

An observation on the unexpected frequency of some multiple infections

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Studies of trypanosome infections in over 3 500 young and adult cattle in the Lambwe Valley of Kenya showed the presence of Trypanosoma congolense, T. vivax, and T. brucei in single or multiple infections. Some of the multiple infections were much more frequent than would have been expected on the basis of chance, but only if T. brucei was one of the infective agents. Some studies of malaria infections in man show a similar phenomenon.

Robson & Ashkar (1972) recently carried out an examination for trypanosomes in 3 695 cattle, comprising 987 calves and 2 708 adults, in the Lambwe Valley, South Nyanza, Kenya. The numbers found infected with *Trypanosoma congolense*, *T. vivax*, or *T. brucei*, in either single or multiple infections, are shown in Table 1. It appeared possible to the author that the numbers of some of the multiple infections recorded were greater than would have been expected from the average infection rates for each species of trypanosome. This problem was investigated in the following way.

METHOD

If infections with three different pathogenic organisms, *A*, *B*, and *C*, are randomly distributed in a total population, *N*, 8 mutually exclusive classes of infection are possible, as follows:

- (1) triple infections with *A*, *B*, and *C*;
- (2) double infections with *A* and *B*;
- (3) double infections with *A* and *C*;
- (4) double infections with *B* and *C*;
- (5) single infections with *A* only;
- (6) single infections with *B* only;
- (7) single infections with *C* only;
- (8) no infection with *A*, *B*, or *C*.

The grand total of these 8 classes will be *N*.

The probable frequency for each of these 8 classes can be calculated in the following way.

Let the proportion of animals infected with *A* be *a* (=sum of numbers in classes 1, 2, 3, and 5 divided

by *N*); let the proportion infected with *B* be *b* (classes 1+2+4+6/*N*), and let the proportion infected with *C* be *c* (classes 1+3+4+7/*N*).

Then, clearly, the expected number of cases of triple infections will be

$$a \cdot b \cdot c \cdot N$$

The expected number of cases of double infection with *A+B* will be

$$a \cdot b \cdot (1-c) \cdot N$$

the factor $(1-c)$ representing the fact that they must be from that part of the population not infected by *C*. Similarly, the expected numbers of cases of the other double infections, *A+C* and *B+C*, will be, respectively,

$$a \cdot c \cdot (1-b) \cdot N \quad \text{and} \quad b \cdot c \cdot (1-a) \cdot N$$

In the same way, it follows that the expected numbers of cases of each single infection will be as follows:

$$\begin{aligned} \text{with } A \text{ only, } & a \cdot (1-b) (1-c) \cdot N \\ \text{with } B \text{ only, } & b \cdot (1-a) (1-c) \cdot N \\ \text{with } C \text{ only, } & c \cdot (1-a) (1-b) \cdot N \end{aligned}$$

and the expected number of uninfected animals will be *N* less the sum of the seven previous classes—which equals

$$(1-a) (1-b) (1-c) \cdot N$$

RESULTS

An examination of the data of Robson & Ashkar (1972) gave the following results.

Comparisons between infections in calves and adults.

- (1) There was no significant difference between rates of infection with *T. vivax* in calves and adults

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Table 1. Pathogenic trypanosome infections found in cattle in the Lambwe Valley, Kenya

	<i>T. congolense</i>	<i>T. vivax</i> only	<i>T. brucei</i> only	<i>T. congolense</i> + <i>T. vivax</i>	<i>T. congolense</i> + <i>T. brucei</i>	<i>T. vivax</i> + <i>T. brucei</i>	<i>T. congolense</i> + <i>T. vivax</i> + <i>T. brucei</i>	Total uninfected	Total examined
calves	35	52	13	4	4	11	0	868	987
adults	251	122	69	12	42	27	12	2 173	2 708
total	286	174	82	16	46	38	12	3 041	3 695

($\chi^2=0.190$; $0.7 > P > 0.5$). (2) There was a marked increase from calves to adults in the rates of infection with both *T. congolense* ($\chi^2=44.44$; $P > 0.0005$) and *T. brucei* ($\chi^2=13.67$; $P > 0.0005$). (3) There was a significant increase in the proportion of triple infections, from 0/987 to 12/2708 (P (by exact calculation)=0.024).

