PST PEDIATRIC SURGERY IN TROPICS

Pediatric Surgery in Tropics
2024 (Oct-Dec); Volume 1, Issue 4: Pages 216-248
DOI: 10.5281/zenodo.13893347

Tropical Surgery Review

Maggot Infestation (Myiasis) in Children

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Keywords
Fly larva
Ivermectin
Maggot therapy
Myiasis (Myasis)
Turpentine
Parasitic infestation
Wound healing

Abbreviations
AMP - Adenosine mono-phosphate
ASEM - Alimentary secretions and excretions of maggots
ENT - Ear-nose-throat
MMP - Matrix metallo-proteinase
MM - Medicinal maggots
MT - Maggot therapy
WM - Wound myiasis

Abstract

Myiasis (myasis) is a parasitic infestation of fly (diptera) larvae. Maggots are both a pest and a therapeutic agent. Ayurvedic surgeons of ancient India (2000-600 BCE) have described Krimi-Karna (aural myiasis) and Krimija-Siroroga (nasal myiasis). They also used maggot therapy (MT) to heal wounds (Krimi Upattikara Chikitsa).

About 95% of pediatric myiasis is due to 80 species of flies belonging to 4 major categories: blowflies, flesh flies, botflies and house flies. Hence, myiasis is not one disease; but a group of diseases caused by various dipteran larvae. Cochliomyia, Chrysomya and Wohlfahrtia are the 3 important deadly maggots.

Myiasis is common in those who live in unhygienic environments or those who are unable to care for themselves. No age is immune and the youngest patient was a 1-day-old newborn. Virtually all body parts are affected with more frequent involvement of the intact skin, superficial wounds, body orifices and umbilical cord.

The diagnosis of surface myiasis is straightforward. Doppler ultrasound showing a hyperechoic wavy spindle-shaped shadow writhing in a hypoechoic tunnel (Bouer's criteria) is pathognomonic of maggots hidden in deeper tissues. Exact species identification is desirable, though it is not essential for the clinical management of myiasis. Retrieved maggots should be fixed in 70% alcohol rather than in formalin for entomological examination.

All infestation with wild maggots should be considered as a disease and treated by manual removal. Left over dead or ruptured maggots may evoke more troublesome inflammatory reaction than live maggots. Vermifuges (turpentine) Larvicides (ivermectin), asphyxiants (mineral oil), baits (bacon) and paralyzers (lignocaine, ether) are commonly used in the treatment of myiasis.

Laboratory cultured medicinal maggots are used to promote wound healing by debridement, disinfection and cellular proliferation. Current pediatric experience with MT is limited to anecdotal case reports. Some of the recent randomized controlled trials question the claimed benefits of MT.

INTRODUCTION

Parasitic infestation in which Dipterous larvae (maggots) spend a part of their life cycle in vertebrate (human or animal) host is called myiasis.[1] Diptera are two-winged insects, commonly known as flies (Greek: *Di* - two; *Ptera* - wings). This definition differentiates myiasis from the larval infestation of other insects (e.g. scabies, lice) and nematodes (e.g. ascariasis). The economic impact of maggot infestation in livestock is tremendous as they cost billions of dollars annually by affecting the yield and quality of milk, meat and leather.[2] But the actual impact of human infestation has not been well studied. Myiasis remains a neglected zoonosis.[3]

Myiasis is frequently misconstrued as a disease of unhygienic, invalid people of underdeveloped tropical countries. Perhaps, this could be the reason for poor funding of maggot research in the Western world. Contrary to the general notion, myiasis is the fourth commonest travel-associated disease noted in 7-10% of Western travelers.[3-5] Diaz rightly remarked, "Ectoparasitic diseases, including myiasis, are no longer infestations of children and socio-economically disadvantaged populations in tropical countries; they have re-emerged as unusual, but not uncommon, infectious diseases worldwide."[6]

In recent years, demonized imagery of maggots has undergone transfiguration. From being a 'foe of health' they have metamorphosed into a 'friend of therapy'.[7] Laboratory cultured maggots are now used in the treatment of chronic non-healing wounds.[8,9] Forensic importance of maggots and their ecological role as decomposers are also well appreciated.[10]

HISTORY

The status of maggots in human history has swung between 'enthusiastic receptions' and 'disdainful rejections'.[11] Prehistoric cave dwellers must have been annoyed by maggots despoiling their precious trophies of hunting, the uncooked meat.[11] At the same time, aboriginals of the Australian, Myanmar, Ngemban and Mayan tribes appear to have known the therapeutic potentials of maggots in wound healing.[12] Astonishingly, Mayan healers unwittingly knew a technique of culturing disinfected medicinal maggots. They dressed wounds with a piece of cloth soaked in animal blood and dried in sun light. Blood soaks must have attracted flies to oviposit and solar ultraviolet rays must have disinfected the eggs. With this dressing, they expected swarming maggots after a few days. It is worth remembering that until Francesco Redi (1626-97 CE) disproved the Aristotelian theory of abiogenesis[13] by his famous meat-jar experiments, no one knew the link between maggots and flies.

The oldest textual reference to human myiasis is found the Ayurvedic medical texts of ancient India. Both Charaka and Sushruta (circa 1200-600 BCE) have mentioned 20 different types of *Krimis* (worms) including maggots. Ayurvedic physicians classified pathogenic *krimis* into *rakthaja* (blood), *kaphaja* (mucus) and *malaja* (fecal) origin. *Romaja* (hair) *krimi* described by Sushruta grossly resembles *Dermatobia* of the modern medicine. Sushruta's description of *Krimi-granthi, Krimi-karna* and *Krimija Siro-roga* are unmistakably that of orbital, aural and nasal myiasis respectively.[14]

> *"The disease of the head in which a pricking and tingling pain is felt inside the head as if being stung by some poisonous insect, and which is accompanied by a watery discharge mixed with blood from the nose, should be attributed to the existence of local parasites. This disease is a dangerous one and is known as the Krimija Siro-roga. The patient should be made to snuff in a quantity of animal blood. The worms or parasites, lured with the smell of the blood, would greedily come down into the passages of the nostrils when they should be carefully extracted by means of a tong" [14]*
>
> *(Sushruta Samhita - Bhishagratna Translation)*

Sushruta described two different techniques of maggot extraction: (1) Application of goat meat (*mamsa achadana*) to bait the worms out; (2) Applying vermifuges such as cow urine and herbal

decoctions in the form of fumigants, *nasyas* (snuff) or *avapidas* (liniments).[14,15] Sushruta was much ahead of his times when he advocated application of clarified butter or mustard oil to bring out maggots from deep burrows. This is principally similar to the asphyxiant therapy of modern days.

Ayurvedic physicians also used maggots to treat incurable cancers (*Kaphaja Arbuda*) and non-healing ulcers (*Dushtavrana*).[15] They applied *Dooshya Mamsa* (animal flesh) to wounds which would attract flies to lay eggs o it.[16] This technique, referred to as *Krimi Upattikara Chikitsa* has recently been rediscovered as 'bacon therapy'.[17] Probably, Hindu surgeons used obligate maggots to eat away live tumor tissues and facultative maggots to digest necrotic debris.[14] In colonial India, myiasis of the nose was known as *peenash* (Sanskrit: *Pee* - fetid, *Nash* - nose).[18,19] It is not clear if maggots were the cause of foul breath or *vice versa*.

Maggot infestation is well described in several mythologies. According to Homer's Iliad, the Greek hero Achilles requested his mother Thetis to protect his wounded friend Patroclus from being devoured by maggots.[20] *Garuda Purana* of Hinduism warns that in the nether life maggots will eat away the sinners (*Krimi-Bhojanam*).[19] The same theme is also found in the Old Testament, wherein Job lamented, "My body is covered with worms and scabs, my skin is broken and festering"(Job 7:5). The Exodus of the Old Testament also described an epidemic of myiasis (fly plague) in Egypt (Exodus 8:21).[11] King Herod, according to the Bible, was said to have died of myiasis-induced gangrene.[11] Flies and maggots are considered a symbol of *Nergal*, the Mesopotamian god of death.[11] Consequently, in ancient Babylonia, amulets were designed in the form of maggots. In Nordic mythology, *Leki* - the God of death - was believed to enter a house in the form of maggot creeping through a keyhole.[11] A wish-note buried with a Giza Mummy reads, "The maggots will not turn into flies within you".[11] Thus, Egyptians knew about the metamorphosis of maggots in to flies, a phenomenon that was rediscovered by Redi after several millennia. In hieroglyphics, double headed arrows represent maggots and flies.[11] Perhaps, ancient Egyptians symbolically meant that maggots are double edged swords!

