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The prevalence and epidemiology of toxoplasmosis in Ontario

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SUMMARY

The results of testing 7060 human serum specimens obtained in the Province of Ontario, Canada, were analysed for the presence of antibodies to *Toxoplasma gondii*. Of these samples 38 % were serologically positive at a titre of 1/16 or greater. The age-specific rates climbed from 2·7 % in infants between 6 months and 1 year of age, to about 50 % in individuals aged 25 years or over. Variations in prevalence were noted between different areas within the province and evidence is put forward to show that an inverse relation exists between urban size and toxoplasma prevalence. Seasonal and annual variations were not shown to be significant. On the basis of a very small sample of specimens, cat ownership did not appear to cause a significant increase in the risk of acquiring this infection.

INTRODUCTION

Although toxoplasmosis is known to be endemic in Ontario, little information is available with respect to its prevalence, incidence and epidemiology throughout the province. Previous studies (Ffrench & Fish, 1961; de Savigny, 1974) have demonstrated that about 40 % of the population may possess serum antibodies to *Toxoplasma gondii* as shown by the Sabin-Feldman Dye test or the Indirect fluorescent antibody test. Nevertheless, the route by which these individuals acquire infection is still far from clear.

It is known that, apart from the congenital route of infection, humans may acquire infection in one of two ways (Quinn & McCraw, 1972): either by ingestion of undercooked meat which contains toxoplasma cysts, or alternatively by the accidental ingestion of oocysts shed by infected cats in their faeces. Cats presumably acquire infection by eating meat from other infected animals. The relative importance of these two routes is not clear. About 40 % of the pork, 80 % of the mutton and up to 40 % of the beef available in Ontario is obtained from serologically positive animals (I. R. Tizard, unpublished observations). Given the relatively high meat consumption of the Ontario population and the tendency to eat steaks 'rare', it is probable that this constitutes a significant source of infection. In contrast, cats shed millions of oocysts for several weeks after acquisition of infection without apparent ill effect (Frenkel & Dubey, 1972).

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These oocysts sporulate and can remain infective under optimal conditions for many years. While resistant to cold they are very susceptible to drying and the significance of this source might be expected to be much reduced by the conditions met with in an Ontario summer.

In this report we describe the results of testing over seven thousand serum samples for antibodies to Toxoplasma. The object of the report is to provide data on the prevalence of infection throughout Ontario and, as far as the material permits, to identify some of the factors which influence this prevalence in the hope of eventually being able to determine with some confidence the relative routes of infection by *Toxoplasma gondii* in the human population.

MATERIALS AND METHODS

Samples

The samples analysed consisted of 7060 serum specimens submitted for testing by 105 physicians or hospitals from the whole of Ontario to the Toxoplasmosis Diagnostic Laboratory, University of Guelph, between January 1961 and December 1975. Although these samples were derived from patients suspected of having toxoplasmosis, we consider the sample to be essentially random for the following reasons.

Firstly, The prevalence and distribution of titres in this sample does not differ significantly from a sample of 1312 sera collected at random from the Biochemistry Laboratory, St Joseph's Hospital, Guelph and from several Public Health Laboratories in the Niagara Peninsula. Secondly, the clinical signs of toxoplasmosis, are, in the vast majority of individuals, so non-specific and usually so clinically insignificant (Frenkel, 1972), that we feel that it is not usually possible to diagnose this infection on the basis of clinical signs alone.

Serology

The Sabin-Feldman Dye test was performed using a standard technique (Sabin & Feldman, 1948) and employing the R. H. strain of *Toxoplasma gondii* as antigen.

Analysis of data

The results of each test, together with other available data on the patient were transferred first to punched cards and secondly to magnetic tape. The stored data were then analysed and cross-tabulated using the programme SPSS6 (Nie, Bent & Hull, 1970) on an IBM 370/155 computer of the Institute of Computer Science at the University of Guelph.

RESULTS

Prevalence

In the fifteen years between 1961 and 1975, 7060 serum samples were submitted for testing by Ontario physicians. Of these samples 38 % were serologically positive as determined by having a titre of 1/16 or greater; 9·4 % of the samples had a titre of 1/1024 or greater. Thus almost one in ten of the individuals tested had an

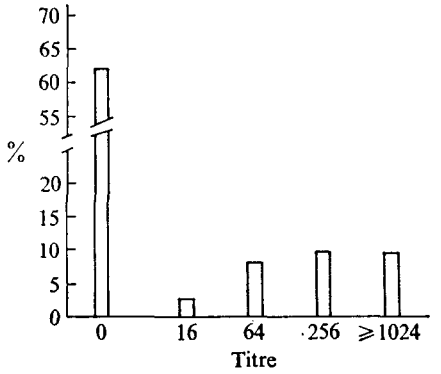

Fig. 1. The distribution of titres in 7060 samples tested. A titre of 1/16 is generally considered to be positive while a titre of 1/1024 is indicative of acute or recent infection by *Toxoplasma gondii*.

