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Schistosomiasis: An Assessment of Past Eradication as a Guide for Future Strategies in the People's Republic of China

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Abstract
Conservative estimates suggest that approximately 200 million people have schistosomiasis and 650 live in endemic areas and thus are at increased risk for contracting the infection (World Health Organization [WHO], 2007a). Of particular interest is that the prevalence of schistosomiasis in the People's Republic of China where, in spite of large governmental initiatives, it remains at concerning levels in some areas. Further, the rates of schistosomiasis infections are predicted to increase because of a decrease in the funds allotted to the effort, the ecological and social ramifications of large building projects, and the inability to sustain short-lived approaches to control the disease. As a result, re-emergence has occurred in some areas once considered under transmission control. This paper will explore past strategies implemented in China, examine factors that enabled Japan to successfully eradicate the disease and discuss some new approaches that could enable China to reach its ultimate goal of complete eradication of schistosomiasis.
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Background

Schistosomiasis is a parasitic infection that is estimated to affect 200 million people worldwide (World Health Organization [WHO], 2007a). Further, 650 million people live in endemic areas and thus are at increased risk of acquiring the infection (WHO, 2007a). Schistosomiasis has only recently received global recognition as a significant health burden. It is categorized as a neglected tropical disease which further demonstrates this lack of attention. However, China's Ministry of Health has made the eradication of schistosomiasis, particularly the S. japonicum species, a top priority over the past 50 years (Utzinger, Xiao-Nong, Ming-Gang, & Bergquist, 2005). However, in spite of China's efforts, schistosomiasis remains endemic in at least seven provinces (Hunan, Hubei, Jiangxi, Anhui, Yunnan, Sichuan, and Jiangsu) and there is evidence of re-emergence in areas once considered under control (Zhou, et al., 2007; Liang, Yang, Zhong, & Qiu, 2006). Data from 2000 estimated that the prevalence of the disease decreased significantly in China to 694,788 people (Zhou, et al., 2005). However, in 2003 prevalence increased to approximately 843,011 people infected (Zhou, et al., 2005). Notably, the latter date is after financial support from the World Bank had ended.

One important factor for this rise of schistosomiasis was the end of a financial loan provided by the World Bank. The World Bank Loan Project (WBLP) (1992 and 2001) lent approximately 71 million dollars that complemented approximately 82 million dollars from the Chinese government to be used to decrease the rates of schistosomiasis infections in China (Ross et al., 2001; Wag, L., Utzinger, & Xiao-Nong, 2008).

Another factor that has made eradication especially difficult is flooding that occurs approximately every 10 years which increases the incidence of schistosomiasis (National Oceanic and Atmospheric Administration, 1999). Flooding produces ecological changes that increase the habitat of the vector that transmits the disease to humans. Flooding stimulates a migration of people from the flooded endemic areas to non-endemic areas, bringing the infection along with them. It also increases individuals’ contact with the water which is a direct result of the flooding (Wu et al., 2006).

Another factor that has been predicted to increase the prevalence of schistosomiasis is the Three Gorges Dam, a highly controversial hydropower dam building project on the Yangzi River. Expected to be completed in 2009, it is intended to serve many purposes such as preventing flooding, decreasing air pollution, and creating a renewable energy source that can support economic growth (Yardley, 2007). However, this is at the expense of other potential problems such as possible environmental pollution, the displacement of 1.13 million people, and the possibility of large landslides (Yang, 2007). As a result of the migration, and environmental changes, several studies predict an increase in the prevalence of schistosomiasis (Li, Y., Zhao, Z., Ellis, M., & McManus, D., 2007).

