Dracunculiasis (guinea worm disease): eradication without a drug or a vaccine

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Dracunculiasis, commonly known as guinea worm disease, is a nematode infection transmitted to humans exclusively via contaminated drinking water. The disease prevails in the most deprived areas of the world. No vaccine or medicine is available against the disease: eradication is being achieved by implementing preventive measures. These include behavioural change in patients and communities—such as self-reporting suspected cases to health workers or volunteers, filtering drinking water and accessing water from improved sources and preventing infected individuals from wading or swimming in drinking-water sources—supplemented by active surveillance and case containment, vector control and provision of improved water sources. Efforts to eradicate dracunculiasis began in the early 1980s. By the end of 2012, the disease had reached its lowest levels ever. This paper reviews the progress made in eradicating dracunculiasis since the eradication campaign began, the factors influencing progress and the difficulties in controlling the pathogen that requires behavioural change, especially when the threat becomes rare. The challenges of intensifying surveillance are discussed, particularly in insecure areas containing the last foci of the disease. It also summarizes the broader benefits uniquely linked to interventions against dracunculiasis.

1. Introduction

Dracunculiasis, commonly known as guinea worm disease, is caused by a 60–100 cm long nematode worm, Dracunculus medinensis. The disease has been known to humankind since antiquity. The ‘fiery serpents’ of the Israelites were possibly guinea worms. The first known mention of the disease was in the Turin Papyrus in the fifteenth century BC by the Egyptians; it has been since described by ancient Greek, Roman, Arab, Persian and Indian physicians [1]. Guinea worm disease derived its common name from its prevalence on the Gulf of Guinea [2]. It is known to cause temporary incapacitation and sometimes is associated with permanent disability [3,4], resulting in loss of income and reduced school attendance among the already-deprived communities and households associated with the disease. The Dogon people of Mali refer to dracunculiasis as ‘the disease of the empty granary’ [3]. Significant progress has been made in reducing the incidence of the disease by more than 99 per cent. This paper reviews the progress made during the eradication campaign, the lessons learnt and the remaining challenges.

2. Biology of the parasite

Dracunculiasis is transmitted exclusively to humans via drinking water contaminated with infected copepod Cyclops, the intermediate host of D. medinensis. Following ingestion, the Cyclops die and release D. medinensis larvae, which penetrate the host stomach and intestinal wall, and enter the abdominal cavity and retroperitoneal space. The larvae develop and mature into adults; after copulation, the male worms die and females grow to a length of 60–100 cm and...
migrate in the subcutaneous tissues towards the surface of the skin. About 10–14 months after infection, the female worm induces a painful blister on the skin, mostly from the lower limbs; the blister ruptures, and larvae are released on contact with water by the adult female worm as it emerges. The larvae are ingested by a *Cyclops* and after two moults (in about two weeks) develop into infective larvae. Drinking unfiltered water from stagnant water sources containing the infected *Cyclops* perpetuates the transmission cycle [5]. Although no vaccine is available for prevention or medicine for mass treatment [5–8], the transmission cycle can be broken at different points by avoiding contaminated sources of drinking water, filtering unsafe water with cloth and fine-mesh strainers before consuming, drinking water from improved sources and controlling the vectors of transmission (figure 1).

### 3. Decision to eradicate

The adoption in 1986 of resolution WHA39.21 acknowledged the special opportunity afforded by the International Drinking Water Supply and Sanitation Decade (1981–1990) for combating dracunculiasis. The resolution noted the importance of maximizing the benefits to health of an intersectoral approach in the context of primary healthcare; the progress achieved by the National Guinea Worm Eradication Programme of India; and the increasing awareness and actions being taken against the disease in Africa and its successful elimination in several countries. Furthermore, the resolution endorsed efforts to eliminate the infection country by country and to provide through a combined strategy safe drinking water sources, active surveillance, health education, vector control and personal prophylaxis; it called on all Member States affected by dracunculiasis to establish, within the context of primary healthcare, plans of action to eliminate dracunculiasis [10]. The 45th World Health Assembly in 1991 further resolved to eradicate dracunculiasis by 1995 [11]. This decision had evolved based on various discussions and several factors.

#### (a) The disease burden

In 1947, more than 48 million people were estimated to be affected by the disease in Africa, India and the Middle East [12]. During the 1970s, the disease was reported to be distributed in the rural areas of India, the Islamic Republic of Iran, Pakistan, Saudi Arabia, Yemen, and East and West Africa [13–15]. In 1976, the World Health Organization (WHO) estimated a prevalence of 10 million dracunculiasis cases globally [15]. By the 1980s, the disease was known to be endemic in 20 countries in Africa, the Middle East and Asia.

