Angiostrongylus cantonensis, Rat lungworm (RLW) in East Maui

By Chad Meyer, MD May 8, 2017

Fortunately dengue virus did not become established in east Maui as a result of the 2001 dengue fever outbreak. Effective interventions included community responses to decrease mosquito breeding sites, and a vigorous campaign by local public health personnel and resources from CDC Atlanta and Puerto Rico. It is also worth noting that dengue fever outbreaks generally occur in crowded urban settings and that rural conditions in east Maui were in our favor.

RLWorm is different. It is a zoonotic disease - a biologic process maintained in animal populations, but with the potential for "spill over" into human outbreaks. The zoonotic cycle associated with rat lung worm involves a roundworm parasite (Angiostrongylus), a definitive host (a rat species), and an intermediate host (snail species). Once this zoonotic cycle is established in an area, it is extremely difficult, if not impossible to eradicate. This is the current situation in East Maui and parts of Hawaii Island; efforts instead should focus on effective control directed at reducing population densities of rats and snails, and their contact with humans.

The current RLW outbreak has several basic components: Snails, rats, roundworms.

Additionally, human activities have driven the evolving emerging disease epidemic. Snails have been exported from native habitats as new food items (escargot) and aquarium pets. Some have claimed that the the Giant African Snail (first reported in China 1931) was responsible for introducing RLW into southern China. Regardless of its origin, RLW infected rats from southern China and SE Asia have spread the worm via cargo ships throughout the Pacific basin and beyond.

"Angio-stron-g-ylus" is a roundworm - other members of this phylum include the parasites ascaris, hookworm, pinworm, filaria (human filariasis), Dirofilaria (dog heartworm), and Trichinella (trichinosis from undercooked pork), as well as thousands of marine, freshwater, and terrestrial species. The complete Angiostrongylus **life cycle requires five larval molts** (two in the snail and three in the rat).

Adult male and female worms inhabit and reproduce in the rat's pulmonary arteries. The eggs hatch into **L1** larvae move through the air sacks (alveoli) in the lung, then ascend the wind pipe (trachea) and enter the esophagus; from here they passage the intestine and are excreted in rat poop. Snails become infected when passing through rat feces, and additional molts **(L2 and L3**) occur in the snail. The **L3** larvae in the snail are infectious for rats, and for dog, cats, and many other species including humans. It is important to note this is the only larval stage infectious for humans. In the zoonotic cycle, a rat eats the snail and the **L3** larvae move from the rat intestine and via blood circulation take up residence in the brain where **L4** and **L5** molts occur.

After **L5** the worm is now a mature adult (male or female) and becomes established in the rat's pulmonary artery - reproduction and eggs follow, and the cycle is complete - the rat, subject to repeated snail exposures and reinfection cycles will excrete larvae infective for slugs (not animals and humans) for the rest of its life. Persons infected with Angiostrongylus do not excrete **L5** larvae in stools and person to person transmission does not occur. Humans, like dogs, cats, and many other mammals (exception rodents) are called "dead end hosts" because the worm fails to complete its life cycle. Infection stops in the brain - rare or no infection in the pulmonary artery, no intestinal infection, no way of passing on the parasite. Important, to note, the RLW parasite cannot be passed on from person to person, or from an infected dog or cat.

Snails

David Baldwin's collection of Hawaiian snails in the late 1800's contained 1144 land snails. Later counts put the number at 750, still a remarkable example of radial evolution. Four species of introduced snails have displaced native snails and are predominantly responsible for recent Hawaiian outbreaks of RLW disease. Consider the following time line.

Giant African Snail
(Lissachatina fulica), native East Africa (Kenya, Tanzania), introduced Hawaii 1936

Cuban
(Veronicella cubensis) native Cuba, introduced Hawaii 1985

Apple snail
(4 separate species, Pomacea canaliculata biggest problem this group), native South America, intro Taiwan, then Philippines, then Hawaii 1989

Semislug
(Parmarion martensi) presumed native SE Asia, introduced Oahu1996, H Island 2004, Maui (recent 1-2 yrs).

