The problem of water contamination with *Dracunculus medinensis* in southern Sudan

Kelly JK *MBBS* and Pereira G *MBBS(Hons)*

Corresponding Author: Kelly J kurlk@telstra.com

Abstract

Dracunculiasis is a disease caused by drinking water contaminated by a nematode called *Dracunculus mediensis*. Mortality is low but the disease has a major impact in terms of disability and socioeconomic cost for poor rural communities in affected regions. A multi-intervention program has been successful in bringing the world close to eradication of this disease with the most successful intervention being filtration of water. This improvement has not been so evident in Southern Sudan. After reviewing the main aspects of Dracunculiasis and its control, this article focuses on the barriers to achieving eradication in Southern Sudan and offers some solutions. Civil war, the focus on more pressing issues such as basic survival, lack of infrastructure, nomadism, remoteness of the region and climactic factors are identified as barriers to disease control. Resolution of the civil war and the use of village based workers to provide filters and provide health education are considered the main solutions. The authors further explore how the latter approach may be strengthened.

Key Words: guinea worm, dracunculiasis, Sudan, control, barriers.

Introduction

Dracunculiasis, or Guinea Worm (GW), is a disease caused by the nematode *Dracunculus medinensis*, whose lifecycle is critical to the characteristic way in which the disease is spread. Mortality from GW is extremely low, but the disease has significant socio-economic impact because it affects so many people in the most productive age groups, during the seasons of the year that are critical to community well-being. A program aimed at the reduction in prevalence and eventual eradication of GW was established in the 1980s and 1990s employing several strategies, the most successful of which was filtering of water to remove *Cyclops*, the intermediate host. This was successful in most counties although GW continues to be endemic in Southern Sudan where 80% of the world's cases now occur.

The lifecycle of *Dracunculus medinensis* involves humans ingesting water containing minute crustacean copepods, *Cyclops*, containing the parasite, and is completed when the infected case re-contaminates water sources. The clinical illness, Dracunculiasis, or Guinea Worm (GW), consists of the expulsion of the adult female worm through the skin, usually on the lower limb, which results in pain, and often, secondary infection with subsequent temporary incapacity.

Few people die of GW, with an estimated mortality of less than 0.1% (Adeyeba 1985). The importance of this environmental health issue is three-fold. Firstly, it affects people of school/working age since 58% of those affected are 15 to 49 years of age (Smith et al 1989). Secondly, it disables them for long enough so as to hamper education since 58 to 76% were unable to leave their beds for a month (Adeyeba and Kale 1991) and thirdly, it affects production. The seasonal nature of emergence means that cases occur as clusters so that it is difficult for others to assume the role of the affected person. Furthermore, this seasonality occurs at important times for the production of crops, for example, just after the rains (Belcher et al 1975).

The global GW eradication campaign had its origins in the early 1980s with the decade of water and sanitation, and India was the first to develop a national program in 1982. A global partnership involving the Centre for Disease Control, the Carter Centre, UNICEF, the African Regional Committee of the WHO and the 1990 World Summit for Children developed a strategy, after the World Health Assembly 'declared its commitment to eradication of GW by 1995'. Given the life-cycle of the parasite and the absence of an effective vaccine, a number of interventions were considered: (i) provision of a safe water supply, (ii) filtration of drinking water to remove *Cyclops*, (iii) case finding and appropriate management, (iv) ensuring that cases avoid contact with ponds, (v) killing or removing *Cyclops* from ponds (Cairncross et al 2002). For a number of reasons, filtration of drinking water proved most successful, resulting in 151 countries being certified as free of dracunculiasis, including India, Pakistan, Iran, Egypt, and Libya (WHO 2000).

South Sudan is still endemic for dracunculiasis (Richer 2002) although the data available suggests that it is improving (Hopkins and Withers 2002). There are several reasons for the difficulty in reducing the occurrence of GW in Sudan, most important of which might include its remoteness; the terrain, which is largely under water during the rainy season, making it difficult for index cases *not* to spread the parasite into surface water; the nomadism and 'transhumance' (herding of cattle with the nomadic group) of the population; the lengthy civil war; low impact to national economy; and the prevalence of other, perhaps more urgent health issues related to malnutrition.