#### (b) Emerging opportunities

After the successful conclusion of the smallpox eradication campaign in 1979, public-health experts, notably at India’s National Institute of Communicable Diseases [16] and the United States Centers for Disease Control and Prevention, sought other potential disease candidates for eradication [17]. Dracunculiasis was considered a suitable candidate because its geographical distribution is limited to tropical or subtropical areas, transmission is seasonal [13,18], diagnosis is unambiguous by visual recognition of the emerging worm through a painful blister or ulcer [19], the intermediate host is non-airborne and there is no known animal reservoir [6]. Moreover, there is no further multiplication of the parasite in the vector, unlike that of malaria. Based on the understanding of its local epidemiology, occurrence of the disease can be forecasted by geographical area and time period, permitting advance
Table 1. World Health Assembly resolutions on dracunculiasis.

<table>
<thead>
<tr>
<th>World Health Assembly</th>
<th>year</th>
<th>main focus</th>
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<tbody>
<tr>
<td>WHA 34.25</td>
<td>1981</td>
<td>International Drinking Water Supply and Sanitation Decade: dracunculiasis as indicator of progress [32]</td>
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<tr>
<td>WHA 39.21</td>
<td>1986</td>
<td>endorsed combined strategy: safe water provision, active surveillance, health education, community mobilization, vector control personal prophylaxis [10]</td>
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<tr>
<td>WHA 42.29</td>
<td>1989</td>
<td>declared goal for eliminating dracunculiasis in the 1990s, invited other development agencies, organizations, foundation to support the country and ensured funding [33]</td>
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<tr>
<td>WHA 44.5</td>
<td>1991</td>
<td>country by country certification of elimination of dracunculiasis, certification by WHO. National goals to interrupt transmission by 1995 [11]</td>
</tr>
<tr>
<td>WHA 50.35</td>
<td>1997</td>
<td>political support and availability of resources for completion of dracunculiasis and support the work of International Commission for the Certification of Dracunculiasis Eradication (ICCDE) [34]</td>
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<tr>
<td>WHA 57.9</td>
<td>2004</td>
<td>Geneva Declaration for the Eradication of Dracunculiasis by 2009 [35]</td>
</tr>
<tr>
<td>WHA 64.16</td>
<td>2011</td>
<td>provision of adequate resources for interrupting transmission and certification of eradication of disease, supporting surveillance in dracunculiasis-free areas, annual reporting of the progress to WHA [36]</td>
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planning for focused and effective implementation of interventions for interrupting transmission. Its potential for eradication was asserted in 1993 by the International Task Force for Disease Eradication, which after reviewing 94 infectious diseases concluded that dracunculiasis is one of six eradicable diseases [20].

The launch of the International Drinking Water Supply and Sanitation Decade of 1981–1990 encouraged the World Health Assembly to note in resolution WHA34.25 that the decade presented an opportunity to eliminate dracunculiasis as a public-health problem in affected areas, where the prevalence of the disease could serve as a uniquely visible and measurable indicator of progress during that period [13].

Following the momentum generated by the resolution, the first international meeting (‘Workshop on opportunities for control of Dracunculiasis’) was held in June 1982 [21,22]. In 1983, India officially launched its National Guinea Worm Eradication Programme as a centrally sponsored programme after assessing the extent of the disease’s distribution since 1980 and formulating a strategy for eradication through a National Task Force set up in 1980 [23]. In 1984, the United States Centers for Disease Control and Prevention was designated as a WHO Collaborating Centre for Research, Training and Control of Dracunculiasis [24]. Since then, it has developed operational guidelines in collaboration with The Carter Center’s Global 2000, the United Nations Children’s Fund (UNICEF) and WHO and continues to provide technical assistance to the programme, including laboratory support.

(c) Cost-benefit

Another aspect influencing the decision to eradicate was the important socioeconomic toll of the disease on affected communities and countries and the cost-benefit of public-health interventions. The cost in lost school attendance and revenue from decreased agricultural productivity for individuals and the community can be very high. The economic loss of dracunculiasis in India alone was estimated to be 11.7 million man-days annually among 4 per cent of the 12.2 million people living in endemic villages [25]. In 1985, researchers noted that dracunculiasis has an impact on school attendance in Benin and Nigeria, and on agriculture in Benin and Burkina Faso [26,27]. In 1987, a study in Nigeria estimated an annual loss of US$ 20 million per single crop (rice, yam and cassava) from farmers incapacitated by the disease for an average duration of five weeks [3,4,28,29].

In 1956, referring to the eradication of yaws in Haiti, it was concluded that interventions for disease eradication programmes should be considered as a capital investment rather than as a recurrent expense once the disease is eradicated [30]. Using a project horizon of 1987–1998, the World Bank estimated an economic rate of return under conservative assumptions of 29 per cent [31].