Schistosomiasis and Transmission

In order to develop a strategy towards schistosomiasis eradication it is important to have a basic understanding about the disease especially in respect to the mode of transmission. Schistosomiasis is caused by a parasitic worm that infects animal hosts including humans. The infected hosts are often asymptomatic but some may experience a rash, fever, and/or chills soon after the infection (Center for Disease Control [CDC], 2008). If untreated, chronic symptoms include malnutrition, anemia, and damage to liver, lungs, intestine, and bladder (CDC, 2008). Schistosomiasis enters through the skin of a human or another animal in a contaminated water source. Once it travels through the skin barrier it travels through blood stream, matures throughout its journey and eventually lays eggs primarily near the small intestine where the eggs ultimately leave the bloodstream and enter the intestinal lumen (CDC, 2008). These eggs then exit in the feces where, if disposed of inappropriately near a water source, they can hatch and attach to a water snail upon which they develop and then ultimately leave in search of another animal host (CDC, 2008). Re-infection is possible and, in fact, is quite common, so this must be taken into account when developing an approach towards eradication (Zhou, Zhao, & Jiang, 2007). Because the infectious cycle is dependent upon the presence of the snails, schistosomiasis is a water-based disease and thus cases tend to be concentrated around large water sources. There are different strains of schistosomiasis specific to geographic regions and their pathogenic characteristics vary based on the strain (WHO, 2007a). Of importance, one primary strain found in China S. japonicum, continues to infect populations well into their 60s while the most other common strains mainly infect those 19 or younger (Jordan, & Webbe, 1993). This is significant when trying to tailor strategies towards the target population. Another unique feature of this strain is that animals other than humans are highly susceptible to this parasite and serve a significant role in transmission. It is estimated that in some areas transmissions from animals such as water buffalo is as high as 90% (Utzinger, Xiao-Nong, Ming-Gang, & Bergquist, 2005).

Evaluation of Past Approaches

An evaluation of China's eradication efforts over the past fifty years, as well as progress and research in other countries will shed some light on the most effective approaches. Figure 1 provides a very basic representation of the transmission cycle and highlights different potential targets that can be used in order to break the chain of transmission. Snail Hosts

One approach that has been utilized focuses on the snail component. A theoretical elimination of the snail host would break the transmission cycle by preventing the transmission from a contaminated source to snail host by removing the snail vector ("A" in Figure 1). However, manipulating the snails has been difficult to carry out. One of the problems is that snails have a high reproductive capability and if only a few snails survive, they can rapidly revive the snail population. While targeting the snails has been effective in decreasing the transmission of the disease to some extent, it must be a continual process or any gains will be rapidly surrendered. (Utzinger, Xiao-Nong, Ming-Gang, & Bergquist, 2005). To further complicate matters, molluscs, chemicals targeted against snails, are expensive, and difficult to employ (Ohmura, Iwanga, Nara, Matsuura & Yasunooka, 2003; Changsong et al., 2002). The purchase of molluscs has been one of main uses of the
funds distributed by the World Bank. The end of this funding will make it even harder to obtain the necessary amount of these agents to keep the snail population in check and consequently, a restoration of the snail population would be likely. Another important thing to note about molluscs is that they are toxic to animals, such as fish, that share the snail’s environment (Chinna et al., 2003). Further, while the issue is often not discussed, it is likely that the snails play a notable role in the local ecosystem, beyond being a host to the schistosomiasis larvae, and it is important to consider the potential ecological implications of eliminating the snail species entirely.

