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Guinea worm disease: epidemiology, control, and treatment *

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Guinea worm infection is one of the most easily prevented parasitic diseases, but it is nevertheless a common cause of disability in rural areas of Africa, south-west Asia, and India. Infection occurs when drinking water is infested with infected Cyclops, *a microcrustacean. Worms up to 70–80 cm in length develop in the subcutaneous tissues of the feet or legs and larvae are liberated to renew the cycle when an infected individual steps into a well or pond from which others draw drinking water. Infection is markedly seasonal because of* (a) *the influence of the climate on the types of water source used and* (b) *the developmental cycle of the parasite. The disability may be economically very important if the period of infection coincides with busy periods in the agricultural year. Sieving water through a cloth is sufficient to remove the* Cyclops, *but on a public health scale improved water supplies are required for control. Once the cycle of reinfection can be broken in any district the disease disappears. Chemical treatment of water bodies with temephos is also an effective and safe way of controlling transmission. Treatment consists of rolling out each emerging worm onto a small stick, a few centimetres each day, and certain drugs reduce the pain and pruritis and enable the worm to be removed more quickly.*

Infection with guinea worm (*Dracunculus medinensis*) is a common and neglected cause of disability in rural areas of Africa, south-west Asia, and India, where the people rely on ponds or wells for their drinking water. Treatment is not very satisfactory and better methods are required but the most urgent need is for well conducted control schemes aimed at making the drinking water safe.

Guinea worm disease, dracontiasis, has been known since antiquity and the current position is well illustrated by two quotations from recent reports on studies in Ghana. Regarding treatment, one worker stated "Although all the villages were within 32 km of a hospital none of the patients had sought, or been taken for, medical treatment." [a] and in connexion with the epidemiology and control of the infection another group of workers reported that "Guinea worm disease is the major preventable cause of agricultural work loss in the Danfa Project areas. Few other diseases coincide with major agricultural activities, and even year-round malaria causes little prolonged disability in relatively immune adults. In spite of its prevalence and the suffering it causes, guinea worm is one of the most easily prevented parasitic diseases." [b]

In the simplest course of the disease a mature female worm (about 70–80 cm long) lies subcutaneously in the tissues, usually of the feet or legs, provoking the formation of a small burning blister at its anterior end. This bursts and about 5 cm of worm is extruded from the resulting ulcer, particularly following immersion in water. After about 4 weeks, once the complete worm has been eliminated, the ulcer heals rapidly. However, dracontiasis can be an incapacitating disease because of the tissue reactions the parasites

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[a] LYONS, G. R. L. *Bulletin of the World Health Organization*, **47**: 601-610 (1972).

[b] BELCHER, D. W. ET AL. *American journal of tropical medicine and hygiene*, **24**: 243-249 (1975).

may provoke. Cellulitis is particularly severe when worms are damaged in the tissues, especially when this occurs around the joints, and abscesses and chronic ulcerations can persist for months when there are many worms present, sometimes leading to permanent disability from fibrous ankylosis of joints or contractures of tendons. Secondary infection along the track of the worms in the connective tissues is also very common. It is an unusual parasite in that the same person may be reinfected year after year without developing any immunity to reinfection.

Guinea worm disease is primarily a disease of poverty, afflicting communities living in remote rural areas without adequate water supplies; it is particularly widespread in India and West Africa, but there are also foci in Iran, Pakistan, and other countries in south-west Asia, and in north-east Africa.

EPIDEMIOLOGY

The prevalence of dracontiasis shows marked variation with the season and this is closely bound up with the mode of transmission and with the extraordinary life style of the causative organism, the nematode *Dracunculus medinensis*. An important factor that reinforces the seasonal nature of infection is that the female worms in the human body take approximately one year to mature and release larvae into water to initiate the following year's infection. The larvae require a period of development of about a fortnight in a freshwater microcrustacean, *Cyclops*, before the disease can be transmitted to a new host through the ingestion of infected *Cyclops* in drinking water. Suitable conditions for infection occur only where water for drinking is taken from stationary bodies of surface water such as ponds, large open wells with steps leading down to the water as found particularly in India, or the type of covered rain-filled cisterns that provide the only source of drinking water in rural areas of southern Iran. Infection is not associated with running water or with draw-wells with a circumference of less than 3 metres. Infection is also limited to tropical and subtropical regions because the larvae develop best between 25 and 30°C and will not develop at all below 19°C.