(d) Support for eradication

Since the inception of the global eradication campaign, there has been continuous support from countries and communities affected by the disease as well as partners in the public and private sectors.

The World Health Assembly has adopted a total of seven resolutions on dracunculiasis eradication (table 1), compared with 27 resolutions on smallpox eradication and four resolutions on eradication of poliomyelitis. Similar resolve was echoed at the regional level of WHO during the first African regional conference on dracunculiasis eradication held in Niamey, Niger in July 1986, shortly after WHA39.21 was adopted.

These regional conferences brought together ministries of health and partners and were sometimes attended by current or former Heads of State to advocate dracunculiasis eradication. Following the adoption in 1988 of resolution RC38/13 by the African Regional Committee [37], Cameroon, Ghana and Nigeria took action to eradicate dracunculiasis with national case searches conducted during 1988–1989; most countries carried out national case searches between 1990 and 1992 and scaled up interventions from 1991 to 1993. A total of eight African regional conferences on dracunculiasis have been held; the last conference took place in Abuja, Nigeria, in April 2008.

In 1986, The Carter Center began its involvement in dracunculiasis eradication [3] and has played a crucial role in the global campaign since then, tirelessly advocating, fund-raising and assisting endemic countries to interrupt transmission.
4. The eradication strategy

Evidence from various studies on the natural history of the disease, proven interventions and experiences in countries [22] and lessons learnt from the successful smallpox eradication programme and the not so successful malaria eradication programme have shaped the dracunculiasis eradication strategy [6,38–40]. The eradication strategy, based on the following interventions (i) surveillance (including case management and containment); (ii) provision of safe drinking-water sources; (iii) vector control; (iv) health education (personal prophylaxis); and (v) certification of eradication, was endorsed by the World Health Assembly [10,11].

(a) Surveillance

Surveillance is a key element of disease control programmes, but it is the most crucial element in the final stage of the dracunculiasis eradication programme. The objective of surveillance and reporting is to promptly detect all cases until the last case of the disease is contained and the absence of transmission is confirmed. Endemic countries pass through three different stages: endemic; pre-certification; and post-certification. After interrupting transmission of the disease, the country enters a pre-certification stage of at least 3 years. During this stage, a country must show evidence of sustained absence of transmission through nationwide surveillance in order to be eligible for certification as dracunculiasis-free. Once WHO has certified a country free of dracunculiasis transmission, it enters the post-certification surveillance stage, which is continued until eradication of dracunculiasis is declared globally.

Where the disease occurred in the remotest and difficult to access areas of endemic countries, with limited access to primary healthcare services, surveillance involved the community in detecting, containing and reporting dracunculiasis cases [41,42]. Active house-to-house case searches were carried out: communities were shown a guinea worm photo identification card to assess whether anyone had seen a person with an emerging worm, as was carried out in the smallpox eradication campaign of the 1970s [43,44]. However, because community-based surveillance (CBS) relied on a supportive infrastructure of supervisors to train, monitor and collect monthly reports from health workers, implementation was restricted to known endemic and at-risk villages until zero cases had been reported for 3 years or transmission was no longer a risk. Dracunculiasis was reported through the national health information systems of affected countries [26,45,46]. Today, a case of dracunculiasis is immediately notified for prompt investigation and containment, and cases are reported monthly to the national level even if zero cases are detected [47].

With the decline in the number of cases and to increase the sensitivity of surveillance, eradication programmes announced a reward for notifying cases that are subsequently confirmed as dracunculiasis. A similar strategy was used during the smallpox eradication campaign [48]. The International Commission for the Certification of Dracunculiasis Eradication also recommends that national dracunculiasis eradication programmes announce a suitable reward for individuals reporting cases and for patients [49]. The amount of the reward in endemic countries and countries in the pre-certification stage ranges from US$ 40 to US$ 160 [47].

(b) Case management and containment

Every case that is detected should be treated to prevent further transmission. The tried-and-tested treatment is to roll the worm gradually from the body using a stick or a match [6]. In some parts of Ghana and India, guinea worms were extracted surgically [50,51] with varying results. The Indian Guinea Worm Disease Eradication Programme expressed concerns about this practice and its clinical sequence and recommended against surgical extraction [52]. The practice was withdrawn from the Ghana Guinea Worm Eradication Programme in 2000. In the absence of any effective drug to kill the parasite, development of drug resistance is not a concern for the programme.

A dracunculiasis case is reported to be contained if all of the following criteria are met: the case is detected before or within 24 h of the worm’s emergence; the patient did not contaminate any water source after the worm’s emergence; the patient received proper care by cleaning and bandaging the wound until all the worms are fully expelled; the patient received health education on not entering any water source; and a supervisor verified the case as dracunculiasis within 7 days [53]. Case-containment strategies have been implemented in all endemic countries since 1995 [54].