Aulus Cornelius Celsus (circa 25 BCE – 50 CE) in his *De Medicina* described ear infestation due to *Wohlfahrtia magnifica* maggots and its treatment in great details.[21] Ambroise Pare (1510-90 CE) was the first to note the beneficial effects of maggots on wound healing.[12] However, he did not deliberately advise maggot therapy (MT). Similar observations were also made by Dominique Jean Larrey (1766–1842, the personal physician of Napoleon Bonaparte) and William Williams Keen (1837–1932, the army surgeon of the North States). John Forney Zacharias (1837–1901) is credited with the first intentional use of MT during the American Civil Wars of 1860s.[12] William Stevenson Baer (1872–1931), the founding chairman of orthopedics at the Johns Hopkins University,[22] successfully used MT in 1930s to treat more than 60 children with chronic osteomyelitis and bedsores.[23](Fig. 1) When two of his patients died of tetanus following MT, Baer realized the need of using disinfected maggots. His student Livingston popularized MT. However, the discovery of antibiotics in 1940s dampened the enthusiasm on MT. The pendulum swung back and the interest in MT was rekindled in 1970s when antibiotic resistance emerged as a great threat. Ronald Sherman and Edward Pechter rediscovered and popularized MT in 1983.[7,8,] In 1995, the International Biotherapy Society (IBS) was founded to sponsor annual conferences on MT.[24,25] In January 2004, the Food and Drug Administration of America (US-FDA) approved medicinal maggots under the category of medical devices rather than merely as a drug.[24] Since then, several randomized controlled trials on MT have been published.[26]

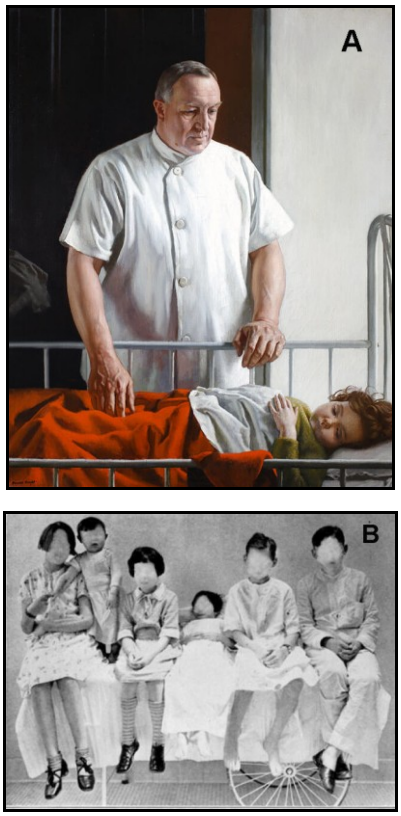


Fig 1. *(a) William Stevenson Baer (1872–1931), the pioneer of maggot therapy (Painting on display at the Orthopedic department of the Johns Hopkins University); (b) Photograph of Baer's patients (From Baer's original publication in the Journal of Bone and Joint Surgery 1931) (Public domain pictures)*

ETYMOLOGY AND NOMENCLATURE

In 1815, Kirby and Spence first used the term *Scholechiasis* to describe infestation by larva of any insect.[2] In 1837 Frederick William Hope, an English clergyman, Oxford professor and entomologist, coined the term *Myasis* (sic) to differentiate dipterous fly larvae from other the larvae of other insects (Greek: *Myia* - fly; *sis* - disease).[27-29] He suggested, the term *Scholechiasis* be restricted to infestation of *Lepidoptera* larvae and *Canthariasis* to *Coleoptera* larvae.[28] The term *Myiasis* is restricted to wild infestation while *'maggot therapy'* refers to iatrogenic infestation.[30] Myiasis is also known by a variety of vernacular names.[31,32] (Table 1)

Table 1. Synonyms of myiasis

Ancudo †
Bekuru †§ (Brazil) [32]
Berne † (Brazil) [50]
Bicherio § (Latin America)[Bapat]
Borro† (Bolivia) [32]
Colmoyote † (Mexico) [32]
Flystrike ‡
Gusano de mosquito / zancudo † (Venezuela) [32,50]
Gusano de monte † (Venezuela) [32,50]
Gusano de peludo † (Bolivia) [32]
Gusano macaco † (Venezuela) [32,50]
Ikitugu † (Brazil)
Kitudn † (Brazil)
Krimija ‡ (India)
Kturn † (Brazil)
Macaco †§ (Guyana) [32]
Maggot infestation ‡
Mberuaro † (Brazil)
Mirunta † (Peru) [32]
Miruta †[54]
Mosquito worm † (Trinidad)[4,32]
Moyocuil (Moyocutli) † (Mexico)[4,32]
Muskieten worm † (Suriname) [32]
Myiasis (Myasis) ‡#
Nuche † (Columbia)[Goldman]
Peenash *§ (India)[Center]
Suglacuru † (French Guyana)[4,32]
Suylacuru † (French Guyana)[4,32]
Torcel † (Central America)[Hunter]
Torsalo † - (Costa Rica)[Goldman]
Tupe † (Ecuador) [32]
Ura † (Argentina, Paraguay) [32]
Ver macaque † (French Guyana)[(32]
Verme de mata † (Venezula) [32]
Vermes Nasi * (India)[31]
Warble † (veterinary term)

Source: Center[18], Doss[31], Francesconi[4], Goldman[50], Hunter[32], Bapat[41], Quintanilla-Cedillo[54]
† Vernacular synonyms of furuncular myiasis.
** Synonym of nasal myiasis*
§ Spelling variantions in English: (Peenash, Pinash, Penash), (Bekuru, Bikuru), (Macaco, Macaw)
‡ General terms that are independent of the affected anatomical site.
 # Frederick William Hope originally spelt it as 'Myasis'(sic)

Table 2. Modified anatomical classification of human myiasis §

ECTOPARASITE

Non-inhabitants

Sanguinivorous (Blood sucking) *

Dermal inhabitants (Cutaneous myiasis)

Follicular
Wound (Traumatic)
Migratory (Creeping or Subdermal)
Umbilical †

ENDOPARASITE

Endoluminal (Orificial)

Nasal
Aural
Oro-pharyngeal
Orbital (Ophthalmomyiasis externa) ‡
Tracheal
Genitourinary
- Female - vaginal
- Male - Penile, preputial, scrtoal
- Urethrovesical

Gastrointestinal
- Anorectal
- Intestinal - Gastric, Enteric

Parenchymal (Visceral)

Cerebrospinal
Ocular (Ophthalmomyiasis interna) ‡
Pulmonary (Lower respiratory)

§ Combines the classifications of Bishopp [34], James [33] and Zumpt [1]

** These free living larvae in the environment approach hosts for just blood meals rather than infesting their body*

† Umbilical myiasis is exclusvely occur in neonates

‡ A distinction is made between orbital (eyeball socket) and ocular (eyeball chambers) myiasis.

The nomenclature of skin infestation (cutaneous or dermal myiasis) varies according to the location of maggots. It may be *furuncular myiasis* (dermis), *migratory myiasis* (subcutaneous plane) or *wound myiasis* (surface of an already existing wound).[29] The term *'traumatic or wound myiasis'* was first used by James in 1947.[33] The adjective 'traumatic' is inappropriate as it is also known to occur in ulcerated malignant tumors and in non-traumatic neuropathic ulcers.

CLASSIFICATION

Clinical myiasis is classified differently by various authors.[2,4] In 1915, Bishopp classified it based on the affected organ.[34] James in 1947[33] and Zumpt in 1965[1] modified Bishopp's anatomical classification. (Table 2) Patton[35] considered that the anatomical classification is inappropriate because, a given species can cause disease in many anatomical sites and the same anatomical site may be infested by many species of maggots. Based on the host-parasite interaction, he proposed an ecological classification as *'Specific (obligate)'*, *'Semi-specific (facultative)'* and *'Accidental'*.[35] Hall[2] modified it by adding *'primary'*, *'secondary'* and *'tertiary'* subcategories to the *facultative myiasis*. (Table 3) Zumpt [1] renamed *accidental myiasis* as *pseudomyiasis*. Anatomical classification is clinically more practical, while ecological classification gives better understanding of the pathogenesis.[2] Sometimes, myiasis is also classified into *benign* and *malignant* depending upon the tissue invasion aggressiveness of the infesting maggots and the clinical outcome of the patient.[36]

ENTOMOLOGY

Flies are universal and diverse. Approximately, they consist of 150,000 species, 10,000 genera and 150 families.[4,37] The Order *Diptera* has two major Suborders, the *Nematocera* (Greek: *nema* - thread-like; *cera* - antenna) and the *Brachycera* (*brachy* - short). The former consists mostly of blood sucking insects such as the mosquitoes that act as vectors for many viruses and protozoa.[37] Rarely, *Nematocera* larvae can cause *accidental myiasis* in children.(Table 4) Human myiasis is caused by the 4 families of Brachycera: the *Muscidae* (house fly), *Oestridae* (botfly), *Calliphoridae* (blowfly) and *Sarcophagidae* (flesh fly).(Table 5) Just about 80 species of these 4 families are responsible for 95% of human myiasis.[2]

Table 3. Ecological classification of human myiasis

Category	Definition†
Obligate myiasis	Aggressive maggots that depend on a host for completing the life-cycle. (They are capable of penetrating intact skin and feed on healthy tissue)
Facultative myiasis*	
Primary myiasis	Free living maggots* that can grow in host tissues only when they are damaged
Secondary myiasis	Free living maggots* that depends on another larva to establish infestation in host tissue. (It is a form of mixed infestation.)
Tertiary myiasis	Free living maggots* that grow in hosts that are near death
Accidental myiasis (Pseudomyiasis)	Free living or dead maggot that pass through a host without undergoing further developmental changes

† These definitions are as per the original descriptions of Hall.[2] Later authors have distorted the definitions in many different ways. Some of them have used 'obligate myiasis' synonymous with 'primary myiasis' and 'facultative' equal to 'secondary'.

** Free living maggots may complete their life cycle either on dead decaying matters or on a living host tissue*

Table 4: Rare accidental myiasis in children*

Anatomical location	Name of the maggot species
Intestine	*Eristalis tenax* *Megaselia scalaris* *Telmatoscopus albipunctatus* *Hermetia*
Genitourinary tract	*Eristalis tenax* *Megaselia scalaris* *Piophila casei* *Psychoda albipennis* *Scenopinus*
Wounds	*Megaselia scalaris*
Eye, ENT	*Drosophila melanogaster* (Fruit fly)
Nosocomial	*Megaselia scalaris*
Skin-furuncular	*Hermetia*

** Source: Francesconi [4]*

Therefore, it must be emphasized that myiasis is not one disease; but a group of diseases caused by varius dipteran larvae. Clini-cal features of each species differ significantly that they should be considered as separate disease entities.