Semislug
(Parmarion martensi)
Above: Gloved thumb at left of image for scale.
Below: Group of Semislugs with cluster of eggs.

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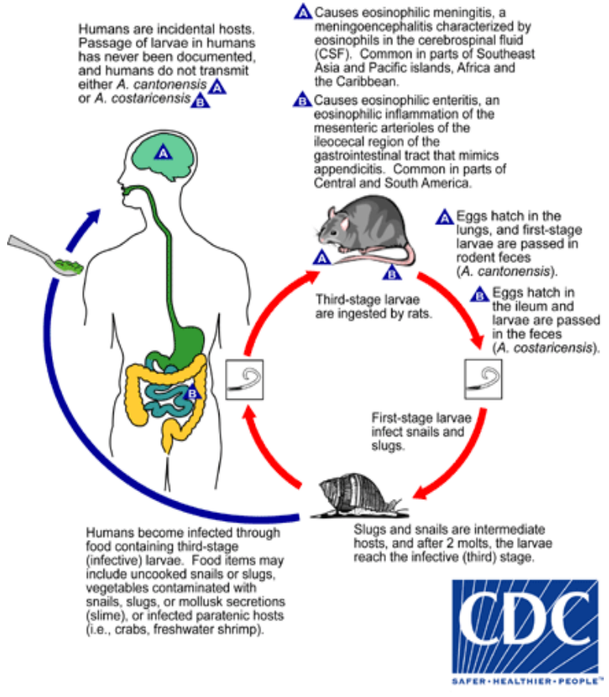
Snails have been relocated into non-native environments worldwide, primarily as intended new food sources (escargot), and as aquarium pets. Unique species characteristics drive their impact in non-native locations. Apple snails prefer slow moving fresh water. Their introduction has dramatically affected crop yields in rice and taro cultivation. They have been a nuisance for our taro farms since 1989. A comprehensive review of their introduction, effects on wet taro, and attempts at control are available on line and highly recommended for anyone interested in this subject at:

• Statewide strategic control plan for apple snail (Pomacea canaliculata) in Hawaii (Levin 2006) (182 pp.; 8,455 kb*)

http://www.hear.org/articles/pdfs/applesnailcontrolplanlevin2006.pdf

Outbreaks of RLW disease on Hawaii Island and Maui have both followed introduction of Parmarion, suggesting this is driving recent human infections. The semislug Parmarion has unique behavior that is important to understand and incorporate in control. Where the apple snail inhabits taro fields, and the cuban snail frequents home gardens, Parmarion is "peri-domestic." It will invade trash containers, climb house walls, get into pet foods left outdoors, and climb on decks and balconies in search of fruit. It is also described as "polyphagous," has a wide diet. In addition, studies on Hawaii Island have shown 75% Parmarion samples positive for RLW compared to 25% for the cuban snail, and it also appears to have higher concentrations of the worm, or "worm burden." All of this makes Parmarion a highly "efficient vector" for RLW, and danger for infection. Complete elimination of this snail is unlikely, but effective control measures can reduce its numbers and reduce risk of contact.



Rodents

Rats frequently become infected with RLW. Field studies on Hawaii Island showed greater than 90% of rat populations infected, and having high levels of parasites in their skat.. Rats commonly have multiple snail exposures essentially becoming infectious for life. As a consequence rats are called "amplifier hosts," ---greatly increasing the risk of disease spread, and need to be part of intervention strategies.

Human Infection

Most human infections occur when a whole snail is eaten - either by accident or drunken dare, or when escargot is not properly prepared. Juvenile forms of Parmarion can have high parasite loads and be infectious. In addition to being small, they can be translucent and difficult to spot. Please refer to a complete list of safe food processing available through community educational materials. Essentially no dip solution kills or removes RLW. Accepted recommendations include hand washing of each piece of fresh produce (example lettuce) under a stream of water, including close visual inspection of all sides of the produce. Case histories of recent infection suggest kale may be a high risk food. Spotting small juvenile snails or semislugs on the irregular and dark surface of kale is more challenging than for lettuce.