**Human Host**

Another widely used approach is treating those infected in order to prevent transmission (“C” in Figure 1). The drug Praziquantel is now considered the gold standard treatment supported by the WHO (WHO, 2008). At a mere 20 cents, it is relatively inexpensive for an average treatment with a low occurrence of side effects (WHO, 2008). It is important to note that the drug treats schistosomiasis, but it does not prevent future infections. Fortunately, only one dose annually has been shown to be enough to significantly decrease rates of transmission (Zhou, Zhao, & Jiang, 2007). This is especially important where mass chemotherapy campaigns are implemented. The general recommendation suggested by the WHO is to treat groups that are at increased risk in high endemic areas, such as school children and those with occupations in contact with potentially infected water, and to treat those in non-endemic or low endemic areas on a case-by-case basis (WHO, 2008). Much of the eradication effort world-wide appears to focus on school-based programs; such programs have been found to be highly successful (Yuan et al., 2008). Because Praziquantel is an oral agent, administration does not require the medical training and expertise of a skilled professional so the agent can be provided by teachers, utilizing the school systems already in place as the distribution system. However, unlike schistosomiasis in most other regions, the *S. japonicum* species which is predominant in China affects patients well into middle age. Thus, while using the school system to distribute the drug is an important approach, it will merely capture a fraction of the population at risk. This highlights the need for a more extensive and communal approach to medication distribution and education. During the period of the World Bank Loan Project, other methods such as pamphlets, and radio programs were used to help educate the public and raise awareness (Changsong et al., 2002). However a study by Li, He, Zeng, and McMannus (2003), notably after the large educational campaign, indicated that schistosomiasis infections were being missed in fishermen. Sixty nine point eight percent of those in the study tested positive for schistosomiasis and 26% had never been treated. This highlights the need for new approaches to reach high risk populations.

**Animal Host**

Because animals such as water buffalo and oxen are a huge component of the lifecycle of the organism, treating livestock with anthelmintic drugs is a major strategy in early transmission. Unfortunately, other animal hosts have a greater rate of re-infection than humans (Wang et al., 2006). Consequently, to be effective this approach would require more frequent courses than the annual recommendation for humans.

**Education**

Education plays a significant role in limiting transmission by encouraging regular screenings and medication compliance (Yuan et al., 2008). In addition education can help prevent transmission by teaching the population about prevention of human and animal fecal contamination of water sources, and methods to prevent infection. Such methods have been successful in China (Chen and B in Figure 1.2). The study by Hu et al. (2005) demonstrated both the short and long-term success in the effects of education in a 12-year intervention study on compliance and incidences of re-infection. However, again, the same issue arises of how to reach not only those in schools, but the community as a whole, especially those at particularly high risk such as fishermen and farmers.

**Sanitation and Environment**

The final method that needs to be discussed is perhaps one of the most important: sanitation and habitat change. These areas were, however, not a major focus of the initiative funded by the World Bank Loan Project (Changsong et al., 2002). While this is probably the most expensive type of intervention in the short-term, the long-term benefits would likely surpass the costs as these interventions would not only target schistosomiasis, but would also help in the fight against other water-related diseases. It is estimated that 95,600 deaths can be attributed to poor hygiene, poor water source, and sanitation in China (WHO, 2007b). It is important to note that this estimate only includes deaths and does not number people infected. Most recent data collected by WHO in 2006 found that in China only 65.0% of the population has access to improved sanitation (WHOIS, 2006a). This highlights an important area for improvement.

**Case Study of Effective Eradication: Japan**

Japan is similar to China in that the same species of schistosomiasis (*S. japonicum*) is predominant and has similar environmental factors contributing to the prevalence of the disease. However, Japan successfully eradicated schistosomiasis in 1996 (Ebisawa, 1998). Japan used approaches such as changing agricultural methods, education, eliminating the snail’s habitat by turning marshlands into playgrounds, using molluscides, while clearing the sides of waterways, which is where the snails hibernate in the winter (Ebisawa, 1998). It is interesting to note that while there still are snails in the rice fields, they do not appear to be transmitting schistosomiasis (Ebisawa, 1998). In comparing Japan’s and China’s efforts, it appears that China’s primary approach focused on education, mass-chemotherapy, and the use of molluscides, while Japan placed very little emphasis on decreasing in the snail habitat or cementing the waterways (Changsong et al. 2002). China, having focused on killing the snails has proven only temporally effective and unsustainable without sufficient funds, the prevalence of the disease once again increased (Changsong et al., 2002). Japan, on the other hand, adopted the more sustainable, and ultimately successful, approach of eliminating the snail’s habitat.