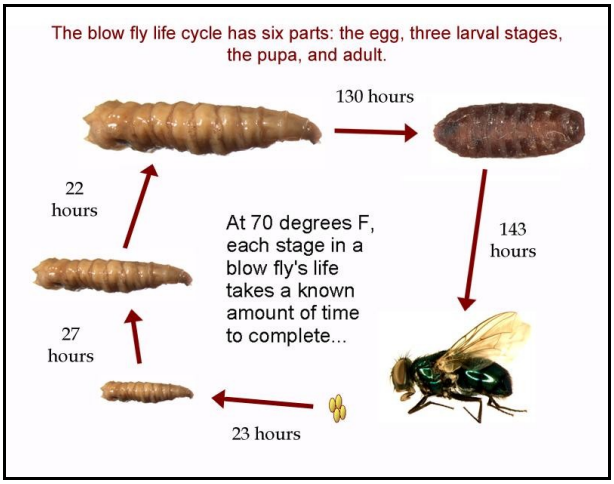


Fig 2. *Life cycle of flies (Courtesy of National Library of Medicine and Cleveland Museum of Natural History)*

Life span of many adult flies ranges between 1 to 10 days.[2,33,37] (Fig. 2) Therefore, they are in a great hurry to complete their reproductive life. A majority of flies oviposit, while some species like *Sarcophaga* larviposit.[30] Depending on the type of species, gravid flies are capable of laying 150 to 2000 eggs per batch.[2] An average female fly will

lay 4 to 5 batches of eggs in its life span. Flies oviposit either directly on the host tissue or on leaves and garbage from where they are transferred to the host. Fly eggs are very resistant to chemicals and hence can easily be disinfected using 5% formalin, 60% alcohol, mercury bichloride or acetic acid. This property is exploited in laboratory culturing of medical maggots.[38] From preventive medicine point-of-view, this is a disadvantage that they cannot be destroyed by even strong chemicals.

Dipteran eggs usually hatch in warm, moist, putrid substrate. They may remain dormant for several months until a suitable environment is available. Some species (e.g. *Cuterebra*) require a sudden fluctuation in environmental temperature for hatching. Usually such temperature change occurs in the months of March-April, June-July, and September-October. These periods coincide with the peak incidence of clinical myiasis.[2]

Larvae usually take 5-10 days to mature.[2,37] They pass through 2 or 3 stages of instars in the human hosts.[2,33] After 7-14 days of maturation, pupae fall off from the host and develop in soil. Maggots of different species vary in their shape and physical dimension (Fig. 3); but they are generally 2-30 mm in length and 1 to 7 mm in diameter. They are mostly spindle shaped with the oral end narrower than the posterior end. The paired, black respiratory spiracles at the caudal end are often mistaken for eyes.

Table 5: Entomology of common flies causing pediatric myiasis

Binomial name of the fly	Common name	Parasitism	Natural reservoir	Affected organ §
Alouattamyia baeri [2]	-	Obligate	Primates	(Rare) Lung, Throat, Skin
Auchmeromyia senegalensis [3]	Congo floor maggot	Obligate*	Man	External Blood suckers
Calliphora hilli	-	Facultative	Decomposed flesh	Eye
Calliphora vicina	Blowflies	Facultative	Decomposed flesh	ENT, GIT, TW, GUT
Chrysomya albiceps [3]	-	Facultative	Garbage, Feces	TW, Nose
Chrysomya bezziana [3]	OWSW	Obligate,	Sheep	TW, ENT
Chrysomya megacephala [3]	Oriental latrine fly	Facultative	Decaying flesh, Feces	TW, Ear
Chrysomya rufifacies [3]	Hairy Maggot fly	Facultative	Garbage, Feces	Tw, Nose
Cochliomyia hominivorax [3]	NWSW	Obligate	Mammals	ENT, Mouth, TW
Cordylobia anthropophagia [3]	African Tumbu fly, Mango fly	Obligate	Mammals, Chicken, Soiled linen, Feces	Skin
Cordylobia rodhaini [3]	Lund's fly	Obligate	Wild mammals, Soiled linen	(Rare) Skin
Cuterebra [2]	Rodent botfly	Obligate	Rodents, Grass	Skin, Viscera, Eye, RT
Dermatobia hominis [2]	Human botfly	Obligate	All mammals, Few birds	Skin
Eristalis tenax	Rat-tailed maggots	Facultative	Sewage, Polluted water	(Rare) GIT
Fannia canicularis [5]	Little house fly	Facultative	Decaying matter	Nasopharynx, GIT
Fannia Scalaris [5]	Latrine fly	Facultative	Decaying matter	GUT

(Table Continued)

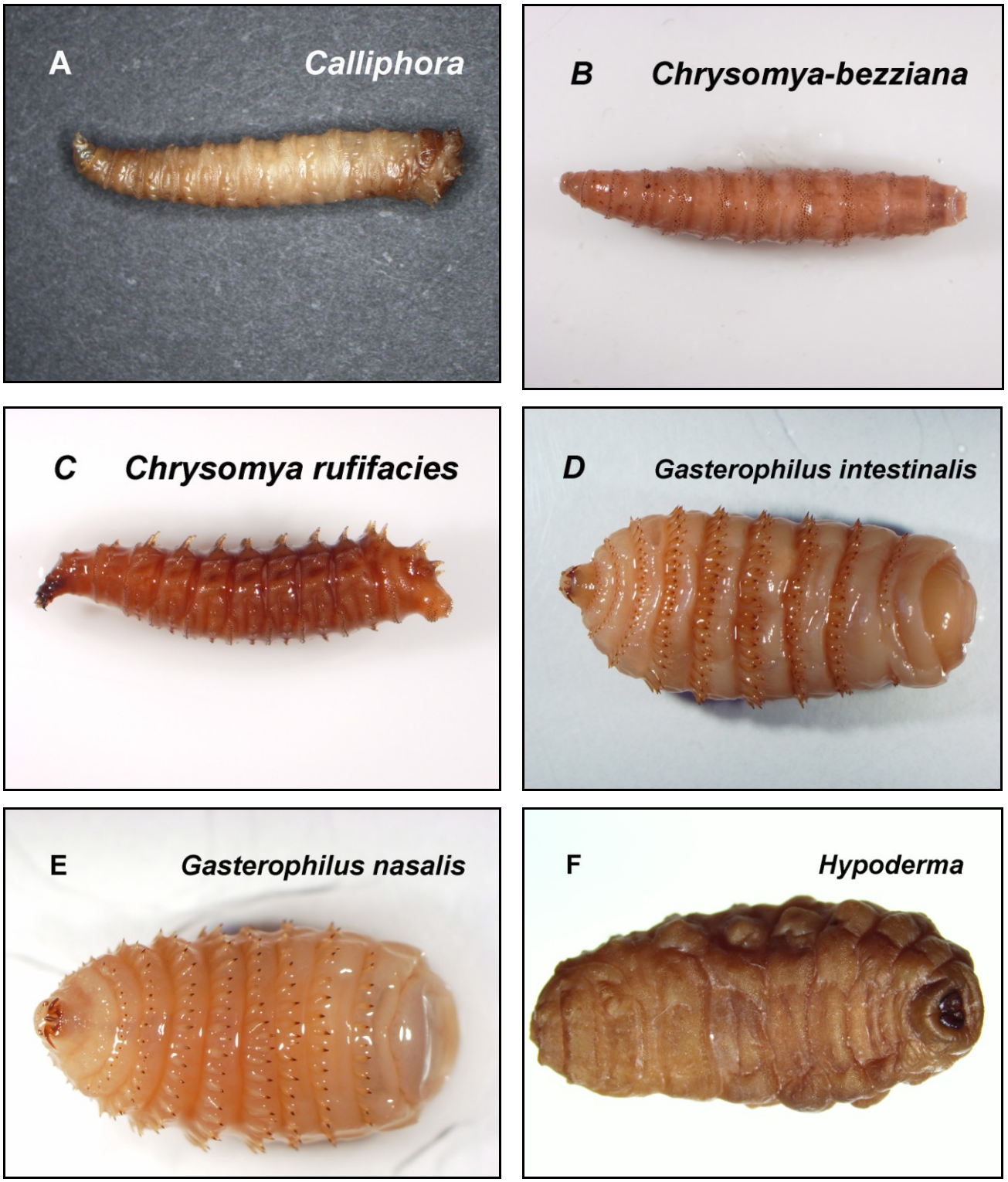
Gasterophilus intestinalis [2]	Horse botfly	Obligate	Wild mammals	Migratory, Eye, ENT, Lung
Hermetia illucens	Black soldier fly	Facultative	Animal wastes	GIT
Hypoderma bovis [2]	Cattle botfly	Obligate	Cattles	Migratory, Mouth, Throat
Hypoderma lineatum [2]	Common warble fly	Obligate	Cattles	Migratory, Brain
Hypoderma tarandi [2]	Reindeer botfly	Obligate	Raindeer, Caribou	Eye, Mouth, Throat, Skin
Lucilia cuprina [3]	Sheep blowfly	Facultative	Decaying matter	TW
Lucilia sericata [3]	Greenbottle blowfly	Facultative	Decaying matter	Nose, TW
Musca domestica [1]	House fly	Facultative	Decaying matter	GIT, GUT, TW, ENT
Oestrus ovis [2]	Sheep nasal botfly	Obligate	Sheep, Goat	Eye, ENT
Parasarcophaga crassipalpis	Flesh fly	Facultative	Decaying matter	Ear
Pharyngomyia picta	Deer throat botfly	Obligate	Wild mammals	Eye
Phormia regina [3]	Black blowfly	Facultative	Decomposed flesh, Cattle	TW
Piophila case	Cheese skipper fly	Facultative	Barks of trees	Rectum, GIT
Protophormia terranovae [3]	-	Facultative	Decomposed flesh, Cattle	TW
Rhinoestrus purpureus	Nasal botfly	Obligate	Horse	Eye
Sarcophaga peregrina [4]	-	Facultative	Excreta, Garbage	GIT
Sarcophaga ruficornis [4]	-	Facultative	Excreta	TW, Ear
Sarcodexia lambens [4]	Flesh fly	Facultative	Excreta	GIT
Sarcophaga haemorrhoidalis [4]	Fecal fly, Filth fly	Facultative	Excreta	TW, GIT, Ear
Tubifera tenax	-	Facultative	Sewage	GIT
Wohlfahrtia magnifica [4]	Spotted flesh fly	Obligate,	Livestock	ENT, Mouth, TW, Skin
Wohlfahrtia meigeni [4]	-	Obligate	Livestock	TW (infants)
Wohlfahrtia opaca [4]	-	Obligate	Livestock	TW
Wohlfahrtia vigil [4]	Fox maggot fly	Obligate	Livestock	TW (children), Skin

