and only come to the ground to move from tree to tree. If *M. ulcerans* is a soil pathogen, koalas would spend less time exposed to infection than terrestrial species, including humans.

A third explanation for the higher prevalence in koalas than humans is that there may be a high rate of transmission between koalas. Transmission of *M. ulcerans* infection between humans is unusual (Uganda Buruli Group, 1971), although it probably does occur (Radford, 1975; Hayman, 1985). Transmission between brushtail possums living in the same room has been demonstrated (Bolliger et al., 1950). Koalas are solitary animals and only come together for brief social encounters (P. J. Mitchell, unpubl. data). However, the high prevalence in the more socially active age group and sex suggests that the infection might be transmitted during social encounters, by direct contamination of wounds sustained during these encounters or by the contamination of climbing surfaces and the subsequent infection of small wounds on the hands and feet. However, it is likely that koalas and humans initially became infected from a common source in the environment on Raymond Island. The failure to find that source probably indicates problems in isolation techniques rather than the absence of an environmental source of *M. ulcerans*.

ACKNOWLEDGMENTS

The assistance of Colin Brimblecombe, Geoff Freeman, Ray Catto, Ray Medling and staff at the Regional Veterinary Laboratory, Bairnsdale, Victoria and Fairfield Hospital, Fairfield, Victoria is gratefully acknowledged.

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Received for publication 25 July 1986.