To further ensure proper case containment, especially when numbers of cases are reduced and localized, national programmes have established case-containment centres in existing health facilities or temporary camps where patients are admitted and treated; health education is provided until the worm has been completely expelled, and any contact of patients with unsafe drinking water sources is prevented.

(c) Access to improved drinking water

The link between the prevalence of dracunculiasis and the lack of access to improved drinking-water sources is well recognized [55–57]. Communities identified by the Guinea Worm Eradication Programme as endemic for dracunculiasis are prioritized for access to improved water supplies. Methods to improve drinking-water supplies for affected communities include: protecting hand-dug wells and sinking deep-bore wells, improving existing surface drinking-water sources by constructing barriers to prevent humans from entering the water; and filtering surface water through sand filters [56,58]. Ministries of water and sanitation with the support of UNICEF and other partners such as Japan International Cooperation Agency (JICA) played a key role. Access to improved drinking-water supplies in affected communities provides a sustainable solution for eradication. However, insufficient resources, difficulties in sinking deep-bore wells resulting from complex hydrogeological structures [59], and unsuitable water quality in certain areas [60] led to the goal of providing universal access to improved drinking water in all villages (including dracunculiasis-endemic communities) not met by the end of the International Safe Drinking Water and Sanitation Decade. Dracunculiasis eradication programmes have continued leveraging access for improved water sources [61] in remote communities.

(d) Vector control

Vector control consists of killing the Cyclops (intermediate host) by applying a chemical called temephos. When applied
to unsafe drinking-water sources at monthly intervals during the transmission season, temephos is effective in killing the *Cyclops*, thus reducing the likelihood of individuals contracting the infection [62,63]. The challenges of treating ponds with temephos include calculating the appropriate quantity for application, the intensity of labour [6] and the difficulty in reaching remote areas. In addition, there may be difficulties in identifying which surface water sources are potentially contaminated and which need to be treated. Without a complete census of potentially unsafe drinking-water sources in use by communities, contaminated water sources continue to be used and transmission is perpetuated.

To supplement vector control by treatment of water sources with temephos, the adult *Cyclops* measuring about 1 mm can be removed simply by filtering drinking water through an ordinary nylon cloth or steel mesh.

**(e) Health education**

The objective of health education is to ensure that greater numbers of individuals and communities adopt behavioural practices aimed at preventing and interrupting transmission. Practices include voluntary reporting of dracunculiasis cases and knowledge of the reward scheme, prevention of patients from entering drinking-water bodies, regular use of drinking water from improved water sources and, in the absence of such sources, filtering water before drinking. The required know-how is transferred by health staff and volunteers using simple and professionally crafted messages [6] to individuals and communities.

Although filtration appears to be easy and effective, challenges remain in individual and household compliance with straining all unsafe drinking water before consumption and, more importantly, in the agricultural fields or when travelling. In many endemic communities, challenges have been overcome by sustained behavioural change communication supported by community empowerment and mobilization campaigns. To address particular issues, such as filtering unsafe water for nomadic communities and cattle herders, innovative methods include designing portable water filters (‘pipe filters’) for use in the field and funnel filters for filtering water through plastic containers (used to carry water to and from the field).

Advocacy and information, education and communication materials have been prepared and disseminated through poster, radio and television broadcasts, town criers and markets. In resource-poor situations, face-to-face communication (social mobilization and house-to-house visits) appeared to have been the most significant strategy for disseminating messages [64]. Behavioural changes have to be brought about in the community to achieve the required impact, which remains a challenge. Ownership by all communities and commitment to the programme have made a remarkable difference.


All national programmes implement a combination of all the above-listed interventions to interrupt transmission. Surveillance remains the crucial overarching intervention to detect each worm emergence at the earliest to effectively contain any subsequent transmission. Programmes have given varying emphasis within this overall mix of interventions depending on local conditions. For example, the Indian Guinea Worm Eradication Programme considered the vector control as a cost-effective strategy and emphasized identification of all potential unsafe drinking water sources and their aggressive treatment with temephos monthly [23]. However, in areas and countries where application of temephos in the very large surface water sources was difficult, alternative approaches were adopted such as preventing entry of humans into the water, providing the surface water after pumping through sand filters and making it potable. Countries in Africa such as South Sudan and Ghana accorded a greater emphasis in the provision of filters and health education to prevent transmission.