Source: Azami [(40)] , Hall [(2)]
Family attribution: [1]Muscidae, [2]Oestridae, [3]Calliphoridae, [4]Sacrophagidae, [5]Fannidae

ENT - Ear, nose and throat, RT - Respiratort tract, GIT - Gastrointestinal tract, GUT -Genitourinary tract, TW- Traumatic wounds, OWSW - Old World screw-worm, NWSW - New World screw-worm

Lucilia was previously known as Phaenicia; Sarcophaga haemorrhoidalis as S. cruentata

** Sanguinivorous (live in soil but approach host for blood meal); §The term skin refers to furuncular myiasis*



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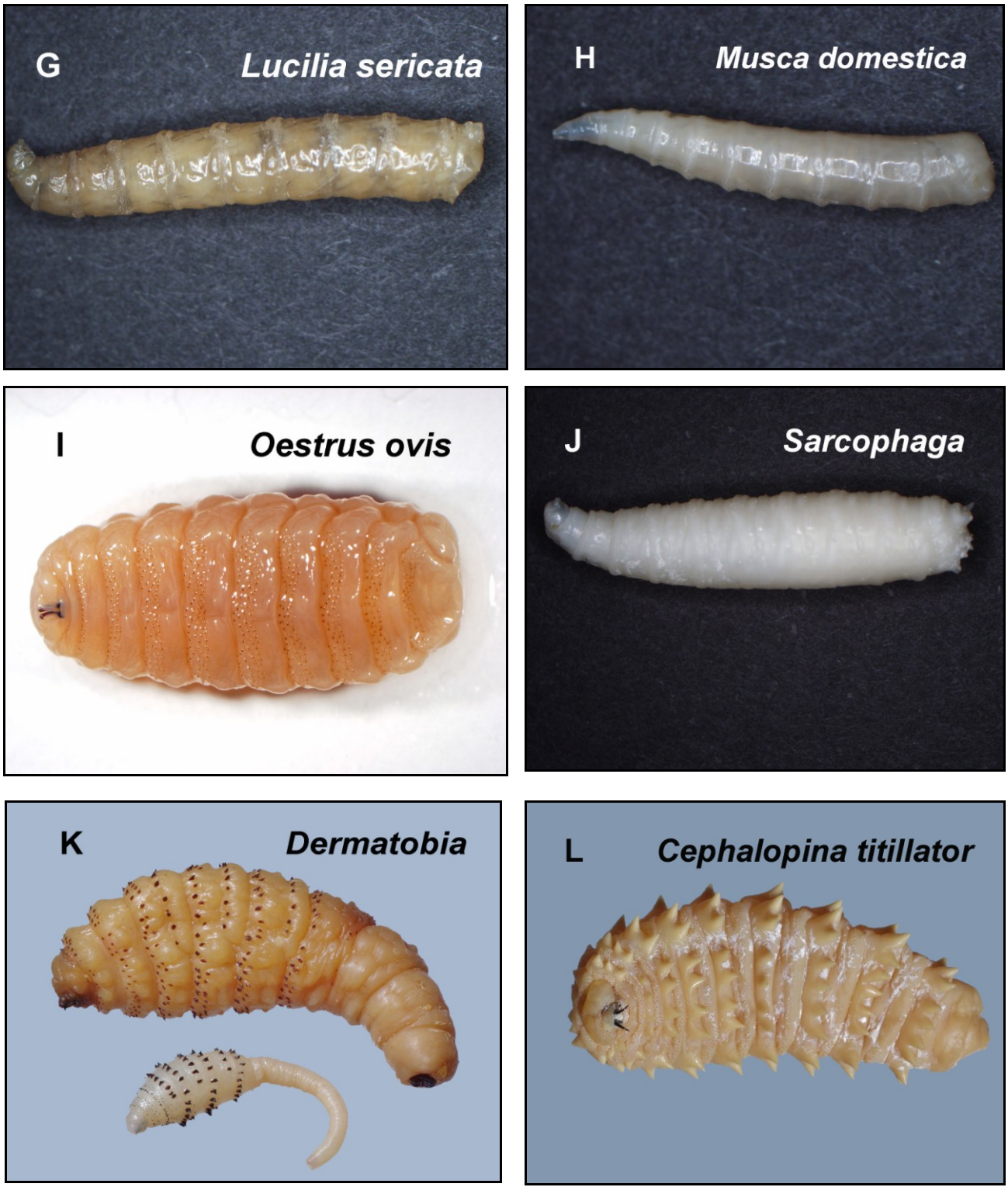

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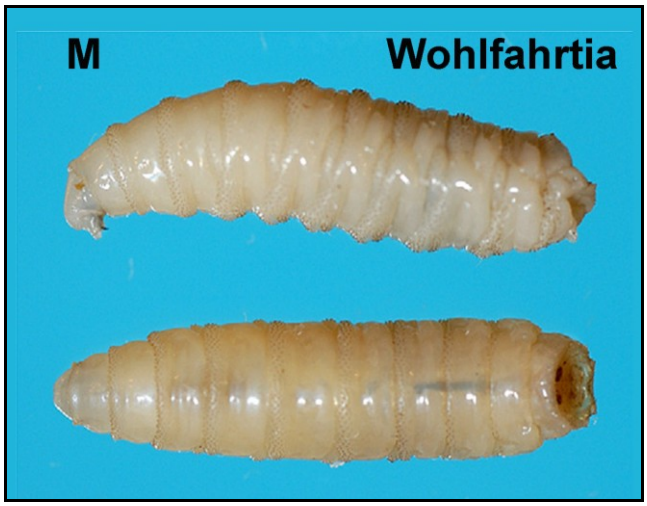

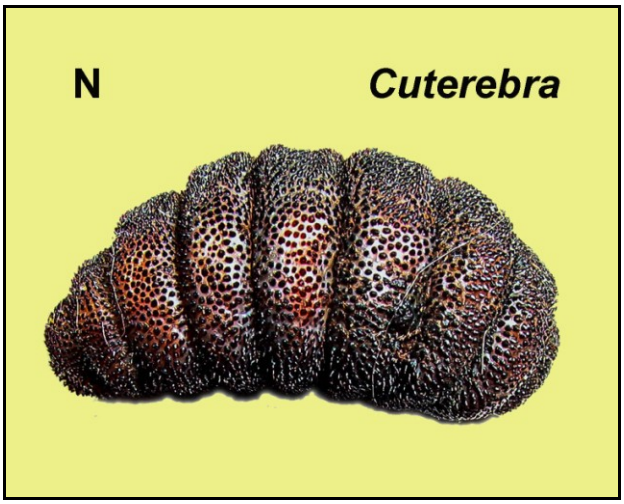

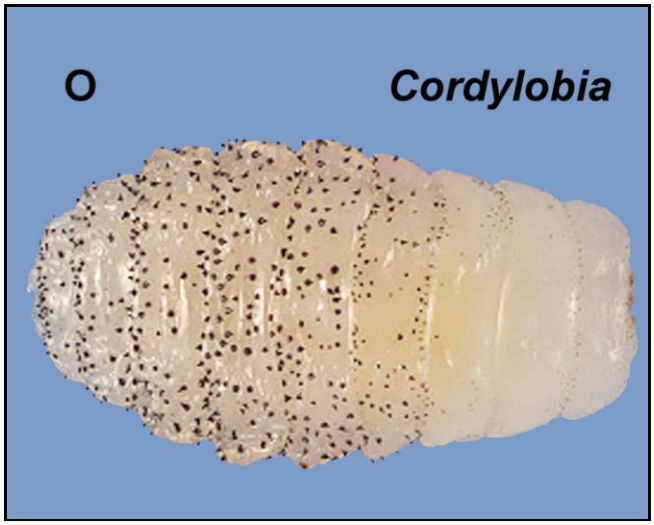

Fig 3. ***Morphological of maggots affecting children.***

In all the imgaes, maggots are oriented with their oral end towards the left side. (Photo credits: Fig. A-J are reproduced with permission from Dr. Lyn Knott, School of Veterinary Sciences, University of Queensland; Fig. K by Acarologiste from Wikimedia Commons under CC-BY-SA-4.0; Fig. L by Daktaridudu from Wikimedia Commons under CC-BY-SA-4.0; Fig. M by James Kalisch, Entomology Department, University of Nebraska at Lincoln from DOI:10.29011/2688-6383.000023 under fairuse; Fig. N from the Western College of Veterinary Medicine, University of Saskatchewan under fairuse; Fig. O by Rebecca Graham, from the Pest and Diseases Image Library (Image ID: 5489545) at Bugwood Center for Invasive Species and Ecosystem Health, University of Georgia under CC-BY-NC 3.0)

ETIOPATHOGENESIS

In 1897, Stecle described the link between myiasis and flies.[27] Myiasis is not one disease, but a group of disorders caused by different species of dipteran larvae. Pathogenesis of obligate and facultative myiasis differs significantly. Obligate larvae essentially require a host to complete their life cycle and they are aggressive in nature. They may painlessly penetrate intact skin and start feeding on even live tissues when necrotic tissues are exhausted. On the other hand, facultative maggots mostly grow in dead decaying matter. They are less aggressive and can grow only on pre-existing necrotic tissues. As they are incapable of causing harm to the live tissues of the host, they are ideal for MT. Two of the primary facultative blowfiy larvae (*Lucilia sericata*, *Lucilia cuprina*) are widely used in MT. *Oestridae* have both facultative and obligate species while *Sarcophagidae* are mostly facultative pests. There are only 3 obligate screwworms[2] (*Cochliomyia hominivorax*, *Chrysomya bezziana* and *Wohlfahrtia magnifica*) which are highly dangerous that they may even kill the host.