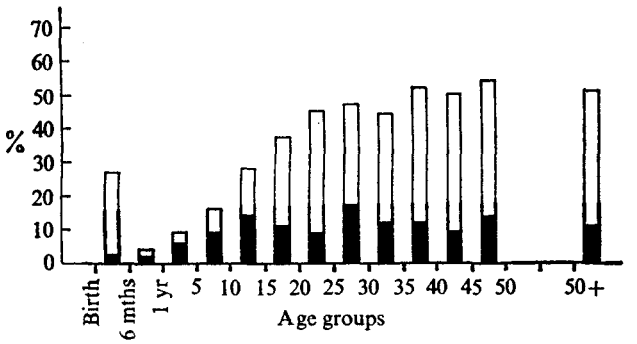

Fig. 2. The distribution of antibody titres to *Toxoplasma gondii* in the Ontario population with respect to age. □, Positive at ⩾ 1/16. ■, Positive at ⩾ 1/1024.

antibody titre generally considered to be indicative of acute toxoplasmosis (Robertson, 1961). We have observed a similar high prevalence in healthy veterinary students (unpublished observations). The distribution of titres in the sample was bimodal (Fig. 1) so that sera tended to be either negative or relatively strongly positive. The absence of samples with low antibody titres is also seen in completely random samples and is unexplained.

No significant differences were observed between samples from male and female patients.

A number of factors which might possibly influence this prevalence were also analysed. They include the age distribution of population, their geographical location, and annual or seasonal trends.

The age distribution of titres

The prevalence of antibodies in children between birth and six months of age was fairly high (Fig. 2), presumably as a consequence of the transfer of IgG antibodies across the placenta from the mother. Of these infants, 27% were serologically positive although only 2·7% of them had a titre of 1/1024 or greater. As

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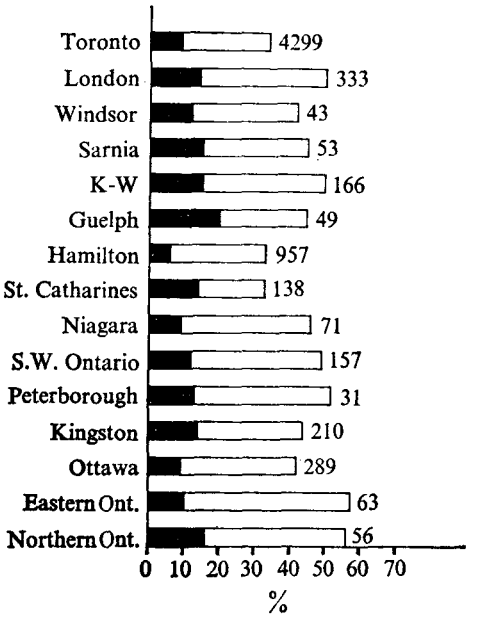

Fig. 3. The results of Sabin-Feldman Dye tests performed on samples from different cities or areas in Ontario. □, Positive at ⩾ 1/16; ■, positive at ⩾ 1/1024. South-western Ontario includes samples from areas west of Highway 400. Eastern Ontario includes samples from East of Highway 400 and south of Sudbury and North Bay. Northern Ontario includes samples from Sudbury, North Bay and all areas North and West of there. K-W is Kitchener-Waterloo. The numbers following each bar indicate the number of samples tested.

maternal antibodies are catabolized, the percentage of positive reactions drops so that in the 230 samples tested from children between 6 months and 1 year of age only 4·3 % were positive although 1·3 % had a titre of 1/1024 or greater.

The prevalence of positive reactions climbed in older children to reach 45·1 % in individuals between 21 and 25 years of age giving an annual incidence of 1·78 %. After 25 years, the prevalence appeared to stabilize remaining relatively constant at around 50 % in the older age groups.

The influence of geographical location on positive reactions

The results of tests performed on samples submitted from different areas or cities in Ontario are seen in Fig. 3. The numbers of samples submitted from many areas are low and all have been mathematically adjusted to account for differences in the age distribution of the sample populations. In general, however, Toronto and Hamilton stand out as having a very low prevalence (the results from St Catharines are probably not completely random since a single physician in this town submitted all of them). Kingston and Ottawa occupy an intermediate position while the rural areas of Eastern, Southwestern and Northern Ontario as well as Kitchener-Waterloo and London appear to have a relatively high prevalence. While too much should not be made of this, we suggest that the prevalence of antibodies may be related in some way to the size of urban areas. This suggestion is supported by a