Effect of water source on transmission pattern

Ponds

Natural or artificial ponds are used as sources of drinking water in the Sahel and Guinea savanna areas of Africa and in the Sind desert area of Pakistan and thus provide foci of transmission. In semi-arid, wet- and dry-climate areas with an average rainfall of less than 65 cm concentrated into 3–4 months of the year (e.g., Chad, northern Ghana, Mauritania, Niger, northern Nigeria, Senegal, Sind Province of Pakistan, Sudan, Uganda, in the north of the United Republic of Cameroon, and in Upper Volta), water is obtained from safe bore-wells for most of the year when the ponds are dry, and the maximum incidence of infection occurs during and after the end of the rainy season, particularly when water levels become low in the ponds. Under these conditions infection is markedly seasonal, patent guinea worm disease being confined to less than 5 months of the year with a peak during the harvesting season at the end of the rains.

In humid-climate savanna areas of Africa that have an annual rainfall of more than 150 cm, as in Benin, southern Ghana, Ivory Coast, southern Nigeria, and Togo, ponds contain water all the year and infection may be apparent in man for up to 8 months of the year. However, most cases of dracontiasis occur in the latter half of the dry season, extending to the main planting time after the early rains. There are very few cases in the rainy season because there is so much surface water.

Wells

In villages in endemic areas where draw-wells provide the only source of water, transmission of guinea worm is not commonly found. Conditions are not suitable for the breeding of *Cyclops*,and in a well constructed well there is a surrounding parapet which prevents larvae from reaching the water.

Step-wells, however, which provide the main source of drinking water in many rural areas of India, are ideally suited for *Dracunculus* transmission. These wells are usually a few metres in diameter, providing ideal conditions for *Cyclops* breeding, and the steps leading down to the water result in affected limbs being immersed when the person dips a water container into the well. In these areas the transmission pattern is similar to that found in the humid areas of West Africa. Little or no disease is found during the monsoon season when the water level is high, and peak transmission occurs towards the end of the dry season before the main rains in June or July.

Cisterns

Large covered cisterns (known as "birkehs") filled with rainwater provide the only source of drinking water in the semi-desert areas of southern Iran. The water in the cisterns rarely dries up completely but disease occurs principally when they are half full, and ceases for the 2 months before the rains. Again there is little transmission during the rainy season when the cisterns are full.

ECONOMIC EFFECTS OF THE DISEASE

Dracontiasis is very rarely a killing disease and infection is usually followed by spontaneous recovery even in the absence of any treatment. However, it does cause a degree of disability from the painful ulcers and abscesses, which usually occur on the feet and legs, and which can last over a period of several months if there is infection with more than one worm.

It is difficult to determine the economic effects of disability among communities of self-employed farmers, but the seasonal nature of crop production means that its effect on agricultural output may be considerable.

In southern Ghana, 21 men incapacitated by guinea worm disease were interviewed in order to determine the effects on the whole household of infection in the male farmer.[c] The average period of complete disability in untreated patients was about 15 weeks, but the peak infection rate coincided with the planting or harvesting periods, 75–80 % of crops being produced in this area between June and September. A similar situation probably obtains in all endemic areas of West Africa, and in south-western Nigeria up to one-quarter of the working population aged from 15 to 40 years may be incapacitated for at least 10 weeks in each year.[d] Approximately 0.5 % of sufferers become permanently disabled.

[c] BELCHER, D. W. ET AL. *American journal of tropical medicine and hygiene,* **24**: 243-249 (1975).

[d] KALE, O. O. *American journal of tropical medicine and hygiene,* **26**: 208-214 (1977).

PROSPECTS FOR CONTROL

While the concept of the global eradication of a parasitic disease has rather fallen into disrepute, dracontiasis should be one of the easiest diseases to prevent. This is because the period of infectivity is only a matter of weeks, human infection has to be contracted each year, there is no important animal reservoir, and transmission is limited to small, easily defined foci. Once transmission is interrupted in an area for a single season, infection ceases entirely unless it is reintroduced from outside. Even without any specific control measures the infection appears to be rather unstable and in many areas it disappears and reappears in local communities over the course of a few years, depending on factors such as changes in climatic conditions, on the one hand, or on migration of infected individuals, on the other. For example, infection vanished completely from the Sind desert area of Pakistan in the early 1930s, following a severe drought when the ponds never filled, and the region remained disease free until infected people moved into the area following partition in 1947.

For individual protection, even a measure as simple as sieving drinking water through a cloth will filter out any infected *Cyclops*. Unfortunately, the necessity for such measures is not usually appreciated and for community control there are two possible lines of approach: (*a*) improvement of the water supply, or (*b*) water treatment.