**Recommendations for Future Interventions**

Lessons from the past suggest that rather than a program directed at one specific vulnerable part of infectious cycle, the most effective approach would be a coordinated effort aimed at multiple different targets within the cycle. Moreover, the weaknesses of past approaches must be addressed and the strategy must be modified in order to prevent further re-emergence, control the spread and to eventually eradicate the disease.

**Funding**

Finances appear to be a significant limiting factor in the methods used for schistosomiasis eradication. Given decreased financial funds due to the termination of the World Bank Loan Project, the goal should be not only to restore the necessary financing, but also to prioritize efforts so that the financing available is used efficiently. According to the WHO (World Health Organization Statistical Information System [WHO/SIS], 2006b), the Chinese government’s total expenditure on schistosomiasis was 9.9% out of the whole governmental budget in 2006. Japan, on the other hand, spent almost twice that amount, as a percent of total expenditures, and in 2006 17% of their government funds went to healthcare. This focus on health might have played a role in Japan’s success. According to data in 2007, China has the second highest health expenditures in the world (Central Intelligence Agency Fact Book, 2008). Thus even a small percentage increase could have great potential in improving the health status of the population. As discussed earlier, China is currently finishing the Three Gorges Dam hydroelectric project. The project has attracted much controversy especially due to the significant social, ecological and health ramifications (Yardley, 2007). Thus, this seems like an opportune time to apply political pressure on China so that more funding could be allocated towards healthcare and sanitation. Data from WHO in 2006 indicates...
perhaps the most important step. This decision should be a combined effort of groups such as the Ministry of Health in China, environmental organizations, schistosomiasis researchers, sanitation organizations, zoontic disease specialists, as well as other health policy organizations. While schistosomiasis is but one of the many health concerns facing many of the people in China, much of this money should be devoted towards more sustainable, longer-term efforts directed at improving the sanitation infrastructure which would, in turn, help eliminate numerous health problems. Such focuses should include developing proper sanitation and sewage infrastructure, thereby breaking the cycle of infection by separating the source of drinking and bathing water from both human and human-defeating. Filling in unused marshes will decrease not only the population of snails that are involved in the transmission of schistosomiasis but also other water-related illnesses and vectors which transmit 
diseases. Additionally, perhaps more specific to schistosomiasis, lining the waterways with concrete was an especially efficient and effective way to eradicate schistosomiasis in Japan to decrease transmission of schistosomiasis (Ebisawa, 1998). These larger societal efforts take longer to implement and are rather expensive, however they would ultimately be quite effective. Community-Specific Interventions

While it is important to approach the problem from the top, it is also important to tackle the problem locally. However, in order to be most effective, the methods have to be tailored specifically to each region. Thus, instead of just developing one standardized community-based plan, it would be important to have some initial assessment by a team of experts. This team would include public health advisors, researchers, zoontic disease specialists, veterinarians, and ecologists. This committee would visit the particular region of interest in order to fully understand the living conditions and the current state of health in the area. Issues such as sanitation, health care access, geography, and social features of the community would be assessed. In addition, this team should have discussions with local governments as well as actual members of the community in order to accurately assess the problem and develop realistic approaches. For example, if there is a center of town perhaps this should be the place to start an educational initiative. It may be necessary to build some form of healthcare center in order to have a rudimentary infrastructure for screening and antihelminthic administration. The team assessment would serve a secondary purpose: it would identify the problem and help empower the community. Finally, the decisions processes of this committee would need to be transparent to the community so that community members are aware of the current suggestions made by the committee.