The course of the infection in humans is similar to other mammals - intestinal absorption followed by transit to the brain, but the life cycle stops in the brain - no significant infection in the pulmonary artery, no intestinal infection, and no way of passing on the parasite. RLW infection in humans is said to usually be mild with only a minority of exposed individuals getting very sick. Medical literature repeatedly states that less than 1-2 % of those infected have severe illness. However, this has never been demonstrated in Hawaii and may not be true for recent outbreaks. This needs to be studied now with seroprevalence (blood antibody tests) in east Maui and Hawaii Island.

It is believed that most of the symptoms in humans result from the body's robust immune response --- we throw eosinophils and cytokines at this big organism (think monster big compared to a bacterium), and there is much collateral, friendly fire damage. Immune suppression (prednisone, prednisolone, and similar steroid Rx) has been reported to reduce headache and other symptoms (Cochrane Literature Review, Sikawat Feb 2015). In addition, the antiparasitic drugs, albendazole and mebendazole may prevent infection if used as an Emergency antiparasitic treatment immediately after a known but accidental exposure -- worm eating. This has not been reported in the medical literature, but would seem a reasonable intervention based on knowledge of infection course and medication pharmacology. However, these two drugs are Class C in pregnancy, and "may have fetal effects," so this needs to be considered before use as emergency treatment. Use of albendazole and mebendazole in treatment along with anti-inflamatory medications after symptom onset is controversial. Literature commonly states concern that their use may worsen the damage by increasing immune response to dying worms. This needs to be further studied.

Recovery-convalescence can take 4-6 months, and in severe cases residual problems may be permanent, particularly muscle strength and mobility. Memory and mental function usually are generally spared. Usual symptoms include severe and prolonged headaches, tingling sensation and muscle and body pains that move from one region to another, hypersensitivity of the skin (irritation with light touch or even breezes - if occurs is very characteristic of RLW). Fever is not that common and when present generally is not high. In more severe cases stiff neck can occur suggesting meningitis. Nausea, and abdominal pain occasionally occur. Sensitivity to light is also common.

Community Interventions

We need to develop a COMMUNITY PLAN

1. We need to recognize this will be different from dengue where the virus was successfully eliminated. Angiostrongylus is here to stay. It is incorporated in the zoonotic cycle of rats and a number of species of snails. Instead of elimination, we need to develop effective interventions that prevent human exposure to the parasite, and that allow us to continue a cultural life style that includes home gardening and a rural life style.

2. An understanding of snail life cycles and behavior can be helpful. A considerable body of snail information is available in scientific and agricultural literature online. For example, it is recognized that the cuban snail prefers garden habitats where it will forage on leafy plants. Parmarion prefers domestic areas, including trash containers, walls and drain pipes, catchment systems, outdoor animal food containers, and fruits left on decks and railings. Environmental steps around homes can greatly reduce Parmarion contacts --- don't leave pet food containers outdoors, particularly at night when snails are active, avoid storing produce and foods in outdoor areas exposed to snails.

3. A snail survey should demonstrate areas where Parmarion is becoming established. Prioritizing efforts directed at these areas may serve to contain further geographic spread.

4. Validation studies are urgently needed to confirm Alicata's 1967 work which showed a 24 hour freeze effectively killed Angiostrongylus infective **L3** stage larvae. Freezing as a readily available, simple intervention would greatly enhance food safety.