Improvement of water supplies

When piped water is provided, guinea worm disease vanishes, perhaps not quite overnight, but certainly in a couple of years. Bore-wells and tube-wells can also provide a constant supply of pure water where their construction is technically feasible. The water is not liable to the contamination that can occur in draw-wells when full and, if used with an elevated tank, can provide the convenience of water on tap. Improved water supplies have benefits far greater than the control of guinea worm infection and help to reduce other water borne diseases such as cholera, typhoid fever, gastroenteritis, hepatitis, and poliomyelitis.

However, much can be done to interrupt transmission even in the absence of more sophisticated methods of water supply. A notable example was the elimination of the disease from Samarkand and Tashkent over 40 years ago by the filling in of step-wells or their replacement by draw-wells. Similar conversions of step-wells have been carried out sporadically in villages in India, and have lowered the prevalence of disease locally in areas of Andhra Pradesh and Rajasthan.

Chemical control

Control of dracontiasis by treatment of water sources has been advocated many times in the past but very few practical control schemes have been attempted.

Recently, organophosphorous compounds have been widely used for the control of insect larvae in potable water stores and have been shown to have good residual action and to be extremely safe. Temephos, one of this class of compounds, was found to be most active when tested against *Cyclops* in the laboratory.[e] In the field, a concentration

[e] MULLER, R. *Bulletin of the World Health Organization,* **42**: 563-567 (1970).

of 0.5–1.0 mg/litre of temephos removes *Cyclops* for 5–7 weeks and, in the climatic conditions of north-west Ghana, when added to ponds in a village, two applications were sufficient to control *Cyclops* for the duration of the wet season; infection in the inhabitants was reduced from 41 cases in the year of treatment to 9 in the following year, all of which appeared to have been contracted from ponds outside the village.[f]

Temephos in a sand granule formulation, at the rate of 10 g per kilogram, provides a very convenient method of adding the compound to ponds as it has a limited solubility and the quantities do not have to be dispensed with any great accuracy. The timing and mode of application of any compound is very important and varies in different endemic areas depending on the length of the transmission season. Larvae take about 2 weeks to develop inside *Cyclops* after they have been voided into the water so that the first application of chemical need not be made until 3 weeks after a pond refills, taking into account the minimum time necessary before the numbers of *Cyclops* can build up so that transmission can occur. Applications should be repeated every 4 weeks during the transmission season, the number of applications necessary depending very much on the local pattern of transmission. For instance, in the Sind desert region of Pakistan, although water is drawn from wells for most of the year, ponds are also used during the rainy season and transmission appears to be confined entirely to those months (June–September) when the ponds contain water. In the contiguous Rajasthan area of India, many traditional step-wells have been built in the rocky soil, 5–10 to each village, and the transmission season is 1–2 months longer. In endemic areas in more southern parts of India, peak transmission in step-wells occurs at the end of the dry season (March–May) and there is no transmission while the wells are full for the months during and after the rains.

Temephos is already being used in vast quantities in West Africa for the control of *Simulium* larvae, which live in the flowing waters of the Volta River basin, and is proving to be very effective for that purpose with very little effect on other forms of aquatic life or on man. In these areas, villagers are adding temephos to ponds on a haphazard basis and it will be interesting to determine whether these measures have any local effect on the incidence of guinea worm infection.

TREATMENT

Until recently the only effective treatment for dracontiasis was the time honoured one of laboriously rolling out each emerging worm onto a small stick, a few centimetres each day, and this treatment is still a very effective one, provided that it is accompanied by measures to prevent secondary bacterial complications. However, in the late 1960s three compounds were tested and reported to have a marked effect on the emerging adult female worms. These are niridazole (usually given in doses of 25 mg/kg body weight daily for 10 days), tiabendazole (50 mg/kg body weight daily for 3 days), and metronidazole (400 mg for an adult daily for 10–20 days).

About 20 clinical trials have been carried out with these compounds in West Africa and India and their effects have always been very similar; a recent double-blind trial with metronidazole in India can be taken as representative.[g] In this trial, as in all others,

[f] Lyons, G. R. L. *Bulletin of the World Health Organization*, **49**: 215-216 (1973).

[g] Pardanani, D. S. et al. *Annals of tropical medicine and parasitology*, **71**: 45-57 (1977).

symptomatic relief of pain and pruritis was obtained and the drug enabled emerging worms to be removed very much more quickly than in patients given a placebo, and with a marked reduction in inflammation. However, the drug had no effect on the pre-emergent worms which subsequently emerged in the usual way, although with less severe lesions than in the control patients. In a few trials in Ghana, India, and Nigeria with metronidazole, results were not so impressive and, although marked symptomatic improvement was obtained, objective evidence of drug effectiveness was not apparent. A possible explanation for the poor results obtained in a trial in Ghana is that all the guinea worm cases found in the area surveyed were treated, this giving a more representative study population than is possible in a self-selected clinic population. It is probable that chemotherapy will be most effective when given at the time the first worm begins to emerge.