The aim of this paper, therefore, is to explore the particular reasons why dracunculiasis is still endemic in Southern Sudan and to suggest strategies for further reduction in its incidence and its eventual eradication.

Investigation

Life Cycle and causes of water contamination

A review of this is essential to understanding the causes of environmental contamination and the interventions.

People become infected when they drink water containing copepods called Cyclops ("water fleas"), which harbour the infected larvae. These are 1 to 2 mm in size and live in shallow types of stagnant surface water such as ponds and shallow wells where they can feed off zooplankton. The ingested copepods are killed by the stomach's digestive secretions. The released larvae penetrate the small intestine and migrate to the connective tissue of the thorax and the abdomen. Over the next 60 to 90 days the larvae mature in to adults and mate. The male then dies and the female over the next 10 to 14 months slowly migrates to the surface of the body (usually the lower limbs) causing a painful blister that ruptures. The human, as a way of gaining symptomatic relief, immerses the affected extremity into cool surface water. This triggers the release of first stage larvae back into the surface water, ready to be ingested by the copepods, thus completing the life cycle (Cairncross et al 2002).

The causes of contamination of water sources by dracunculiasis are therefore:

1. Humans ingesting water contaminated by the Cyclops that have ingested the infective larvae
2. Humans with clinical infection contaminating the water
3. Survival of Cyclops in potable water

Effects of the environmental problem

Magnitude

Dracunculiasis has been present since antiquity. It has been reported from writings from India, Greece and the Middle East and noted in Egyptian mummies as old as 3000 years (Greenaway 2004). In 1986 23 countries were affected with estimated 3.5 million people cases per annum and an estimated 130 million people considered at risk. Thanks to a series of effective interventions implemented in the 1980s as part of a global plan to eradicate Dracunculiasis, up to 98% of the world's caseload has been eradicated. (Cairncross et al 2002). Unfortunately there has been little change in war torn southern Sudan. In 2001 the WHO reported 49,471 cases (78% of all cases reported worldwide.) All but 85 of these occurred in the south (WHO 2005).

Clinical picture

The clinical illness starts off as a small papule that is painful because of the host's immune response. There may be a low-grade fever and nausea. Over the next few days the blister enlarges and ruptures, exposing the adult worm. The worm then slowly makes its way out (Fig 1). This is often expedited by winding it on a stick over several weeks (Greenaway 2004).

On average there are 1.8 worms per case. The lower extremities, usually below the knee are the site of the ulcer in over 90% of cases. Most cases become secondarily infected with bacteria. This is usually cellulitis or local abscess but can be septic arthritis or septicaemia. This secondary infection is thought to contribute to a lot of the pain and disability experienced (Cairncross et al 2002).

Mortality is rare (0.1%) and is usually due to septicaemia or tetanus (Adeyeba 1985).

Figure 1: Removal of guinea worm from a patient's leg in Bahr el Ghazal, South Sudan in 1998.

The significance of this illness as a public health problem lies in the prolonged disability it creates. In two longitudinal studies in Nigeria 58 to 76% of individuals were bed-bound for one month (Cairncross et al 2002).

In a study in Ghana, 28% of patients had continuing pain 12 to 18 months after the illness onset and 0.5% had permanent physical impairment, in the form of "locked" knees or other joints (Kim et al 1997). No immunity is acquired so it is not uncommon for individuals to be infected multiple times (Greenaway 2004).

Socio-economic effects

A conglomeration of factors leads to devastating effects on an affected population's socioeconomic status. It tends to predominantly affect people of working or school age. For example in a Nigerian study, 58% of those affected were between 11 to 49 years. Average length of being unable to work was 100 days (Smith et al 1989).

The disease is known to be seasonal and tends to occur at times when labour demands are at the highest (eg sowing, harvest). The cases tend to occur in clusters, rendering it difficult for some households or villages to cover for the incapacitated. For example it is estimated that the prevalence of cases in affected villages is 15 to 70% (Greenaway 2004).

An estimated annual cost for dracunculiasis in three states of Nigeria based on labour lost in agriculture activities was US$20 million. In Mali it is known as the "disease of the empty granary" (World Health Organization 1998).