Based on experience in Ghana, Nigeria and Pakistan, the recommended strategies were summarized and the following operational phases were described: (i) the first phase consisting of establishment of the national programme office, conducting baseline surveys and preparing a national plan; (ii) the second phase including the interventions to interrupt transmission by implementing training, village-based surveillance, health education, filter distribution, providing safe drinking water suppliers, vector control and monitoring; and (iii) the last phase involving case containment followed by a post-eradication phase [74].

**(f) Certification of eradication**

The need for certification of attainment is inherent in the goal of an eradication programme. WHO established the International Commission for the Certification of Dracunculiasis Eradication (ICCDE) in 1995 [33] as requested by resolution WHA44.5 [10]. The Commission is made up of 12 independent public-health experts, and recommends to the Director-General of WHO the certification of countries as free of dracunculiasis transmission. At its first meeting in 1996, the ICCDE finalized the criteria against which disease-endemic and non-endemic countries are assessed for certification [49]. All countries have to be certified, irrespective of their endemicity status. The ICCDE categorized countries into groups: endemic, in pre-certification and those with more than 3 years without cases. Once transmission is interrupted, the ICCDE recommends a minimum 3-year pre-certification stage, during which a country must show evidence of absence of transmission to be eligible for certification. The process for certification is based on the epidemiological group of the country and is based on a thorough review of the declaration, and a report submitted by the country followed by field evaluation carried out by an independent International Certification Team.
Republic, Côte d’Ivoire and Togo (1990); Niger, Mauritania, Mali, Senegal, Uganda and Yemen (1991); Ethiopia and Sudan (1992); and Chad and Kenya (1993) [58,77–79].

To supplement national case searches, CBS was initiated in Cameroon, Ghana and Nigeria. In 1989, a total of 883,640 dracunculiasis cases were reported to WHO by 15 countries: Nigeria reported 640,008 cases and Ghana reported 179,556 cases [78]. The total did not include cases from other known endemic countries such as Chad, Senegal and Sudan (figure 2) [24]. By 1995, the first target year for eradication, the annual incidence of dracunculiasis had reduced significantly to 152,814 cases. Pakistan interrupted the transmission in 1993 and Kenya reported its last indigenous case in 1994. India interrupted the transmission in 1996, followed by Cameroon, Senegal and Yemen in 1997 (figure 3).

In 2004, the 12 remaining endemic countries pledged to eradicate the disease by 2009, which was endorsed by WHA50.29 [35]. South Sudan, then part of undivided Sudan and in the grip of a 20-year-old civil war, implemented full-scale programme activities only in 2006, thanks to the Comprehensive Peace Agreement of 2005. By the end of 2009, eight of these 12 remaining endemic countries claimed to have interrupted transmission (figure 3), bringing the total number of countries that had interrupted transmission to 16. The number of cases declined to 3190 (a 99% reduction since the start of the global campaign) during the same year; 80 per cent of the cases were reported in South Sudan [81].

By 2012, the number of cases reported to WHO worldwide had dwindled to a historic low of 542 cases reported in 272 villages. Dracunculiasis was limited to four countries (Chad, Ethiopia, Mali and South Sudan), a 49 per cent reduction compared with the 1058 cases reported in 2011 (figure 3). South Sudan reported 521 cases, contributing 96 per cent of the total number of cases in 2012; the 21 remaining cases were reported by Chad (10 cases), Ethiopia (four cases), Mali (four cases) and Niger (three imported cases from Mali) [82].

The eradication target was not achieved in 1995 or 2009. The target might have been unrealistic [83]. During the 1990s, insufficient resources, operational challenges largely owing to conflicts and security concerns, and ensuing inaccessibility prevented programme interventions from being comprehensively rolled out for some time; these factors certainly delayed the eradication process in Mali and South Sudan. Nevertheless, setting targets might have accelerated the course of eradication by energizing and intensifying global efforts, and contributed to significantly reducing the number of cases during 1991–1996 and interrupting transmission in 75 per cent of endemic countries by 2009.

Between 1995 and 2011, the ICCDE met eight times and, on its recommendations, WHO has certified 192 countries, areas and territories free from dracunculiasis, either by having interrupted transmission or by being an entity where transmission is never known to have occurred. As of 2012, a total of 14 countries remain to be certified. There are four endemic countries (Chad, Ethiopia, Mali and South Sudan) six previously endemic countries in the pre-certification stage (Côte d’Ivoire, Ghana, Kenya, Niger, Nigeria and Sudan) and four countries with no-known history of dracunculiasis pending verification (Angola, the Democratic Republic of the Congo, Somalia and South Africa) (figure 4) [47].