Chemotherapeutic trials carried out in experimental animals have provided evidence of the probable mode of action of these compounds, this being rather puzzling as neither metronidazole nor niridazole is active against any other parasitic nematode. In rhesus monkeys infected with human species of guinea worm, none of the three compounds, even when given in high concentrations over periods as long as 30 days, had the slightest effect on the viability of pre-emergent adult female worms. All worms were active when surgically removed and appeared normal histologically when sectioned. Mature female worms when ready to emerge from the skin are non-feeding organisms which are in effect bags filled with more than one million larvae; these larvae were still active after treatment and were capable of developing to the third infective stage when ingested by *Cyclops*. All three compounds were also ineffective against the developing stages recovered from cats 5–8 weeks after infection.

It might be thought remarkable that none of the chemotherapeutic agents reported to have striking effects in aiding the emergence of female worms in man, had any direct antiparasitic effect in experimental animals on the adult worms or on their contained larvae. However, on reflection this is not so strange, as an emerging guinea worm has already lost its anterior end and it is not possible to judge from its appearance whether it is still living or not. All three compounds have marked antiinflammatory properties and it is probable that they act by lessening the intense tissue reaction that develops along the cuticle of a guinea worm once it has provoked the formation of a blister and started to emerge from the tissues. The course of events following emergence, with a rapid infiltration of polymorphonuclear neutrophils, is very suggestive of an Arthus reaction, probably followed by a delayed hypersensitivity response.[h]

Local treatment with hydrocortisone cream containing an antibiotic had an even more marked effect than these orally administered drugs on the ease of removal of worms emerging from rhesus monkeys in the laboratory, although its use has not been evaluated in man.

Thus it appears likely that in man these compounds act against the host reaction rather than on the worms themselves. It is even a moot point whether direct antiparasitic activity against such a large amount of foreign protein is desirable. The organophosphorus compound metrifonate has some action against many helminths including filarial parasites and was the only substance shown to be effective against guinea worms in infected rhesus monkeys. When given at a concentration of 25 mg/kg body weight for 4 days to a monkey with a total of 8 pre-emergent female worms, the adult worms and the

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[h] MULLER, R. In: Soulsby, E. J. L., ed. *Pathophysiology of parasitic infections,* New York, London, Academic Press, pp. 133-147, 1976.

contained larvae were both killed; unfortunately the monkey also died with symptoms indicative of anaphylactic shock. Rather surprisingly another new compound, mebendazole, which is active against many nematode infections, apparently has little effect against guinea worms, perhaps because it is poorly absorbed from the gastrointestinal tract.[i]

In any case, whatever the value of chemotherapy in the treatment of the individual patient, it is clear than none of the compounds at present in use will have any effect in preventing transmission of the disease.

Surgical removal of pre-emergent female worms after local anaesthetic is still practised in India and Pakistan and can be accomplished with a very small incision if the outline of the worm can be seen or palpated. However, the procedure can be hazardous if part of the worm is in deep fascia or is wound around tendons.

DIAGNOSIS

The diagnosis of dracontiasis is usually straightforward once the first mature female worm has provoked the formation of a blister at the site of emergence. Infection can be confirmed if necessary by adding cold water to the ulcer that follows the bursting of the blister and examining a drop of the water under the microscope for the active larvae. Various immunological methods of diagnosis have also been described for patients with patent infections but have little practical application at present. Techniques for earlier diagnosis have not yet been evaluated in man. The indirect fluorescent antibody test is effective with sera from patients with patent infections and in 4 experimentally infected rhesus monkeys could detect antibodies at least 4 months before the first worm emerged. However, early diagnosis is useful only if the infection can be treated and the only compound that has been tested in this way is diethylcarbamazine. This compound was given to 31 villagers about 6 months after they were likely to have become infected; 6 months later, only 2 of the treated group, but 15 of a similar control group, had worms emerging.[j]

FUTURE NEEDS

An immunological test capable of diagnosing early prepatent infections could be useful, as there is evidence that some chemotherapeutic agents are active against developing parasites; also it might be helpful to have a more effective chemotherapeutic agent capable of killing larvae inside adult female worms before emergence. However, the most urgent immediate need is for carefully monitored control schemes, based on water treatment. If such schemes are succesful in reducing or eliminating infection in the locality in the following year, they should provide useful guidelines for eradication of infection over much wider areas.

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[i] KALE, O. O. *American journal of tropical medicine and hygiene,* **24**: 600–605 (1975).

[j] ROUSSET, P. *Bulletin médical de l'Afrique occidentale française,* **9**: 351 (1952).