In a study in affected children missed up to 25% of their school year due to infection (Ilegbode et al 1986). Absenteeism is thought to occur because of either direct infection or to cover the workload of a parent or sibling disabled by the illness. Children of affected families in Kordofan, South Sudan in one study were three times more likely to be malnourished. This was thought to reflect the lost income to the household induced by incapacitating the breadwinner (Tayeh and Cairncross 1996).

The persistence of dracunculiasis in the south also impedes neighbouring countries' ability to eradicate dracunculiasis from their borders due to contamination of the surface water by infected Sudanese nomads. This incurs the costs of having to continue surveillance and national eradication programs in these countries (Cairncross et al 2002).

Management History & Effects

Global Guinea Worm Eradication Programme

Dracunculiasis is a disease amenable to eradication. This is because of a number of features: its vector, *Cyclops*, is not mobile like the mosquito; the carrier state in both intermediate and definitive hosts is of limited duration; and strategies to limit transmission are inexpensive (i.e. cloth filtration); the disease is only found in certain villages of endemicity, and then, only seasonally, allowing a concentration of efforts (Muller 1979). The eradication of smallpox in 1977 is a good example.

The Centre for Disease Control, through a sustained advocacy campaign in the early 1980s, obtained support from the Carter Centre (formed by former US President Jimmy Carter), UNICEF, the 1989 African Regional Committee of WHO and the 1990 Summit for Children. In 1991 the World Health Assembly declared "its commitment to the goal of eradicating dracunculiasis by the end of 1995, this date being technically feasible given appropriate political, social, and economic support" (Edungbola et al 1992). Support was needed both from the international community and the governments of those countries in which Dracunculiasis is present, in order to achieve a therapeutic partnership with local people: the bulk of the staff engaged in the initiative were health workers whose salaries were supported from the budgets of national ministries of health.

India was the first to establish a national eradication campaign in 1982, followed by Pakistan, Nigeria, Ghana and Cameroon in 1990. By 1995 all of the other known countries of endemicity had national programmes.

How Effective were these Efforts?

With the sustained efforts of local staff, supported through a series of regional conferences of national programme coordinators, the eradication programmes achieved appropriate success in reducing the incidence of the disease (Table 1).

Table 1: Reported cases of guinea worm: the decade's progress 20 countries endemic in 1990, 14 countries endemic in 2000. (WHO, Weekly Epidemiological Record, 4 May 2001).

Country (comparison year when not 1990)	Guinea worm cases reported 1990[a]	2000	Cases 2000 as % of cases 1990[a]
India	4,798	0	0
Pakistan	160	0	0
Senegal (1991)	1,341	0	0
Cameroon (1997)	742	5	<1
Yemen (1994)	94	0	0
Kenya (1994)	53	4	<1
Sudan (1995)	64,608	54,890	85[c]
Nigeria	394,082	7,869	2
Ghana	123,793	7,402	6
Burkina Faso	42,187	1,956	5
Niger (1991)	32,829	1,166	4
Togo (1993)	10,394	828	8
Côte d'Ivoire (1991)	12,690	297	2
Mali (1991)	16,024	290	2
Benin	37,414	186	<1
Mauritania	8,036	136	1
Uganda (1992)	126,369	96	<1
Ethiopia	2,333	60	3
Central African Republic (1995)	18	35	(increase)
Chad (1993)	1,231	3	<1
Total	623,844	75,223	12

[a]. Or nearest appropriate year. Some countries were still establishing their national programmes in the early 1990s; their current case numbers cannot be compared with 1990 numbers because they were not yet reporting in 1990 or were reporting by a different system.

A 98% reduction in the number of cases, from 3.3 million worldwide in 1986, to 75,223 in 2000 has been reported (WHO 2001). Sudan, however, performed poorly, a fact that was attributed to the ongoing civil war.

What were the Interventions?

Environmental control of guinea worm relied upon three main components- provision of safe water sources, control of the copepod population in water sources and health education. The three of these are briefly reviewed.

Provision of safe water sources: the copepod only live in shallow stagnant surface water as is found in man-made ponds ('haffnas'), natural ponds and shallow wells. Therefore provision of groundwater access, deep wells and filtration of water is viewed as very effective intervention (National Research Council 1983). It also carries with it the other well-known socio-economic and health benefits of safe water provision, and the eradication goal was originally proposed as a target for the International Water Decade (Hopkins 1983). Unfortunately it costs about $US 10,000 to drill a bore so small villages can miss out and nomadic people can be hard to service in this way. Bores also require maintenance and are susceptible to damage in civil war. They are not sustainable.