5. Water storage and catchment tank safety.
A comprehensive discussion is too lengthy for this article and needs to be addressed separately. The following components need to be addressed. Catchment systems need to be designed and maintained in order to assure safe potable water. The Rat Lung Worm **L3** larvae is larger than giardia and cryptosporidium cysts --- other pathogens that need to be excluded from potable water. Giardia and cryptosporidium cyst are 4-6 microns, and RLW **L3** larva (infective stage for humans) are 26-34 microns wide by 420 - 520 microns in length (Diagnostic morphology of 3rd stage larvae of Angiostrongylus..., *LR Ash, Journal of Parasitology, 1970*.

When installing an effective catchment system it makes sense to use a final "absolute 1 micron" filter which will effectively remove giardia, cryptosporidia, and RLW. Note: a "mean 1 micron" filter which may have pores greater than 1 micron should not be used.

A typical recommended system incorporates a series of 3 filters (25-5-1 micros). In addition a pre-filter or "Y filter" in front of the first 25 micron filter --- inexpensive and as a prescreen decreases the debris load to the more expensive 25-5-1 filters. Other designs may be appropriate and further discussions of this topic are encouraged.

Additional catchment tank issues include:
• maintaining vegetation clear space around the tank base
• tank covers need to rest securely over the top edge of the tank with no tears in the mesh. Inspect for anything compromising the seal of the cover to the tank top edge. A 1/8" aircraft cable with turnbuckles applied circumferentially can further secure the cover to the tank wall.
• copper tape zones around tank circumference will prevent snail ascent. If this is done metal tanks need a layer of insulation with a peel and stick insulator between the copper and actual tank wall to prevent metal conduction and corrosion
• a debris screen between the roof gutters and tank is recommended
• placing a stainless steel or noncorrosive screen over the overflow pipe will prevent snails crawling back up the pipe.
• finally, this seems intuitively obvious, herbicides such as Round-up are best not used around water tanks as weed control.

Additional tank safety reccomendations available upon request:
Eco Products Maui | ecoproductsmaui.com | chris@ecoproductsmaui.com

6. Agricultural interventions
As a farming and gardening community we need to study how best to control snails - what field modifications work best, are easiest to maintain, and economical. Everything is up for study for what works best in east Maui's tropical habitat - dry border areas around garden plots, the use of lime and copper in perimeter areas, drip irrigation, home gardens using potted plants on garden tables (copper strips around the table legs to prevent snail ascent), animal predators - chickens, ducks, baited traps for both snails and rats (simple placement in PVC piping prevents harm to birds and domestic animals).

7. Safe food selection
We should include determining which types of foods are safest and least affected by snails - for example, onion, leeks, oregano and arugula seem to be outside the snail menu, and can be incorporated into healthy and nutritious salads. Many garden and commercial agricultural products may be grown in snail-free environments and be easily inspected. Foods such a poi are rendered safe by heat and pressure used in processing taro.

8. Collaboration and investigation studies
East Maui needs to collaborate with Hawaii Island communities that have been attempting interventions since 2005. They have developed public health initiatives, school projects, and food safety programs that we can draw on. The U of H Hilo School of Pharmacy has developed lab based studies using quantitative PCR molecular diagnostics that we can use for testing infection rates in snails and rats. They also have similar testing for human blood which would enable us to do "seroprevalence studies" from east Maui. This would involve blood sampling from Maui risk groups, checking for Angiostrongylus antibodies. The information would provide better understanding of risk (farmers and gardeners), and of the number of "mildly infected" - if it exists.

The east Maui community has a remarkable resource pool - farmers, gardeners, educators, communicators, and researchers. Controlling RLW will be challenging, but it is our kuleana to effectively respond. For generations indigenous Hawaiian farmers were effective scientists. They closely observed the aina, held it with respect as a sacred gift, tested growing practices, selected plants for eating and medicine. Our generation must do the same:

• Gardeners working together studying snail behavior, discovering the most effective control measures.
• safety modifications for flower and agricultural workers
• determining safest foods for cultivation and eating
• working with other affected communities (Hawaii Island)
• snail and rat studies (population levels, infection rates, control interventions)