Modes of Contracting

Susceptible hosts may contract maggots by many different ways of oviposition: intradermal implantation, contact inoculation, squirt inoculation,

environmental contamination and physical relocation. Raely gravid flies stuck matured larvae to the host skin or hair (larviposition).

Intradermal implantation

Some species of obligate maggots such as the *Dermatobia* oviposit using a phenomenon called *phoresis*.[2] In this, female flies stick the eggs on to the belly of a blood sucking slave insect (e.g. ticks, mosquitoes) without affecting their flying ability. These 'porter insects' inoculate the eggs into the dermis of host during a blood meal. Sudden temperature change inside the host-skin causes the eggs to hatch. Alternatively, the larvae hatched on the surface of porter flies may crawl into the host-dermis at the site of piercing with proboscis. As this transfer happens mostly during sleep, the host is usually unaware of the implantation. In this way, usually a single egg or a couple of eggs can be transmitted.

Contact inoculation

Gravid female flies of facultative species are often attracted by the fetid smell of bacterial metabolic byproducts (e.g. hydrogen sulphide, methane and ethane), alkaline pH of wounds or the smell of flesh and blood. They lay eggs on open wounds when they stroll and feed on the necrotic debris. Hundreds of eggs may be oviposited by a single fly in one sitting. *Hypoderma* oviposit on body hairs.

Squirt inoculation

Body orifices of the host are effectively guarded from insects by robust physiological protective mechanisms such as cerumen (ear) and sneezing reflex (nose). In these circumstances, the female flies oviposit near the orifices so that the hatched maggots may crawl into the lumen. Alternatively, they - with great force - squirt hundreds of eggs directing towards the body orifices while flying at a distance (hence the name 'blowfly').[2] Presence of purulent discharge, as in suppurative otitis media, attracts blowflies.

Environmental contamination

Some species of flies oviposit on green leafs and grass. *Cordylobia* species prefer to lay eggs on soiled linen and undergarments. The eggs are then transmitted to the vulnerable hosts by physical contact. Special adhesive fluid secreted on the surface of the eggs enables their quick transfer by adhesion even if the contact time is very brief.[2] Eggs may also be transferred by contaminated hands into the nose.[27]

Physical relocation

Saprophytic larvae living in contaminated food or drink are ingested by the careless host. Mostly accidental myiasis is acquired in this way. Improper food handling, poor eyesight, mental dysfunctions and attention deficit while eating are the causes of this tragedy.

Pathogenic Behavior

After oviposition, warmth of the host tissue causes hatching of the eggs. The emerging larvae undergo 3 stages of molting, called first, second and third instars respectively. The third instars feed on the live or necrotic tissues and prepare themselves for pupation. The first two stages of instars are highly antigenic, provoking intense host immune reaction. However, third instars learn to downplay thier antigenicity in order to develop symbiosis with the host. The adaptive mechanisms exhibited by third instars include: (1) Alimentary secretions and excretions of maggots (ASEM) contain several chemicals and proteolytic enzymes that control the growth of competitive bacteria in the wound. (*Vide infra*) (2) Maggots, to their survival advantage, develop symbiosis with certain bacteria. For example, presence of *Proteus* in the larval gut is essential for the synthesis of bacteriostatic chemicals in the ASEM which in turn protect the larvae from other pathogenic bacteria. (3) They develop sharp body spines and oral hooklets that prevent accidental slippage from the host before full maturation. (4) They reduce antigenicity of the cuticle to avoid being targeted by the host immune

cells or antibodies. (5) They also secrete immunomodulatory chemicals such as urea to blunt the immune attacks of the host. (6)ASEM also contain several anti-inflammatory modulators that help the maggots from being trapped in the inflammatory fibrosis.

As maggots are highly photophobic they bury their head-ends deep inside the host tissue by burrowing arborizing tunnels. This process is enabled by digestive enzymes present in ASEM and devouring mouth apparatus. When maggots mature into pupae, they either slip out quietly or are ejected out of the host by the pressure of tissue edema.[2] As this happens mostly during night sleep, the host may not be aware of the pupal exit. Pupae get buried into the soil to complete their life cycle before emerging as adult flies. (Fig. 2)

The basic pathogenicity of maggots can be summarized as follows: (1) Damage caused to the host tissue by digestive enzymes and chemicals present in the ASEM; (2) Mechanical damaged caused by the chewing and crawling activities of the maggots; (3) Provocation of immunemediated inflammatory reaction in the host; (4) Systemic absorption of larval excreta and toxin and (5) Promotion of secondary bacterial infections, especially that of *Proteus* and *Escherichia coli*.

RISK FACTORS

Myiasis is known as a disease of uncleanliness and poverty.[39] More than 90% of the affected patients are illiterates and economically poor while only 5% are of middle class.[27,39] It affects those who are unable to maintain personal hygiene or those who live in unhygienic conditions. Unemployment, illiteracy, improper garbage disposal, close proximity of farm animals and unsafe water resources are associated with myiasis. Although it is generally common in rural and slum communities, in an Iranian study 86% of patients were from urban areas.[40] Cultural practices that predispose to myiasis include smearing cowdung on house floors, native treatment of wounds with raw herbal pastes made of contaminated leaves, defecation in open grasslands, sitting or sleeping on mud floor, using dried camel dung to mop-up the last few drops of urine (an Arabian habit), applying honey to wounds as home remedy and bathing in public pools where cattles are also washed.

Those who cannot care for themselves because of physical or mental disabilities are more prone for myiasis. They include infants, mentally retarded (e.g. cerebral palsy), neuromuscular cripples (e.g. paraplegia), visually challenged, orphans without proper care-takers and debilitated patients (e.g. malnutrition and cancers).[41]

Predisposing necrotic tissue that attract facultative myiasis include fungating tumors, noma, pyoderma, leprosy, neuropathic or trophic ulcers (e.g. meningomyelocele, bedsores), necrotizing faciitis (e.g. Fournier's gangrene), contaminated traumatic wounds due to farm or road accidents and purulent discharge from body orifices (e.g. atrophic rhinitis, suppurative otitis media).

A warm humid climate is essential for the hatching of dipteran eggs. Hence, myiasis is typically a disease of tropics and subtropics. It is common in sea-shore areas than at high altitudes.

DEMOGRAPHY

Distribution of myiasis is global with the highest incidence in the tropical countries. Previously, the fly species of a geographic location were thought to be unique and specific. However, with increasing international travels, the geographic differences are slowly fading away.[4] For example, *Cochliomyia* (New World screw-worm) maggots entered Libya in 1988 from America, which is 7000 km away.[42,43] On the other hand, in 2014, *Chrysomya* (Old World screw-worm) larva from Africa threatened the Australian health care system.[44] *Chrysomya bezziana* (20%) and *Lucilia sericata* (30%) are the two most common forms of myiasis in

Asian and African countries.[40] *Oestrus ovis* infestations are rare in children.

Species identification is rarely done. Myiasis is not a notifiable disease. Physicians often consider it a minor problem of wound healing. There are no official data bases of human myiasis. Consequently, authentic demographic data on myiasis is scarce.[3,4] The exact incidence of clinical myiasis is not known.[45] Traumatic wound myiasis has been reported in 5.1% of septic wounds in an Egyptian hospital.[3,46] In 1993, Singh from Rohtak, India reported 94 cases of pediatric myiasis over a span of 6 years.[47] Pediatric infestations form 38% of all human myiasis.[47]

Myiasis is an occupational hazard for shepherds, animal handlers and agricultural workers. It occurs without any age or sex predilection. However, a systematic review of oral myiasis found it to be common in boys.[48] The youngest reported patient is a 1-day-old newborn.[49] There are some evidences that the demographic pattern of myiasis is changing over time. For example, in 1979-80, about 30% of ENT (ear-nose-throat) myiasis occurred in the first decade of age, while it dropped to 15% in 2003-04.[27]

Biological life-cycle of various species of flies differs with seasons. Cases of *Wohlfahrtia* and *Cuterebra* infestation are common in summer months, *Oestrus ovis* in autumn, *Hypoderma* in winter and *Cordylobia* in rainy seasons (when sylvan, the natural host, approaches villages). *Gasterophilus* maggots occurs throughout year without any seasonal fluctuation in incidence.[4] In India 10% of myiasis occurred during January-March, 0% during April-June, 15% during July-September and 75% during October-December.[27]

PATHOLOGY

Pathological changes caused by maggots differ between surface dwelling facultative maggots and aggressively invading obligate maggots. Wound myiasis is usually benign. Chemicals present in the ASEM of facultative larvae suppress inflammatory reaction of the host tissues. On the other hand, obligate maggots may cause considerable damage to host tissue by the strong digestive enzymes present in ASEM. These enzymes are capable of eroding even bones.