Control of copepod populations: in ponds, small dams and wells with temephos, an organophosphate that can be used in drinking water was used with great success in the Indian campaign (Carter 1999). It does require the know-how to measure the correct volume of the water; a spray can of insecticide and the ability to repeat the procedure at least every month. Unlike the step-wells of India, the pools of water in Sudan are more difficult to dose as the volume is harder to measure. Furthermore the insecticide can be diluted by rainfall.

Health education: had two main arms- social marketing via a variety of media and government trained health personnel, and village-based volunteers. The main jobs of the village-based volunteers were to distribute filter cloth; find and manage cases using provided medical kits; perform case surveillance; and convey the two main health messages of the campaign (Gbary et al 1987). Health education messages focused on drinking safe or at least filtered water and for affected individuals to avoid immersing in the water sources. The prevention of pond contamination by patients was a major feature of the 4,304 health education sessions performed by village volunteers during 1999, following a training course developed by WHO and the Carter Centre in collaboration with the non-governmental organizations (NGOs) operating locally and through the Sudan Ministry of Health (Cairncross et al 2002). Filter cloth was initially made of cotton but these quickly became clogged. Nylon cloth was found to be more sustainable and largely provided by overseas donors (Duke 1984). Because many villagers would rely on surface water in the fields, pipe filters were distributed, to be used as straws. Initially, filters were sold at a small price to attach a value to them but in the end all countries distributed them free-of-charge as uptake was not sufficient.

The Situation in the Sudan

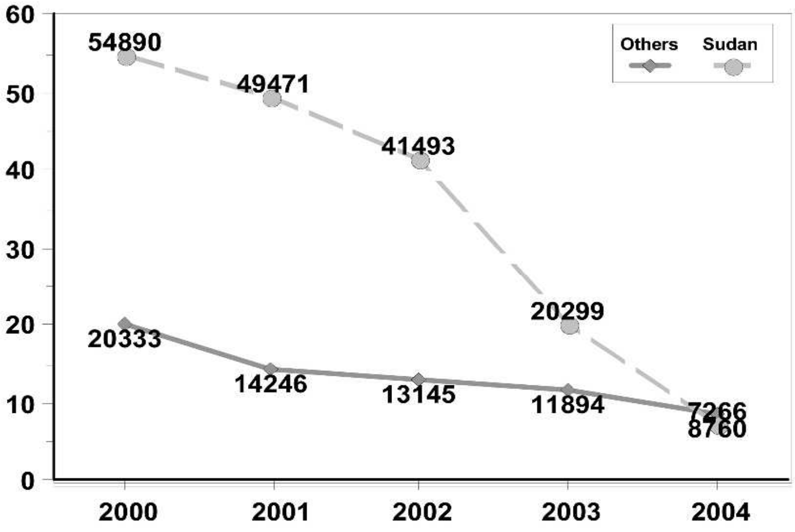
Sudan gained independence from Britain in 1956; the first civil war went from 1955 to 1972, and the second from 1983 to the present. The conflict is between the Arab north (government of Sudan, based in Khartoum) and the Indigenous south; it is sometimes described as a religious war (Muslim north, Christian and animist south), but has much to do with access to power and natural resources. This protracted conflict is blamed for the lack of eradication of Guinea Worm in South Sudan, where 80% of the world's cases of Guinea Worm are now found (Richer 2002).

Sudan did have a government-sponsored eradication programme; however, this only succeeded (and was only really implemented) in the north, where support for the government exists. Furthermore, nomadism and transhumance compounds the problem (the population of south Sudan are amongst the last traditional nomadic herders in the world). Ernesto Ruiz-Tiben, technical director of the Carter Centre's Guinea Worm Eradication Program, explains that "the war and the absence of infrastructure in southern Sudan makes it very difficult to organise a program in endemic villages" (Carter Centre 2003).

Despite the difficulties, a four month cease-fire was brokered by former US President Jimmy Carter in 1995, between the government of Sudan and the Sudan People's Liberation Army, to permit health workers to distribute 200,000 cloth filters to 2000 villages (among other valuable public health interventions). Since the cease-fire, government authorities, the UN, the Carter Centre, and over 20 NGOs have focused on targeting the disease in the south. 600,000 cloth filters have been distributed annually, and in 2001, 8 million pipe filters were distributed (Hopkins and Withers 2002).