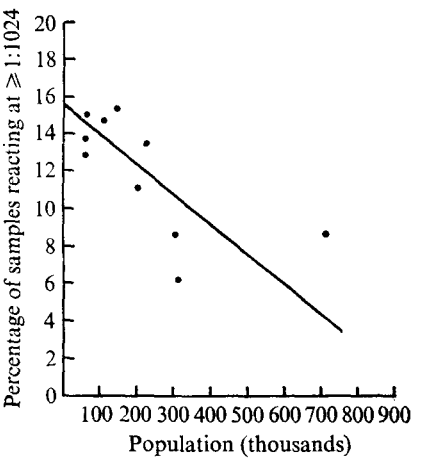

Fig. 4. The negative relation between urban size and the percentage of serum samples reacting at a titre of 1/1024 or greater. $r = -0{\cdot}686$; $P \geqslant 0{\cdot}028$.

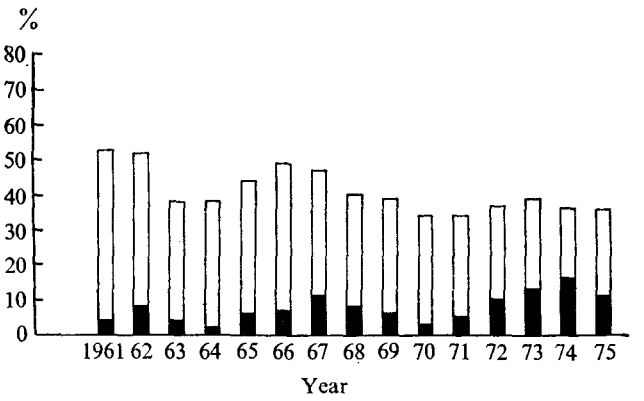

Fig. 5. The results of Sabin-Feldman dye tests conducted yearly 1961–75. □, Positive at ⩾ 1/16; ■, positive at ⩾ 1/1024.

remarkable negative correlation shown between antibody titres in ten selected Ontario cities and their population (Fig. 4). That is, antibodies to *Toxoplasma gondii* are more prevalent in small cities than in large suggesting that toxoplasmosis is a rural infection.

Seasonal and annual influences on levels of antibodies to Toxoplasma gondii

When samples originating from other parts of Canada were analysed, an apparent cycle was noted in the prevalence of antibodies to Toxoplasma (Tizard, Fish & Quinn, 1976). That is, the prevalence of positive reactions rose and fell as part of an apparent six year cycle. A similar phenomenon is seen in Ontario samples (Fig. 5). The percentage of positive (> 1/16) or high titred (> 1/1024) samples peaked in 1961–2, in 1966–7 and in 1973–4, while troughs were observed in 1963–4 and 1970–1. The significance or importance of this is not known. No

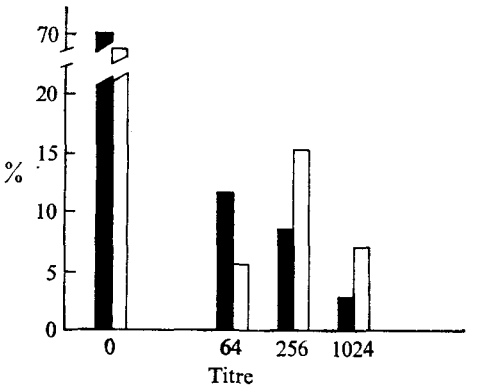

Fig. 6. The distribution of anti-toxoplasma titres in 140 cat-owning and non-cat-owning patients. □, Cat owners; ■, non-cat owners.

consistent features were observed in analysing the dye test results on a monthly basis.

Cat ownership and the prevalence of antibodies to Toxoplasma gondii

From late 1974, physicians submitting samples for toxoplasmosis testing were requested to indicate whether the patient owned or was exposed to a cat. One hundred and forty samples accompanied by this information were tested; 68 were cat owners, 72 were non-cat owners. No significant differences were observed between cat owners and non-cat owners with respect to antibody titres, 30 % of non-cat owners and 34 % of cat owners being positive at 1/16 or higher (Fig. 6). We must conclude therefore that cat ownership *per se* does not confer a significantly increased risk of acquiring this infection.

DISCUSSION

Perhaps the most important feature of these results is the observation that antibodies to *Toxoplasma gondii* are present in a very high percentage of the Ontario population with the possible exception of infants between 6 months and 1 year of age. Consequently, the presence of these antibodies in a patient cannot be considered to be sufficient evidence for the diagnosis of toxoplasmosis. However, a negative serological test should be adequate to definitively exclude the disease. We have found that 27 % of newborn infants possess antibodies and assume that these antibodies are maternally derived. Some support for this suggestion is obtained from the observation that 28 % of pregnant women in Ontario are serologically positive (de Savigny, 1974), and from the rapid decline in antibody titres observed as children grow older.