Infected soft tissues show progressive liquefaction necrosis and hemorrhage.[2] Marginal acanthosis is often seen on the walls of larval burrows.[50] Maggots may damage host blood vessels by the strong oral hooklets and digestive enzymes. Torrential bleeding from eroded major vessels has been reported.[51,52] The typical response of the host immune system to the presence of invasive maggots is dense infiltration of lymphocytes, eosinophils, histiocytes, mast cells, plasma cells, Langerhans cells and Langhans cells.[2] Local edema, peripheral hyperemia, dilated capillaries and regional lymphadenopathy are also seen.

Cell wall protein of maggots triggers T-helper cells, which in turn stimulate plasma cells and B-lymphocytes to produce antibodies.[2] This results in partial resis-tance against reinfection seen in some species, but this immunity is short lived.[2] Fibroblasts tend to halt the invasion of maggots.[2] Migratory maggots of *Hypoderma* species leave behind a trail of edematous yellow-green gelatinous track with eosinophilic infiltration.[2] *Dermatobia* often provoke cell mediated immunity.[2] After the departure of maggots, wound heals fast within 5-10 days.[2]

Myiasis is frequently associated with secondary bacterial infection. The isolates were *Staphylococcus aureus* in 90%, *Escherichia coli* in 2% and *Klebsiella* in 8% of cases.[27]

CLINICAL FEATURES

It is not known as to what proportion of the clinical symptoms is attributable to the predisposing necrotic wounds and how much can be attri-

butable to the maggots per se.[53] General symptoms caused by the toxins or coexisting bacterial infection include fever, generalized or local itching, lymphadenopathy, poor appetite, weight loss and anemia. Local manifestations of myiasis differ according to the infesting species and the affected anatomical area. *(Vide infra)*

Furuncular Myiasis

Furuncular myiasis, also known as *warble disease* in animals, was first described by Blanchard, and later by Sanchez in 1893.[54,55] It is caused by obligate aggressive larvae such as *Dermatobia, Cordylobia, Cuterebra* and *Wohlfahrtia*.[29] They painlessly penetrate the intact skin within 5-60 min of contact and spend 4-80 days in the host.[4,29] Symptoms develop within 2 days of oviposition; but usually 2-7 weeks elapse between the onset of first symptom and identifying the correct clinical diagnosis.[54]. Young children are more vulnerable because of thin skin and poor immunity.

As the eggs of *Dermatobia* are implanted by blood sucking porter insects, lesions are predominantly distributed in exposed body parts such as the limbs and head-neck. On the other hand, *Cordylobia* ovipositing on soiled linen are common in perineum, trunk, thighs and buttocks. Palms and soles are never affected.[54] Usually only one worm is seen per lesion. Rarely multiple maggots, as many as 28, have been be reported.[4,54] Coalescence of closely located lesions may create an illusion of multiple maggots within one lesion. *Dermatobia* lesions are usually single while that of *Wohlfahrtia* are in crops.

At the site of maggot penetration, itching or occasionally a sharp pain is felt. Children may scratch the entry site and cry unconsolably even before the appearance of a skin lesion. The larvae evoke strong immunological reaction at the entry point that they cause a red and tender furunculoid (boil-like) lesion of 0.2 to 2 cm size. Through a pathognomonic central punctum, the respiratory spiracles at the rear end of maggot are exposed to the atmosphere. Unless examined with a magnifying glass the punctum is easily missed. Exacerbated pain during night sleep, formication (a strange sensation of something crawling underneath the skin), paresthesia, a drop of sticky blood stained discharge through the punctum (excreta of the maggot), foul smell and crusting (dried ASEM) are usually seen. In a 5-year-old girl, pseudo-pulsation due to writhing of worms was mistaken for a vascular lesion.[56] Superadded bacterial infection results in diffuse cellulitis and purulent exudate with tiny gas bubbles. Regional lymphadenopathy and systemic symptoms are rare. In scalp lesions focal alopecia around the punctum is common. Morphological variation of lesion includes bullae, vesicles, abscess, ecchymosis, cellulitis, pustules and ulcers.[4]

When left untreated, furuncular myiasis heals spontaneously in 8-30 days when the matured pupae depart from the host. Lesions usually heal without leaving any trace; however, occasionally pigmentation, hypertrophic scar or keloids may result especially in malnourished children.[4]

Sanguinivorous (Blood Sucking) Maggots

Congo floor maggots typically live in soil, but approach the host during night time just for a blood meal. Their importance lies in transmission of diseases such as the African sleeping sickness.

Wound (Traumatic) Myiasis

Maggot infestation of soft-tissue wounds is caused by both facultative and obligate maggots.[3] *Cochliomyia hominivorax*, *Chrysomya bezziana*, and *Wohlfahrtia magnifica* are the most common species involved. In USA, 87% of wound myiasis (WM) is due to *Lucilia sericata, Phormia regina,* and *Cordylobia*.[8] *Cochliomyia* forms 62% of WM in Brazil. Other involved species are *Dermatobia, Musca domestica, Chrysomya megacephala, Parasarcophaga, Calliphora, Lucilia cuprina* and *Sarcodexia lambens.*

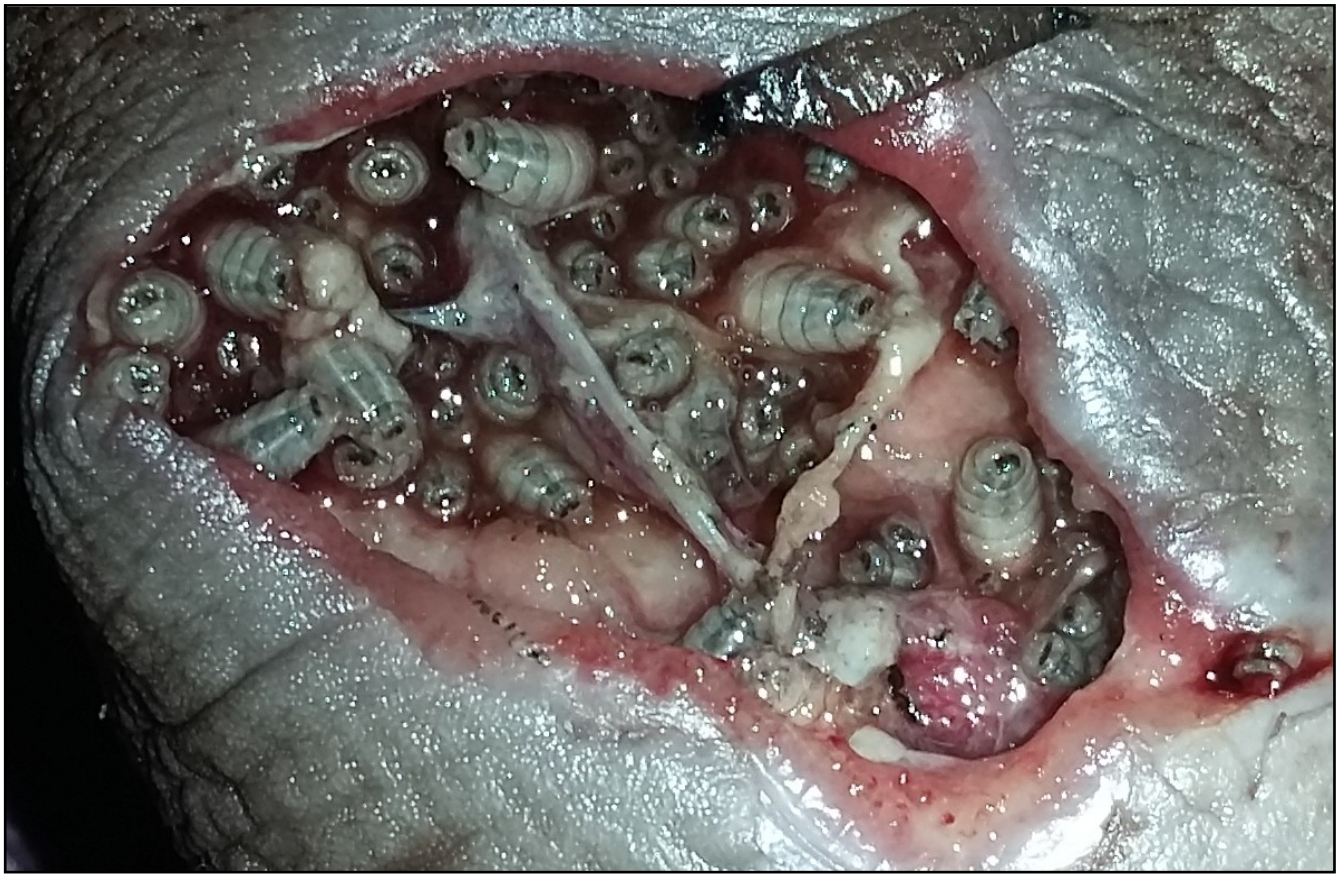

Fig 4. *Traumatic wound myiasis in a 10-year-old boy. The paired block dots are the exposed respiratory spiracles at the posterior end of the maggots. (© Raveenthiran)*

Usually only one species is involved, while in 3% of cases mixed species may be noted.[4,57] Presence of maggots attracts other flies to lay more eggs on to the wound.

Chrysomya bezziana and *Cochliomyia hominivorax* may cause severe pain by scratching with their sharp spines while crawling. There may be as many as 100-500 worms in the deep arborescent burrows of the wounds. (Fig. 4) Scanty amount of foul smelling blood-stained discharge is caused by the excreta of maggots. When necrotic tissues are exhausted, obligate maggots may start feeding on healthy tissue including the blood vessels and the underlying viscera.[52] Regional lymphadenitis is common.