Countries have taken varying periods of time to interrupt transmission and achieve zero reported indigenous cases. Among possible determinants are the burden of the disease (figure 5) and country-specific operational implementation. Transmission dynamics are complex, at the individual and community level; interrupting transmission relies on the intensity and accuracy of control interventions. Future predictions

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**Figure 2.** Dracunculiasis cases reported worldwide, 1981–2011 [80].
based on previous trends may not always be accurate. On the basis of the past trend in the number of cases, it was predicted that Ghana was unlikely to achieve interruption of transmission by 2015 [84]. However, Ghana interrupted the transmission in 2010 and has reported zero cases since May 2010. After having almost no decline in cases between 2001 and 2007, apparently due to not so effective programme implementation, Ghana achieved an unprecedented record of...
reducing the number of dracunculiasis cases from 3358 cases in 2007 to only 501 cases in 2008, 242 cases in 2009 and the last eight cases in 2010 owing to a significant increase in the proportion of cases (above 84%) that were contained since 2007. Figure 6 compares the impact of interventions in Ghana with the percentage change in the number of cases reported the following year. A similar comparison between the number of reported cases and the operational indicators (figure 7) for South Sudan indicates that while the proportion of cases reported to have been contained rose from 49 per cent in 2006–2008 to 74 per cent in 2010–2011, and the percentage of endemic villages with temephos-treated water sources gradually increased from 7 to 85 per cent in 2011, the rate of decline in cases varied between 24 per cent and 49 per cent during 2007–2012.

6. Lessons learnt from the global eradication programme

It has been 22 years since the 45th World Health Assembly resolved to eradicate dracunculiasis. During the course of
the global programme’s implementation, certain lessons can be drawn that affect the course of an eradication campaign and could inform future eradication initiatives, in particular, and public-health practice, in general.

(a) Sustain political commitment

Any effort to eradicate a disease requires sustained commitment from decision-makers at the highest level of government, ministries of health of affected countries and supporting partners. The dracunculiasis eradication initiative benefited from the personal commitment of former and current Heads of State, secured largely through advocacy by President Carter. The ‘guinea worm ceasefire’ of 1996, which allowed active case searches to be carried out in conflict zones of Sudan, demonstrates that with political will even difficult situations can be overcome. Resolutions calling for dracunculiasis eradication and annual reporting to the World Health Assembly maintain the required commitment of ministries of health of affected countries and partners. Key partners—the Carter Center, UNICEF, WHO and its Collaborating Centre at the United States Centers for Disease Control and Prevention—have continued to provide support and assistance to the programme and to the endemic countries. Advocacy and commitment at the highest levels resulted in a continued funding for the programme starting with the United Nations Development Programme, a coordinator of the International Drinking Water Supply and Sanitation Decade, as one of the first funding sources [85]. This funding was crucial to initiate national case searches and establish national eradication programmes. As the cases decline or transmission is interrupted, multiple health challenges compete for scarce resources and the programme may no longer be considered a priority for decision-makers. However, with the unstinted support of governments, UN and international developmental agencies and private foundations, funding for the eradication initiative has now been secured until 2015 [86].

(b) Sustain surveillance when the disease burden is reduced or transmission has been interrupted

When the number of cases decreases or transmission is interrupted, it becomes harder to sustain the commitment of all stakeholders as the disease is no longer perceived as a problem for the community or the health system [88]. This phenomenon is certainly not unique for dracunculiasis, and lapses can lead to costly setbacks and re-emergence of the disease. In Chad, for example, an outbreak occurred in 2010 after the last reported indigenous case in 2000. An almost non-functional national eradication programme may have contributed to suboptimal surveillance. To avoid lapses in surveillance it is important to:

— ensure that transmission has indeed been interrupted in the community by thorough evaluation before transiting previously endemic communities to passive surveillance;
— partnering with and strengthening the Integrated Disease Surveillance and Response (IDSR) system, which provides a nationwide opportunity to improve surveillance of dracunculiasis, especially in formerly endemic and non-endemic areas where dracunculiasis-specific surveillance is not in place. The IDSR is still in different stages of evolution, and the reporting rate varies from country to country. To bridge the gap between communities where dracunculiasis is likely to occur and the facility-based IDSR reporting, the programme relies on the reward scheme and other programmes such as the polio

![Figure 7. Impact of interventions in South Sudan](http://rstb.royalsocietypublishing.org/)
surveillance network, national immunization days and mass preventive chemotherapy programmes for large-scale house-to-house case search activities;

— extending the role of community volunteers. When the disease becomes rare or is eliminated, extending CBS to include other diseases sustains motivation of community volunteers and maintains adequate surveillance for dracunculiasis. Burkina Faso, Ghana, Mali, Niger and Uganda extended the (CBS) system for other diseases, including poliomyelitis, neonatal tetanus, Buruli ulcer, meningitis and even census for deaths [42, 91, 92]. In addition, local staff working on dracunculiasis eradication were often made responsible for delivering other health programmes [6];