If a child is born with stigmata suggestive of toxoplasmosis, it is therefore necessary to ensure that the antibodies present in its serum have arisen as a result of congenital infection or otherwise. Perhaps the single best way of doing this is to test for IgM antibodies to Toxoplasma. These antibody molecules cannot cross

the placenta and their presence in an infant suggests that congenital infection has occurred (Remington, Miller & Brownlee, 1968). These results also provide some information on the prevalence of congenital toxoplasmosis. For example, the incidence of seroconversion is over 1 %/year in individuals between 15 and 25 years of age. Thus about 1 % of young pregnant women may seroconvert during pregnancy. Notwithstanding this, the prevalence of clinically significant congenital toxoplasmosis is probably very considerably lower than 1 % and we must therefore conclude that only a small proportion of pregnancies subjected to toxoplasma infection result in clinically significant congenital infection. This feature must be considered when counselling women who have seroconverted while pregnant.

The low prevalence of antibodies in children between 6 months and 1 year of age is perhaps a reflexion of the true amount of congenitally acquired infection. From one year onwards, the incidence of seroconversion increases so that antibody prevalence rises steadily until about 25 years of age when it stabilizes around 50 %. It is difficult to determine why the incidence of seroconversion should be so high in the under 25 age group and why it should stabilize at this age. One possibility is that institutional exposure such as at school or university is important in younger individuals. This in turn implies contagion, a concept at variance with our current knowledge of the epidemiology of toxoplasmosis (Quinn & McCraw, 1972).

It is currently considered that toxoplasmosis may be acquired through consumption of undercooked meat or by accidental ingestion of feline oocysts (Quinn & McCraw, 1972). If meat is the major source of infection then neither climatic nor geographical variations should be seen in the distribution of the disease. In contrast if cats are a major source of infection then the prevalence of infection should be higher in areas where drying does not occur and at the wettest times of the year. This is in fact the case. The prevalence of toxoplasmosis in Canada is largely determined by rainfall, high rainfall areas such as the St Lawrence lowlands having a much higher prevalence than low rainfall areas such as the southern prairies (Tizard *et al.* 1976). In addition, data from Canada as a whole show that the incidence of seroconversion drops during the high summer months (Tizard *et al.* 1976). From the results reported here it appears that one factor which influences the prevalence of positive reactions is city size. That is, the prevalence is much lower in urban than in rural areas. This may be due to the poorer survival of oocysts on roads and pavements, as compared with grass and soil. Such a suggestion cannot however be more than speculative at this time.

The evidence from the data on cat ownership suggests that, if cats are a major source of human infection, then the spread of disease to humans must be somewhat indirect since owning, or living in a house with a cat does not confer an increased risk of seroconversion.

On the basis of these data, we suggest that while cats are probably the major original source of infection in this province, the disease is acquired by man indirectly. One possibility is that cats spread the infection to meat animals and that it is through these that infection is largely acquired.

When counselling individuals on toxoplasmosis prevention it is probably therefore most important to emphasize the avoidance of ingestion of undercooked or raw meat while the role of the cat may be emphasized to a somewhat lesser extent.

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REFERENCES

de Savigny, D. H. (1974). Canadian Public Health Association Meeting, Ottawa.

Ffrench, G. E. & Fish, N. A. (1961). A survey of toxoplasmosis in an Ontario community. *Canadian Medical Association Journal* **84**, 757.

Frenkel, J. K. (1972). Toxoplasmosis: parasite life cycle, pathology and immunology. In *The Coccidia* (ed. D. M. Hammond and P. L. Long). Baltimore: University Park Press.

Frenkel, J. K. & Dubey, J. P. (1972). Toxoplasmosis and its prevention in cats and man. *Journal of Infectious Diseases* **126**, 664.

Nie, N. H., Bent, D. H. & Hull, C. H. (1970). *Statistical Package for the Social Sciences*. New York: McGraw-Hill.

Quinn, P. J. & McGraw, B. W. (1972). Current status of toxoplasma and toxoplasmosis: a review. *Canadian Veterinary Journal* **13**, 247.

Remington, J. S., Miller, M. J. & Brownlee, I. (1968). IgM antibodies in acute toxoplasmosis. I. Diagnostic significance in congenital cases and a method for their rapid demonstration. *Pediatrics* **41**, 1082.

Robertson, J. S. (1961). Excessive perinatal mortality in a small town associated with evidence of toxoplasmosis. *British Medical Journal* ii, 91.

Sabin, A. B. & Feldman, M. A. (1948). Dyes as microchemical indicators of a new immunity phenomenon affecting a protozoan parasite (Toxoplasma). *Science, New York* **108**, 660.

Tizard, I. R., Fish, N. A. & Quinn, P. J. (1976). Some observations on the epidemiology of toxoplasmosis in Canada. *Journal of Hygiene* **77**, 11.