The subsequent success of the eradication programme in Sudan is illustrated in Figure 2.

Figure 1: Guinea worm cases reported from 2000-2004 (Source: Hopkins DR et al 2005)



Cost

The estimated cost of the global campaign between 1987 and 1998 was $US 87.5 million (Kim et al 1997), which to a large extent came from the governments of Denmark, Qatar, Canada, Finland, Japan, The Netherlands, Norway, Saudi Arabia, Spain, Sweden, United Arab Emirates, United Kingdom, United States of America (Carter 1999). $2 million worth of insecticide and $14 million worth of cloth for filters was donated by the private sector. $28.5 million from the Bill and Melinda Gates Foundation in 2000 ensures funding to the present.

According to a World Bank study the economic rate of return, based on agricultural productivity, is approximately 29%, which will accrue at no additional cost in the future if eradication is achieved. The cost per case prevented is $5 to $8 (Kim et al 1997).

Resolution

There are a number of barriers to eradicating Dracunculiasis in Southern Sudan. The most widely reported barrier was the ongoing civil war. This created increased inaccessibility that is already a problem by virtue of the remoteness of the population and poor infrastructure. Infrastructure is destroyed (roads, safe water supplies and health centres). Civil war renders the national campaign and underlying political support almost useless, since in this case the government is the enemy of the target population. The devastating health effects of the war also make GW a low priority for the target population. The focus is more on survival and basic human needs (eg malnutrition and food security).

Fortunately an end to the north south conflict has offered an opportunity to make some inroads, although the new conflict in western Darfur shows how fragile peace can be.

There are other factors at play that pose significant barriers to eradication. Most of the affected populations are traditional nomadic herders. For centuries their movements have been centred on the herding of cattle along traditional migratory paths. This is known as transhumance (Abdikarim and Velema 1999). This has profound implications for the interventions programs. A water bore will only be used and maintained by an affected population for the short time that they are in that area. This renders as already expensive intervention even less cost effective. Similarly, the monthly reapplication of larvicides in ponds is less likely to be performed by the population. Nomadism renders access and supplies by external program workers more difficult. Historically such groups have often been the last groups to have guinea worm eradicated in countries that have successfully eradicated the condition. For example in Uganda in 1993, 95% of the remaining cases were in two nomadic tribes. Nomadic groups are often subject to inadequate surveillance for guinea worm. In Nigeria 25% of nomadic groups were found to have guinea worm cases in an area where officially no cases had been reported by standard surveillance methods. There are also cultural issues. Furthermore, nomadic groups are often looked down by settlers. There may be mistrust of external bodies, especially when linked with the national government (Abdikarim and Velema 1999).

Traditional use of ponds rather than wells makes it very difficult to correctly dose larvicides into shallow water sources, even if one could get the expertise in to do so, as dosing relies on correct estimation of water volumes. Furthermore water volumes change quite dramatically in the South Sudan because of the effects of the wet and dry seasons. This makes correct dosing of larvicides in ponds even more challenging as the rainfall dilutes the agent. It is therefore no surprise that use of larvicide only covered 2% of accessible villages in South Sudan in 2002 (Hopkins and Withers 2002).

Climatic factors also have a profound effect. The terrain in the wet season is largely under water. Therefore the usual advice for index cases not too re-contaminate the surface water is more difficult to adhere to, even for a motivated individual. The temptation to drink from readily available surface water over that bore hole one kilometre away is likely to be present.

Literacy rates of the south are one of the lowest in the world with only 11% of the population considered literate. This would make training of village based volunteers more challenging.

Lastly the illness, despite its ability to in-capacitate, even in the absence of the civil war, has little effect on the national economy, since the nomadic populations of the south are largely subsistence based. Therefore there is little financial motive for the Sudanese government to support a national program of eradication.

Solutions

With the apparent end to the North South conflict it is hoped that real progress can now be made. This does reflect in the decrease in cases over the last few years.