Migratory (Subdermal or Creeping) Myiasis

Sometimes, an enthusiastic maggot starts migrating aimlessly and is doomed to get trapped deep inside the host tissues. Very rarely, the wondering worm may emerge out penetrating the overlying skin. Migratory lesions are of 2 types: the superficial itchy serpentine erythematous linear tunnels caused by *Gasterophilus* and the painful subcutaneous evanescent cysts caused by *Hypoderma*.[41] About 20% of *Cuterebra* and 2% of *Dermatobia* infestations become migratory myiasis. Ontogenic development of the wondering larvae is arrested depending upon the antigenicity of the species and the depth of migration. For example, migratory *Gasterophilus* larvae seldom pass beyond the first instar stage.

Migratory maggot is common in exposed body parts. The early symptoms are similar to that of furuncular myiasis. As the larva starts migrating, it leaves behind a trail of raised palpable serpiginous red lesion with its rear end healing and fading. Migration of *Gasterophilus* larvae is more bizarre and serpiginous than that of *Hypoderma*. Maggots may survive up to one month and may migrate 1-30 cm beneath the skin.[4,29] Exceptionally, *Hypoderma* can migrate as far as 2-30 cm in 24 hrs and as fast as 125-150 cm in 12 hrs.[4] Usually, larvae migrate in superficial planes, but rarely they may invade internal viscera. Migratory maggots may cause ascites, pleuro-pericardial effusion, regional or systemic lymphadenopathy, arthralgia, myalgia, scrotal edema and meningitis.[4] Neural invasion may cause paralysis of limbs, blindness or death.

Left untreated, migratory myiasis may get spontaneously cured, but with a varying degree of fibrosis and calcification of the dead worm.

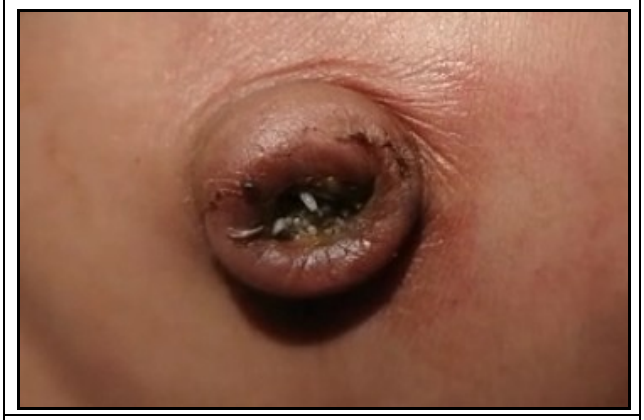

Fig 5. *Umbilical myiasis (© Raveenthiran)*

Umbilical Myiasis

Umbilical infestation is the commonest form of neonatal myiasis.(Fig.5) Fewer than 35 cases have been reported in the literature, of which 60% are from Nigeria and India.[58-61] The incidence is very high in Nigeria that, 12 out of 55 neonates (22%) examined for omphalitis were having myiasis.[60,61] It occurs between 2-20 days of neonatal life with a median of 7 days.[58,59] *Cochliomyia hominivorax*, *Chrysomya megacephala*, *Sarcophaga vilosa* and *Musca domestica* are the common species. Infestation is facilitated by local cultural practices such as applying cow dung or herbal paste made of oviposited leaves to the umbilical cord stump.[62] Omphalitis and portal vein thrombosis are the potential complications.

Nasal Myiasis

Nasal infestation forms about 11% of all myiasis in pediatric practice.[4,45,47] It is commonly due to *Cochliomyia hominivorax*, *Chrysomya bezziana*, *Oestrus ovis*, *Wohlfahrtia magnifica*, *Lucilia sericata*, *Drosophila* and *Calliphora vicina.* Nasal oviposition is facilitated by purulent rhinorrhea or when the protective sneezing reflex is impaired as in atrophic rhinitis, leprosy, rhinoscleroma and tuberculosis. Local pain, headache, mucopurulent rhinorrhea, epistaxis, blocked nose, mouth breathing and anosmia are the usual symptoms. Volley of sneeze expelling maggots is reported in 20% of the affected children.[4,63] In one case, as many as 388 worms were recovered.[19] Maggots slipping back into the throat, especially during night sleep, may cause nocturnal dry cough, dyspnoea, stridor, laryngospasm and even death.

Maggots may corrode even the bone and cartilage, thus leading to complications such as nasal septal perforation, orbital cellulitis, pharyngeal ulcers, saddle nose deformity, oronasal fistula, cerebrospinal fluid (CSF) rhinorrhea, pneumocephalus and meningitis.[4]

Aural Myiasis (Otomyiasis)

Ear infestation forms about 86% of all myiasis in children.[4,47] *Cochliomyia hominivorax*, *Wohlfahrtia magnifica*, *Chrysomya bezziana*, *Chrysomya megacephala*, *Sarcophaga* and *Parasarcophaga crassipalpis* are the common species of otomyiasis. Purulent otorrhea of suppurative otitis media is a risk factor. It is usually unilateral, involving the external auditory canal or middle ear. Rarely, it may be bilateral. It is common below 10 years of

age. The youngest reported patient was a 1-day-old newborn.[49] Passage of worms (81%), otalgia (41%), otorrhea (44%), ear bleed (50%), formication, itching (33%), foul smelling (83%), tinnitus, vertigo, restlessness, perforation of the tympanic membrane and deafness are common.[64] Affected young infants may bang their head without any obvious reason. It is not known if the tympanic membrane is actively perforated by the maggots or if it is a pre-existing lesion that attracted larvae. Worms lodged in the mastoid air cells are difficult to remove and they usually die and get calcified.

Oro-pharyngeal Myiasis

Since the first description by Lawrence in 1909, fewer than 70 cases of pediatric oral myiasis have been reported.[48] It is a form of WM due to poor oral hygiene and suppurative gingivitis. Sleeping with open mouth is a prerequisite for ovipositing. Thus, the risk factors include uncorrected cleft lip, noma, sleep apnea syndrome, adenoid enlargement, facial trauma and anterior open-bite dentition. Breast feeding infants may acquire invisible eggs from mother's unclean breast.[65] Rarely, oral myiasis is due to consumpsion of contaminated food or drink.

It is usually caused by *Cochliomyia hominivorax, Wohlfahrtia magnifica, Musca domestica, Chrysomya bezziana, Oestrus ovis, Hypoderma bovis, Hypoderma tarandi, Musca nebulo, Gasterophilus intestinalis and Calliphora vicina.* The angle of mouth, lips and anterior gingivae are frequently involved. Number of maggots retrieved vary from 1 to 112.[48] About 50% of the affected children are below 5 years of age.[48] Local pain, swelling, redness, halitosis, fornication, sore throat, retching, vomiting and dry cough are the common symptoms. Once, a fibrosed maggot in the submucosal plane was mistaken for a salivary adenoma.[66] Extensive tissue destruction may result in oro-facial or oronasal fistulae.

Ophthalmomyiasis

Eye involvement may be superficial involving the orbital socket and extraocular apparatus (ophthalmomyiasis externa, extraocular or orbital myiasis) or deep involving the chambers of the eye ball (ophthalmomyiasis interna, intraocular or ocular myiasis, ophthalmomyiasis profonde). They form 2% of all pediatric myiasis.[4] In a review of 27 cases of ophthalmomyiasis, there were 2 children, both males, aged 1.5 and 10 years respectively. In one of them maggots infested the empty socket following enucleation of the eyeball for retinoblastoma.[67]

Orbital myiasis involves conjunctiva and lacrymal apparatus. It is caused commonly by *Oestrus ovis and r*arely by *Rhinoestrus purpureus*, *Dermatobia hominis*, *Chrysomya bezziana*, *Lucilia* and *Cuterebra.* Onset of symptoms is dramatically sudden with a foreign body (gritty) sensation and excessive lacrimation. Other symptoms include epiphora, fornication beneath the eyelids, redness of the conjunctiva, photophobia, edema of the eyelids sub-conjunctival hemorrhage, pseudo-membrane formation and punctate keratopathy. The lesion is usually unilateral. Hard nodular lesion of eyelids caused by furuncular type maggots may mimic hordeolum. Number of maggots vary from 1-20. Orbital myiasis may spread to the nose by larvae creeping through the nasolacrimal duct and vice versa. If untreated, symptoms may last for 7-10 days before spontaneous resolution.

Ocular myiasis is a complication of orbital infestation. It affects the anterior or posterior chambers of the eyeball. Maggots may have penetrated the sclera using their strong oral hooklets; but the point of entry is often not obvious. The vitreous chamber is more often affected than the aqueous chamber. Ocular myiasis is more serious than the orbital form, as it endangers the vision. Although, a single worm is usually found inside the eyeball, cases with as many as three worms and bilateral involvement have been reported in the literature.

Anterior chamber myiasis may mimic the uveitis. Eyeball myiasis causes redness of eye, floaters, ocular pain, blindness and scotoma. *Hypoderma tarandi* is more aggressive in causing blindness. Fundus examination may show typical dead worm floating in the vitreous humor. Maggots crawling beneath the retina may leave behind atrophic retinal pigment-epithelial tracks with a characteristic crisscross pattern. Vitreous hemorrhage, fibrovascular proliferation, exudative retinal detachment and retinal scarring are the serious complications of ocular myiasis.