As discussed earlier, education is difficult especially in regions outside of the educational infrastructure. During the World Bank Loan Project there were mass education campaigns that included pamphlets, advertisements, television and movies (Wang, L., Utzinger, & Xiao-Nong, 2008). Finances must continue to be used to disseminate information. As the Chinese government has its own television program this would be an easy and inexpensive way to spread information about the disease (Central Intelligence Agency Fact Book, 2006). However, studies have shown that some groups are still not being captured by such programs. As mentioned previously, fishermen, who are already at increased risk of acquiring the disease, are also less likely to be exposed to information disseminated through the television or through the land-based school systems. Thus, additional methods need to be utilized. There needs to be some parallel infrastructure to that provided in schools. This would have to be community-specific interventions based on the findings of the collaborative group. One approach is for the government to sponsor and subsidize a fencing initiative targeting community members. While creating jobs for some, by keeping livestock from the waterways, it would also create one relatively easy way to reduce animal fecal contamination in the water source. This would not require a significant change in the culture or methods of the local farmers but would nonetheless prevent further contamination of water and thus the spread of disease. The water can be filtered and thus the fencing materials could also provide basic information about schistosomiasis and how to detect and prevent spread of infection. While this may seem odd at first, it is not much different from the way that such information is disseminated by teachers at schools. It may be a little more difficult to target education towards fishermen as they are a migrant group but areas they are found and their habits must be analyzed to determine the best approach for education and treatment.

Anthelminthic agents have been shown to decrease transmission rates. However, using this method alone has not been shown to be effective (Zhou, Zhao, & Jiang, 2007). As discussed previously, drug use in Japan had not relied on anthelminthics in order to achieve successful eradication. While it might not lead to eradication from a public health vantage point, it does help reduce the number of cases. Also, from a clinical and humane standpoint, it is still important to treat the infected individual. Whether to do mass chemotherapy campaigns or screen and then treat only those infected is a different issue. In the most ideal world with infinite resources, a very extensive healthcare system, a highly knowledgeable and health conscious population, with adequate time to visit healthcare providers regularly, each patient would get tested on a case by case basis. A study by Yu et al. (2002) tested three non-medicinal therapeutic methods (screen and provide medication, provide medication to those with high contact to contaminated water, and mass chemotherapy) in three different endemic areas in China and found mass chemotherapy to be the most cost-effective in high endemic regions as well as the most effective in preventing infection, and liver and spinal abnormalities. This method requires community education which has been shown to increase compliance, and a mechanism to deliver the medication through a school or clinic, for example, depending on the individual community. Money that is saved using this mass chemotherapy

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method in high prevalence regions can be redirected towards the more sustainable efforts mentioned previously.

Molluscides are generally regarded highly as a strategy to help prevent infection and many have thought that they contributed to Japan’s success (Ibisawa, 1998). While this approach is important, given finite resources this might not be the most efficient way to eradicate the disease. Because the significant cost and difficulty in distributing the molluscides, and due to their potential to harm the environment, they should be put on the bottom of the list of priorities. In China, molluscides have helped to temporally control rates of transmission of schistosomiasis as this was a large part of a World Bank program. However the snails came back which indicates that perhaps more long term approaches will be cost effective in the long run.

Research

China has produced extensive research on schistosomiasis and such data is critical in determining how to move forward. The government, as well as other organizations that focus on neglected diseases, need to continue this effort. One promising area that needs adequate funding is that of vaccine development.

Many argue that long-term eradication in China is unlikely, if not impossible, without the creation of a vaccine. No vaccines are currently being used on a large scale, and there is one that may be used on animals with some success (WHO, 2008). The Chinese government and the global community at large need to help support this research. This can be done through media awareness and financial support. This is particularly important because the disease is mainly endemic in poorer areas and thus it is not seen as profitable for biotechnology and pharmaceutical firms.

Unlike the oral treatment, this could provide long-term protection which would prevent both initial infection and subsequent re-infection. However, vaccines carry their own set of problems including side effects. With any new drug it is important that the safety is established. Even with a safe drug, dissemination, which is already difficult, would be an even greater issue. Unlike the case of providing an oral medication, if this vaccine is not oral it would require a skilled profession to administer it. Also, focusing solely on vaccines as the panacea may lead some to lose sight of the underlying issue of sanitation and basic healthcare.