Provision of bore hole, deep well or treated surface water and treatment of ponds with 'temephos' are not cost-effective interventions in the South Sudan given the nomadism, use of ponds, rainfall and terrain. The nomadic nature of the population involved means less reliance on external access. Mobile health teams are used in some countries but are thought to be expensive and therefore not sustainable. They are also likely to face cultural barriers (Abdikarim and Velema 1999).

Conversely, health education and provision of filters by village based workers are interventions that circumvent the problem of nomadism. The use of village volunteers has been shown to be effective with other nomadic populations (Abdikarim and Velema 1999) . Even in the absence of filters, health education by village-based volunteers has proven effective in South Sudan. For example in an area of 160 villages in Adior District in Bahr el Ghazal Province, South Sudan, guinea worm incidence fell by 88% when village based volunteers gave health education about prevention of pond contamination. Of note this was in an area where there was a shortage of cloth filters (44% households had one). This health message was the corner piece of 4304 health education sessions by village-based volunteers in (through the Carter centre, various NGOs and the WHO) in 1999 (Cairncross et al 2002).

Village-based workers also enable monthly case surveillance, perform simple case management and can be integrated into other health programs such as vaccination, family planning and primary care. They are also considered inexpensive. It is estimated by Cairncross that on average a health program based on community health workers costs 100 to 200 US dollars per village per year.

Limiting factors to this method are the issues of training, monthly supervision and volunteer attrition. In general attrition rates for community based health workers range between 3 to 77% with higher attrition rates noted when they are unpaid volunteers (Bhattacharyya et al 2001). In Northern Ghana, the rate of attrition at two years was noted to be very low, even when the volunteer's role was integrated with other health programs. In this program, volunteers were nominated and selected by the village leaders. They were provided with finances to cover transport and food during the training period and provided with an attractive tea shirt, occasional training in reading and writing and mosquito net for personal use. There was monthly contact with a regional supervisor who could discuss and convey concerns and receive the monthly surveillance data. Apart from concerns with delays in these monthly visits because of flooding, the program seemed quite happy with the program. Interesting the reasons cited by volunteers for their low attrition rates were related to social status and job satisfaction (Maes and Edmond 2000).