— enhance awareness of the reward. To be effective, the reward scheme needs to be widely publicized [47]. Awareness-raising may yield information on alleged cases of dracunculiasis from all sources, recorded by the programme as ‘rumours’. In areas believed to be free of dracunculiasis transmission, investigation of ‘rumours’ of dracunculiasis cases resulted in the detection of cases and isolated foci of transmission [93]. In the absence of a surrogate marker for dracunculiasis surveillance, like the acute flaccid paralysis for poliomyelitis, indicators for measuring dracunculiasis surveillance include awareness of the reward, recording and investigation of rumours within 24 h; and

— confirm every worm. Diagnosis of dracunculiasis is normally by visual means. However, not every worm is *D. medinensis* [94, 95]. In the last stage of the programme, when cases occur in isolation, worm specimens need to be confirmed by parasitological examination and if required by polymerase chain reaction. Excluding a lone dracunculiasis case on clinical grounds and not taking any follow-up measure can result in continued transmission. On the other hand, continued implementation of interventions when the case is not of true dracunculiasis is equally problematic. Both situations have damaging programmatic and financial implications.

(c) **Role of primary healthcare**

The launch of the dracunculiasis eradication programmes in the 1980s coincided with the emergence of the ‘health for all’ primary healthcare initiative in many developing countries [96]. The relationship of the dracunculiasis eradication programme with the health services differs from one country to the other and has evolved over time. This relationship has been affected not only by the eradication stages (endemic, pre-certification, post-certification) of a country but also by the availability of the primary healthcare network and healthcare reforms initiated by countries. A commonality of dracunculiasis eradication programmes in affected countries has been working within or in close liaison with the healthcare system. In most endemic countries, the programme was operated with the national level providing overall strategic guidance, regular monitoring and evaluation, whereas all interventions were implemented and managed by the primary healthcare system with its outreach services under the supervision of the district and state (provincial or regional) administration. However, in some countries, the limited capacity of the primary healthcare system and its outreach prevented the optimum implementation of the necessary interventions to eradicate the disease. Community participation was crucial to success; community-based volunteers were used to strengthen implementation of activities and achieve the desired impact. To ensure regular supervision and motivation of volunteers and to collect information, the programme recruited additional personnel both locally and internationally. Where healthcare infrastructure was severely limited, CBS networks directed at endemic or at-risk communities were largely controlled and managed directly by a secretariat at the national level with varying levels of interaction and liaison at provincial and district levels. When such direct support and additional resources are withdrawn from areas that achieve interruption of transmission, the responsibility of dracunculiasis surveillance shifts to the district primary healthcare system, which may not be able to assume this additional responsibility and needs therefore to be oriented, trained and motivated to do so.

(d) **Local politics in the installation of improved water sources**

Endemic communities are prioritized for access to improved water sources. However, local politics and communities’ perceptions and values may differ and influence the choice and site of installation of improved water points in the area. Creating community awareness and ownership was key in many communities in the installation of the water points and their subsequent maintenance. It allowed more equitable access and prevented the concentration of improved water sources in one area only (usually in the vicinity of an influential individual such as the village head) or in areas that may not be accessible to communities during the rainy season due to flooding. Installation of new improved sources may not always be enough; ensuring that sources remain functional throughout the year continues to be a challenge. Efforts have been made to train local labourers in the repair and maintenance of the hand pumps, or management by the communities themselves.

(e) **Sustain and report programme effectiveness**

To ensure continued programme effectiveness, it is important to regularly measure the operational indicators and their impact. Standard operational indicators are used in all national programmes to monitor and regularly report to higher levels. National Task Forces set up by ministries of health review the progress of the programme and where necessary recommend corrective measures. In addition to the intrinsic monitoring of the programmes, periodic in-depth evaluations are carried out by independent national or international experts at the request of the ministries of health. The Indian Guinea Worm Eradication Programme commissioned seven independent evaluations between 1985 and 1999. Soon after the independent evaluation carried out in 2007, Ghana interrupted the transmission within 3 years. National programme managers or coordinators meet annually to report on their respective programmes and share experiences. The first national programme managers’ meeting was held in Brazzaville, Congo, on 25–28 March 1991. By 2013, a total of 17 such meetings had been held; the latest meeting took place in Ouagadougou, Burkina Faso on 9–12 April 2013.

Since March 1982, information about progress has been widely disseminated through an annual global progress report on dracunculiasis eradication. Progress reports and, since 2009,
updates on the monthly status of the disease are published in WHO’s Weekly Epidemiological Record. Since January 1983, the WHO Collaborating Centre for Research, Training and Eradication of Dracunculiasis at the United States Centers for Disease Control and Prevention issues a monthly memo on the Guinea Worm Wrap-Up to all programme managers and interested individuals and organizations. It analyses the dracunculiasis situation and the eradication interventions and outcomes. Since 2012, an annual progress report on dracunculiasis eradication is provided to the World Health Assembly.