Comparisons between the expected and found numbers of infections in the various classes for both calves and adults (Table 2). These comparisons show (1) that the numbers of mixed *T. congolense* and *T. vivax* infections are within the limits of expectation, but (2) that all multiple infections in which *T. brucei* is a component are either more frequent, or much more frequent, than would have

been expected (and hence, as a corollary, infections with *T. brucei* alone are less frequent than expected).

In addition to these data on trypanosomiasis in cattle given by Robson & Ashkar (1972), other data on infections with *Plasmodium falciparum*, *P. malariae*, and *P. ovale* in 5 133 human patients were recently obtained by Rickman (unpublished data, 1971) from the same area. The full data for the number of infections in each class of multiple infection are no longer available, but in 2 534 persons found infected with one species or another of malaria parasite, *P. falciparum* was found in 2 291, *P. malariae* in 256, and *P. ovale* in 167, and there were 360 cases of mixed infection.

From these data, the results in Table 3 can be

Table 2. Comparison of the expected and found numbers of infections in calves and adult cattle

Infection	Calves			Adults		
	Expected	Found	χ^2	Expected	Found	χ^2
triple	0.08	0	0.08	1.12	12	105.69
double						
<i>T. congolense</i> - <i>T. vivax</i>	2.84	4	0.47	19.1	12	2.64
<i>T. congolense</i> - <i>T. brucei</i>	1.14	4	7.18	16.4	42	39.96
<i>T. vivax</i> - <i>T. brucei</i>	1.83	11	45.95	8.5	27	40.26
single						
<i>T. congolense</i>	38.94	35	0.40	280.3	251	3.06
<i>T. vivax</i>	62.25	52	1.69	144.3	122	3.45
<i>T. brucei</i>	24.96	13	5.73	124.0	69	24.40
uninfected	854.97	868	0.20	2 114.3	2 173	1.63
totals	987.01	987	—	2 708.0	2 708	—

Table 3. Comparison of the expected and found number of multiple and single malaria infections in humans in the Lambwe Valley, Kenya

Infections	Expected	Found	χ^2
multiple	189.69	360	152.91
single	2 330.90	1 994	48.69
uninfected	2 612.41	2 779	10.62
total	5 133.00	5 133	

deduced. Again, in human malaria, as in animal trypanosomiasis, multiple infections far exceed expectation, although it is not possible in this instance to identify which species of *Plasmodium*, if any, is most frequently associated with such infections.

DISCUSSION

There are obvious immunological or epidemiological implications in the above findings. From the more detailed data on trypanosomiasis in cattle,

it may be suggested either that infection with *T. brucei* makes cattle more susceptible to superinfection with *T. congolense* or *T. vivax*, or, conversely, that infection with either *T. congolense* or *T. vivax* predisposes cattle to superinfection with *T. brucei*, but not with the other species. The fact that *T. congolense*-*T. vivax* mixed infections occur with a frequency within the limits of expectation may suggest that the former is the more likely explanation, and that *T. brucei* infections in cattle, which are generally regarded as of little consequence to the animals themselves, may therefore be of greater epizootiological importance than had previously been thought. Apart from this possible effect in the cattle themselves, it is now well established that some of the *T. brucei* subgroup infections may be *T. rhodesiense* in an endemic sleeping sickness area; thus such infections may also be of great epidemiological significance.

The findings that multiple infections may be more frequent than expected with two pathogens as different as trypanosomes in cattle and malaria parasites in man raises two questions: whether the same phenomenon is known to occur in other possible multiple infections, and what its significance may be.

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RÉSUMÉ

OBSERVATION SUR LA FRÉQUENCE INATTENDUE DE CERTAINES INFECTIONS MULTIPLES

Une étude portant sur 987 jeunes bovins et 2 708 bovins adultes dans la vallée de la Lambwe, au Kenya, a montré la présence de *Trypanosoma congolense*, *T. vivax* et *T. brucei*, décelés sous la forme d'infections uniques, doubles ou triples. La fréquence de certaines infections multiples était supérieure à celle qu'on aurait pu prévoir

en se fondant sur les taux moyens d'infection unique par chacune des espèces de trypanosomes. Un phénomène similaire a été constaté chez l'homme en ce qui concerne la fréquence des infections multiples par diverses espèces de *Plasmodium*.

REFERENCES

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