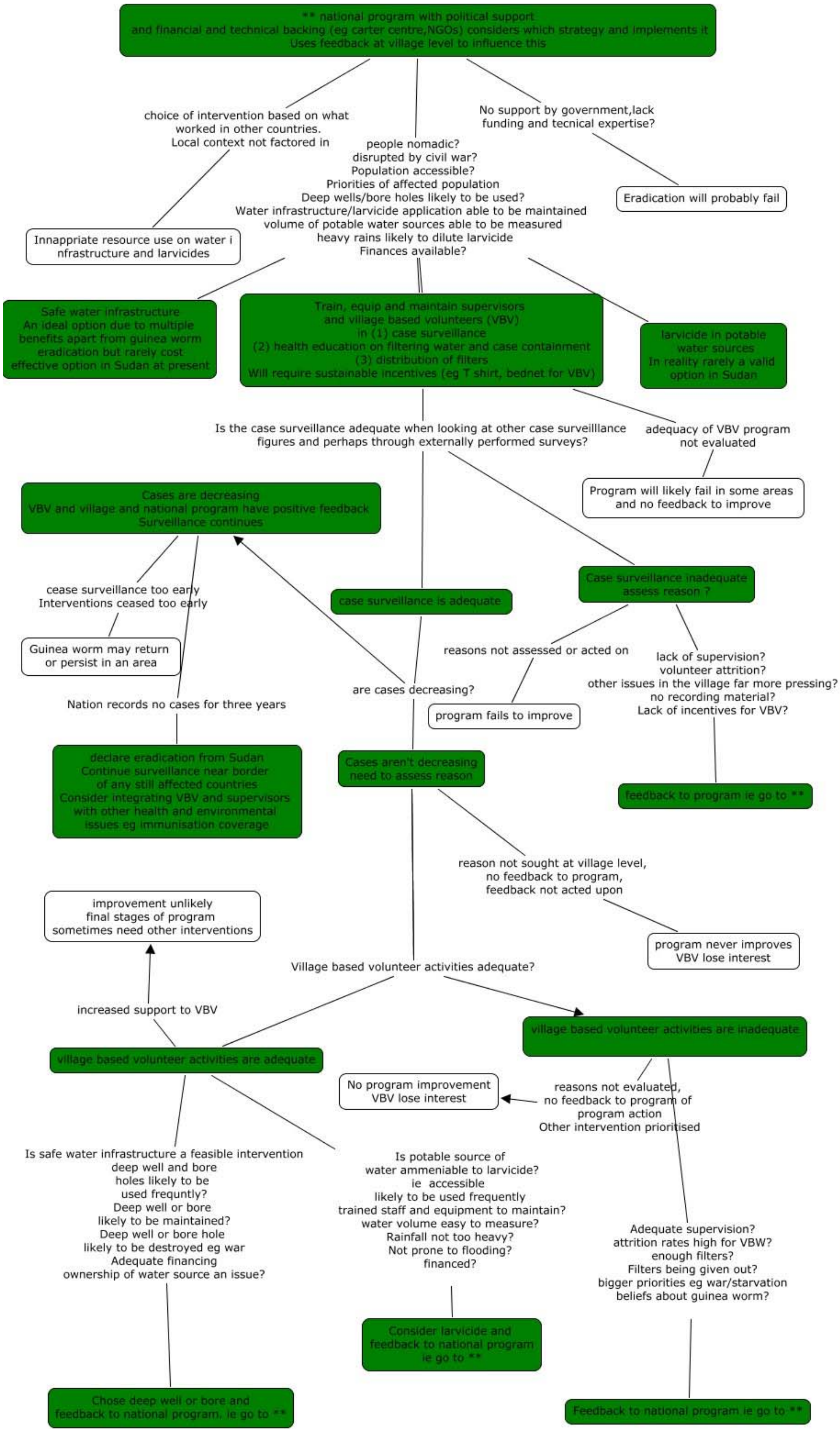
In South Sudan attrition rates of guinea worm volunteers are not officially reported by the major programs (Carter centre, WHO), at least on their website reports. In a UNICEF report, WHO and a partner NGO had trained literate guinea worm volunteers in Sudanese villages remote to health centres to provide standard case management under the program "Essential Community Child Health Care (ECCHC)". In the evaluation of this program between the years 1999 to 2002, attrition rates of village based workers were noted to be high (Zagaria 2002). The authors of this paper therefore advocate the widespread program reporting of attrition rates amongst village-based volunteers and their supervisors in South Sudan. Leaving supplies at posts along the migratory route and ensuring that the nomadic tribes themselves select their own volunteers are considered effective ways of working with nomadic groups in this context (Abdikarim and Velema 1999).

Figure 2 outlines the decisions that have to be made to manage and resolve this persistent problem.

Conclusion

Dracunculiasis is amenable to eradication because of the nature of the organism and the disease, and interventions to this effect are cost-effective. It has been eradicated from most countries through the efforts of the Global Guinea Worm Eradication Campaign, although is still endemic in South Sudan, where 80% of the world's cases occur. This fact is largely attributed to the ongoing civil wars, and perhaps most pertinent is the fact that mortality is so high in Southern Sudan due to malnutrition and other factors directly attributed to war, that Guinea Worm is of a lesser significance to the population. Understanding the lifecycle of Dracunculus medinensis is critical to understanding the clinical and socio-economic implications of the disease, which are devastating to communities; mortality is low ('the disease of empty granaries'). The most effective intervention for South Sudan may well be filtration of drinking water and the presence of community derived, village-based health educators.

Figure 2: Management and resolution flowchart



References

Abdikarim S and Velema JP (1999) Where health care has no access: the nomadic populations of sub-Saharan Africa. Tropical Medicine and International Health, volume 4: 695–707.

Adeyeba OA (1985) Secondary infection in dracunculiasis: bacteria and morbidity. Int. J. Zoonoses. 12: 147-149

Adeyeba OA and Kale OO (1991) Epidemiology of dracunculiasis and its socio-economic impact in a village in south-west Nigeria. West Afr. J. Med 10:208-215

Belcher DW, Wurapa FK, Ward WB and Lourie IM (1975) Guinea worm in southern Ghana; its epidemiology and impact on agricultural productivity. Am. J. Trop. Med. Hyg. 24: 243-249.