7. Remaining challenges and future needs

The challenges that remain to be overcome in order to reach the goal of eradication and its ultimate certification are (i) to interrupt transmission at the earliest in the remaining foci and (ii) to maintain a level of optimal surveillance in the areas now free of dracunculiasis that continue to be at risk of importation of cases from endemic areas. Thus, the real challenge in interrupting transmission is confined to Chad, Ethiopia, Mali and South Sudan.

Appreciable progress has been achieved in the new Republic of South Sudan within a short span of time. The disease is largely confined to three main foci: Kajoera East, Kajoera North in Eastern Equatoria state and Gogrial East in Warrap state. However, because it harbours 96 per cent of the worldwide cases, the global goal of eradication is likely to depend on South Sudan. South Sudan needs to significantly improve its case containment rate to increase the current 49 per cent rate of decline in annual number of cases (figure 7) and to shorten the period needed to interrupt transmission. The poor surveillance and low level of case containment has resulted in a persistence of low grade transmission in Ethiopia. Of the four cases reported in 2012, two were not contained as they were either detected beyond 24 hours from the worm’s emergence or had reportedly entered a water source. It is not yet fully understood why cases occurred in Chad and certain areas (Macina district in Segou region and Djenne in Mopti region) of Mali as the localities where cases were reported in 2012 did not report any cases in the previous years nor was there a history of travel of the cases to known endemic localities. Moreover, the indigenous cases reported in 2012 could not recall all the drinking water sources after a year-long incubation period. To interrupt the transmission effectively, all sources of transmission need to be identified and interventions implemented; each case of worm emergence requires a thorough and detailed epidemiological investigation. This is further complicated as patients travel from place to place, especially nomadic populations, cattle herders or persons displaced due to conflicts. In some situations, the source of infection may remain unexplained for one or more years [47].

Insecurity is another major challenge faced by these programmes. Areas affected by conflicts prevent access by healthcare workers, thus impacting effective implementation of surveillance and containment measures. In 2012, the Malian Guinea Worm Eradication Programme was not fully operating in two provinces (Gao and Timbuktu), and was unable to carry out interventions in the region of Kidal. Surveillance was intensified in Burkina Faso, Mauritania and Niger in an effort to prevent the spread of infection and disease through the refugees fleeing the conflict areas into neighbouring states. The South Sudan programme also faces challenges due to episodic insecurity. Conflicts resulted in movement of population from Pibor to Ethiopia. The Ethiopian authorities are strengthening surveillance in the border areas.

Regular access to endemic areas remains a challenge due to poor road infrastructure and the vastness and remoteness of the area. In Chad, the transmission period coincides with the rainy season, and crossing the often-flooded Chari River poses a major hurdle to health workers. The South Sudan Guinea Worm Eradication Programme is facing similar constraints when reaching out to the endemic areas particularly during the rainy season. The collapse of a steel bridge in Kauto in Kajoera East County of Eastern Equatoria State in May 2012 broke down road communication affecting the movement of staff and supplies. Expensive transportation by air remains the only option.

The programmes have been addressing these issues by analysing the epidemiological data to forecast the risk areas spatially and temporally. By planning well in advance, resources for the interventions and trained volunteers and supervisors are put in place before the onset of the transmission season. Mobile and satellite phones remain the only communication channels when these areas are inaccessible.

Lack of access to improved drinking water still continues to affect the endemic communities. Eighty per cent (388/483) of the villages reporting cases in 2011 did not have a single source of improved drinking water [47]. Acceleration in the provision of improved water sources in the remaining endemic villages is required. Where unfavourable hydrogeological conditions are not conducive to bore wells despite several drilling attempts, innovative solutions are required to convert the water from the existing unsafe sources to safe water.

8. Conclusion

With a total of 542 cases reported in 2012, and the disease limited to foci in South Sudan, Chad, Mali and Ethiopia, the eradication of dracunculiasis is imminent. Challenges remain but can be overcome with an undiluted resolve from the concerned governments, partners and health workers. There is no scope for complacency. The threat to this achievement is limited to inaccessibility of endemic areas owing to insecurity and conflicts. The dracunculiasis eradication programme will leave a legacy of public-health goods in terms of access to improved drinking-water sources, improved surveillance and reduced school absenteeism or loss of income owing to incapacitation from the disease. Once eradicated, dracunculiasis will be the first parasitic disease of humans to have been wiped off the planet, and the first eradication campaign to have been conducted and successfully concluded without a vaccine or curative medicine.

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