Surveillance and Evaluation Methods

No single approach involves using satellites to determine the prevalence of the snails, which, in turn, is proportional to the prevalence of schistosomiasis (Yang et al., 2008). In addition, the prevalence of the disorder can be determined by testing animals at risk for infection by the snail vector. This method, however, relies on access to reliable information which would be an issue that the committee discussed earlier would have to address. Government or study incentives can be used to get people to come to the clinic to be tested. Prevalence findings need to go to some overseeing group that can provide feedback along the way. This can be another role of the committee, or could be reported to the hospital. Through evaluation, transmission transcends mere prevalence numbers. The multidisciplinary committee should also conduct follow-up visits to the endemic regions where they can assess the progress of the program and make appropriate modifications.

Conclusion

Reviewing past approaches to the treatment and prevention of schistosomiasis can help provide insight into the most effective and efficient way for China to proceed in its efforts for schistosomiasis elimination. It is rather evident from the recent literature that while a single approach could help reduce rates of schistosomiasis, for true maintainable eradication, a multi-pronged approach must be adopted. Such approach must address both the short-term goal of treatment and the longer term goal of transmission prevention. This paper provides some new ideas in conjunction with modifications of old strategies in order to achieve this goal. Hopefully such a multi-pronged approach would ultimately enable sustainable eradication of schistosomiasis throughout all regions of China.

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Experiences Abroad
Honduras
Julia Borgi

I spent the summer at a hospital in a village in Honduras, learning firsthand how trust building and relationships between nurses and community members are necessary for effective health promotion and positive patient outcomes. I worked with an American women’s health nurse practitioner and two registered nurses to provide prenatal care at village clinics in the mountains and surrounding areas, routine gynecological care in the hospital and rural clinics, and home visits to families who have a child with a disability. Honduras is one of the poorest countries in the Western Hemisphere, and while there are public hospitals in the cities and small health clinics in rural areas, from what I observed these clinic facilities are under-staffed and provide little more than immunizations, malaria drugs, and worm pills to the population. The hospital, doctors, and nurses I was affiliated with are part of a non-profit Christian organization, but because of the current Honduran political situation I unfortunately cannot acknowledge them by name. All of the health providers speak Spanish, although many are from the U.S. Primary care visits are emphasized, and surgery and inpatient care are available for adults and children who are acutely ill or injured. Although it receives no public funds, the hospital I was at provides essential services at little or no cost to people who otherwise have extremely limited access to health care. The newest public hospital is over an hour away, by vehicle on an unpaved road, and few people have cars so transportation is by foot, bus, motorcycle, or piling into the back of a pickup truck.

The Central American culture of birth is rooted in superstitious beliefs and cultural practices. Some of the pregnant women I encountered would not let anyone know their due date for fear that another woman might put a spell on the labor to wrap the cord around the baby’s neck, killing him. Labor and delivery occur in the home without modern technology or anesthesia, and a traditional birth attendant is present to deliver the baby. These women learn how to attend births by working with another birth attendant, and there is no science-based medical component to their training or practice. Pregnancy complications that are easily being managed in the U.S. can be lethal for a baby or mother in Honduras, because of the lack of access to obstetric care for a medically trained individual. Tragically, the nurses I was with had never heard of a situation where a fetus that was positioned breech was born alive, in the hands of a traditional birth attendant. One of the main goals of the women’s health program begun by the American nurses is to gain trust in the communities, normalizing the idea of private medical care and affording the opportunity for early detection of pregnancy complications which can turn deadly during labor and delivery, like preeclampsia and malpresentation of the fetus. The nurses do not encourage any woman to deliver in a hospital, unless she is medically “high risk,” so in this way home birth traditions may still be safely embraced as long as the woman and baby are healthy.

The nurses I worked with were initially met with some suspicion as they started the women’s health program, but as I participated with them I was struck by their emphasis on building relationships with members of the community. It takes years of commitment and patience. They are deeply involved with spiritual life in the community, attending and participating in a church in a nearby town. One of the nurses is married to a local man and is very involved with her children’s education in the public schools, in addition to her work with the hospital. Because Honduran culture