Bhattacharyya K, Winch P, LeBan , and Tien Y (2001) Community Health Worker Incentives and Disincentives: How They Affect Motivation, Retention, and Sustainability. Published by the Basic Support for Institutionalizing Child Survival Project (BASICS II) for the United States Agency for International Development. Arlington,Virginia. http://www.mostproject.org/CHVs/CommunityHealthWorkers.pdf.

Cairncross S, Muller R, Zagaria N (2002) April Clinical Microbiology Reviews. 15: 223-246.

Carter Center (2003) Profile: Ernesto Ruiz-Tiben, Technical Director, Carter Center Guinea Worm Eradication Program http://www.cartercenter.org/doc1520.htm

Carter J (1999) The power of partnership; the eradication of guinea worm disease, p. 141-147. *In* Cooperation South no. 2. United Nations Development Program, New York, N.Y.

Duke BL (1984) Filtering out the guinea worm. World Health March 1984:29.

Edungbola LD, Withers PC, Braide EI, Kale OO, Sadiq LO, Nwobi BC, Alakija T, McConnon P, and Hopkins DR (1992) Mobilization strategy for guinea worm eradication in Nigeria. Am. J. Trop. Med. Hyg. 47: 529-538.

Gbary AR, Guiguémdé TR, and Ouédraogo J-B (1987) La dracunculose, un fléau éradiqué dans trois villages du Burkina Faso par l'éducation sanitaire. Bull. Soc. Pathol. Exot. 80: 390-395.

Greenaway (2004) Dracunculiasis (guinea worm disease). CMAJ. 170(4)

Hopkins DR (1983) Dracunculiasis: an eradicable scourge. Epidemiol. Rev. 5: 208-219.

Hopkins DR, Withers PC Jr (2002) Sudan's war and the eradication of dracunculiasis. The Lancet Supplement. 260 (December): 21-22.

Hopkins DR, Ruiz-Tiben E , Downs P, Withers C, Maguire J (2005) Dracunculiasis eradication: the final inch Am. J. Trop. Med. Hyg. 73: 669-675

Hours M, and Cairncross S (1994) Long-term disability due to guinea worm disease. Trans. R. Soc. Trop. Med. Hyg. 88: 559-560.

Ilegbodu VA, Kale OO, Wise RA, Christensen BL, Steele JH, Chambers LA, (1986) Impact of guinea worm disease on children in Nigeria. Am J Trop Med Hyg 35:962-4.

Kim A, Tandon A, Ruiz-Tiben E (1997) Cost-Benefit Analysis of the Global Dracunculiasis Eradication Campaign. Policy Reasearch Working Paper 1835. Washington. World Bank, Africa Human Development Department.

Maes, Edmond F (2000) Assessment of community-based surveillance: Northern Region, Ghana. UNICEF mission report. United Nations Children's Fund, New York, N.Y.

Muller R. 1979. Guinea worm disease; epidemiology, control and treatment. Bull. W. H. O. 57: 683-689

National Research Council (1983) Opportunities for control of dracunculiasis; report of a workshop. National Academy Press, Washington, D.C.

Richer M. Overview of the Health Situation in Southern Sudan 2002 http://www.unsudanig.org/publications/assessments/data/health_overview.pdf

Smith GS, Blum D, Huttly SRA, Okeke N, Kirkwood BR, and Feachem RG (1989) Disability from dracunculiasis: effect on mobility. Ann. Trop. Med. Parasitol. 83: 151-158.

Tayeh A, and Cairncross S (1996) The impact of dracunculiasis on the nutritional status of children in South Kordofan, Sudan. Ann. Trop. Paediatr. 16: 221-226.

World Health Organization (2000) Dracunculiasis; certification of absence of transmission. Wkly. Epidemiol. Rec. 75: 77-79.

World Health Organization (2001) Dracunculiasis-global surveillance summary, 2000. Wkly. Epidemiol. Rec. 76: 133-139.

World Health Organization (2005) Communicable diseases Toolkit for Sudan: communicable disease profile 2005- dracunculiasis: 22-25.

World Health Organization (1998) Yoro, the empty granary. Film (35 mm) and videotape. Co production by WHO/ORSTOM/ENMP, Geneva, Switzerland.

Zagaria, N (1999-2002) Essential Community Child Health Care (ECCHC), Southern Sudan 1999-2002 http://www.unicef.org/programme/cimci/assets/Stockholm%20mtg,%20final%20report.doc.