Tracheal (Tracheostomy) Myiasis

Maggots may complicate tracheostomy wounds especially in mentally retarded children.[68] It is commonly due to *Chrysomya bezziana, Cochliomyia hominivorax, Lucilia sericata* and *Musca domestica*.[68]

Urogenital Myiasis

Vaginal (female genital) myiasis

Vaginal infestation is predisposed by not wearing undergarments. Dysuria, genital itching and foul smelling leucorrhea are common. Rarely, vaginal maggots may crawl into uterine cavity; but more commonly the prolapsed uterus in meningomyelocoele is colonized.[69,70]

Preputial, penile or scrotal (male genital) myiasis

Fewer than 6 cases of genital myiasis have been reported in male children[71-73] and the youngest was 7-months old.[73] *Cordylobia anthropophaga* and *Dermatobia hominis* are the commonly isolated species.[73] Although the preputial sac of phimotic boys may get infested, more often furuncular lesions occur on the penile shaft and the scrotum. An 8-year-old boy with scrotal myiasis was mistaken for testicular torsion.[74] A 3-year-old boy with preputial myiasis was mistakenly treated with antibiotics for balanitis.[75]

Urethral (internal urogenital) myiasis

Migratory maggots may rarely reach the urethra or bladder and get mummified. *Megaselia scalaris*, *Psychoda albipennis*, *Eristalis tenax*, *Fannia canicularis, Piophila, Fannia scalaris*, and *Muscina stabulans* are the commonly retrieved species from the bladder. Urinary symptoms include dysuria, lumbago, hematuria, sterile pyuria, albuminuria, uroliths and acute retention of urine. Cystoscopy is not only diagnostic but also therapeutic.[76]

Bone and Joint (Pin-site) Myiasis

Interestingly, maggots that were historically used to treat chronic osteomyelitis, are also considered aa a disease when they occur spontaneously in the exposed bones. 'Pin-site myiasis', a form of WM, occurring at the site of external fixator pins is a well known to complicate Ilizarov procedure in adults and children.[77] Fungating osteosarcomas with myiasis are fortunately rare nowadays.[78] Creeping maggots may detach mucoperiosteum from the bone cortex thereby causing excruciating pain and new bone formation.

Cerebrospinal Myiasis

Since the first description in 1939 by Frumin and Katsnelson[79] fewer than 20 cases of cerebral myiasis have been reported in the world literature, of which 30% are in children.[80,81] It is often a complication of orbital, aural or nasal infestation.[79,82,83] Nasal maggots invade the frontal lobe (38%), while aural larvae invade the temporal lobe (14%).[80] In 19% of cases, they occurred following head injuries.[Ramon] Frequently, the trailing end of the migratory tunnel of maggots heals completely that the route of entry into the brain remains undetectable in 33% of cases.[80,82] The youngest reported patient was a 5-month-old infant, in whom *Dermatobia* maggots from a scalp wound penetrated the anterior fontanelle to cause fatal cerebral myiasis.[84] The commonly involved species are *Hypoderma bovis* (14%), *Lucilia sericata* (5%), *Dermatobia hominis (14%)* and *Hypoderma lineatum* (5%), the duration of symptoms

ranges from 10 days to 2 years.[81] Non-specific chronic headache, seizures, altered sensorium, motor paralysis, intracranial hypertension and extra-pyramidal symptoms are the common symptoms. Interestingly, associated meningitis is rare due to the bacteriostatic property of ASEM.[80]

Gastro-intestinal Myiasis

The first adult patient of intestinal myiasis was reported by Herms and Gilbert in 1930.[85] It is a form of pseudomyiasis due to accidental ingestion of tiny maggots in contaminated food or drink. Oropharyngeal maggots may also get swallowed. The youngest patient was 1-year old.[85] The cuticle of maggots can withstand the corrosive action of gastric acid. In fact, 2 children with gastric infestation have been described.[85] *Sacrophaga haemorrhoidalis* is the commonest gastro-intestinal maggot in the Indian subcontinent.[85] Other reported species are *Fannia canicularis*, *Hermetia illucens*, *Piophila casei*, *Muscina stabulans*, *Megaselia scalaris*, *Eristalis tenax*, *Musca domestica*, *Phormia regina*, *Lucilia cuprina*, *Tubifera* tenax, *Sarcophaga crassipalpis, Sarcophaga peregrina* and *Stomoxys calcitrans.* Concomitant helminthic infestations are common in intestinal myiasis. Asymptomatic passage of maggots in stool or vomitus is not rare. But it should carefully be differentiated from post-defecation contamination from the environment. Vague abdominal colic, flatulence, dyspepsia, rectal bleed, nausea, hematemesis, vomiting and perianal itching are the frequent symptoms.[85,86] Duration of symptoms may range from 2 weeks to 5 years.[85]

Anorectal Myiasis

In 1972, Aspock reported the first and youngest case of rectal myiasis in a 4-month-old boy due to *Fannia canicularis*.[87] Since fewer than 10 cases of rectal myiasis have been reported in the pediatric literature. Usually eggs are laid in the perineum and the hatched maggots crawl into the rectum. A 12-month-old infant got infested by consuming contaminated over-ripe banana.[88] A 4-year-old Indian girl developed *Chrysomya bezziana* larvae on the surface of prolapsed rectum.[89] Rectal myiasis causes bleeding which may be just blood streaks in stool, dripping at the end of defecation or frank bloody diarrhea.[90,91] A 8-month-old with *Sacrophaga* infestation passed hundreds of worms in bloody diarrhea.[91] In a 2-year-old girl, rectal myiasis due to *Parasarcophaga crassipalpis* was associated with Salmonella food poisoning.[92] Recto-perineal fistula has been reported in association with anorectal myiasis.[93]

Pulmonary Myiasis

Lung infestation is a form of pseudomyiasis due to *Cuterebra, Alouattamyia baeri*, *Megaselia spicularis*, and *Gasterophilus.* Maggots reach the lungs either by aspiration from oro-pharyngeal lesions or through pleural space from chest-wall wounds. Brassy cough, blood tinged sputum and wheezing are the common symptoms. Chest x-ray or CT scan may show coin-shaped opacity or calcification.[94]

Nosocomial and Epidemic Myiasis

In 1980, Mielke and Schlote first reported hospital acquired myasis.[4,95] It is rare in rich countries and is under-reported from poor countries. As a result its exact incidence is not known. Although it can be easily dismissed as a deficiency of medical services, true hospital and community outbreaks have been reported, especially from intensive care units and preterm nurseries.[95-99] It is commonly due to *Lucilia sericata*, *Megaselia scalaris*, *Sarcophaga, Cochliomyia hominivorax* and *Musca domestica*. Nasal and ostomy infestations are common.

DIFFERENTIAL DIAGNOSIS

The diagnosis of myiasis is straightforward when the worms are clinically visible. On the other hand, when they are hidden in deep burrows, the lesion may be mistaken for a variety of diseases. (Table 6) Particularly, pseudomyiasis poses considerable diagnostic challenge. Detailed travel history and careful clinical examination are the key for correct diagnosis.

Table 6. Differential diagnosis of pediatric myiasis

Clinical Type	Differential Diagnosis
Aural	Otitis externa, Suppurative otitis media, Eustachian catarrh, Foreign body
Furuncular	Delusional parasitosis, Furuncle (Boils), Cellulitis, Insect bite allergy, Infected sebaceous cyst, Tungiasis, Pyoderma, Herpes, Hemangioma, Arteriovenous malformation, Prickly heat (Miliaria)
Migratory	Cutaneous larva migrans, Gnathostomiasis, Sparganosis, Hyper-eosinophilic Syndrome
Nasal	Sinusitis, Upper respiratory tract infection, Allergic rhinitis, Foreign bodies of nose, Atrophic rhinitis, Rhinoscleroma, Leprosy, Tuberculosis
Ocular	Retinal Detachment, Uveitis, Cavernous sinus thrombosis, Chorio-retinitis, Endophthalmitis
Orbital	Foreign body, Conjunctivitis, Keratitis, Peri-orbital cellulitis, Uveitis, Chalazion, Benign floaters
Oropharyngeal	Pharyngitis, Salivary adenoma, Diphtheria, Peritonsillar abscess, Agranulocytosis, Dental abscess
Penile	Balanitis, Urinary Tract Infection, Urethritis
Pulmonary	Branchial Asthma, Eosinophilia Syndrome, Pulmonary larva migrans
Rectal	Fissure-in-Ano, Rectal Polyp, Intussusception, Enterobiasis
Scrotal	Torsion of testis, Idiopathic scrotal edema
Umbilical	Omphalitis, Patent vitello-intestinal duct
Vaginal	Foreign body, Vulvo-vagnitis

INVESTIGATION

Maggots in deep burrows can be easily seen using a magnifying lens or dermascope. Bright light should be avoided during physical examination. Subcutaneous maggots can be made to wriggle and their movement can be observed by smearing the affected area with liquid paraffin. The mineral oil not only blocks the ventilatory punctum and causes the larvae to writhe in suffocation, but also makes observation of their movements easier by reflecting the light.

Endoscopes such as bronchoscope, nasopharyngoscope, otoscope, sigmoidoscope and cystoscope are useful not only in diagnosis but also in therapeutic removal of maggots. Ophthalmomyiasis necessitates slit lamp examination. However, it is essential to paralyze the maggots with topical anesthetics (lignocaine or cocaine), lest the photophobic worms migrate deeper inside the tissues on examination with a bright light.

Maggots hiding in deeper tissues can be visualized by ultrasonography using a high frequency (10-18 MHz) probe.[100] The larvae are seen as echogenic spindle-shaped structures within hypoechoic fluid filled burrow and pulsatile blood vessels in the periphery (the Bouer's criteria).[100] The thick cuticle and spines of maggots cast distal acoustic shadow.[100] In longitudinal sections of the worms, undulations of the body segmentation may be appreciated. Doppler ultrasonography is 100% sensitive in demonstrating the wriggling movements of maggots.[54,100] Computed tomographic (CT) scan and magnetic reesonance imaging (MRI) are not more useful than Doppler ultrasound in cutaneous myiasis. However, they together with plain x-rays are useful in pulmonary, mastoid, cerebral or bone myiasis.

Hematological investigations are suggestive but not specific of myiasis. For example, *Dermatobiasis* which mimics an abscess will cause eosinophilia rather than neutrophilic leukocytosis.[2]

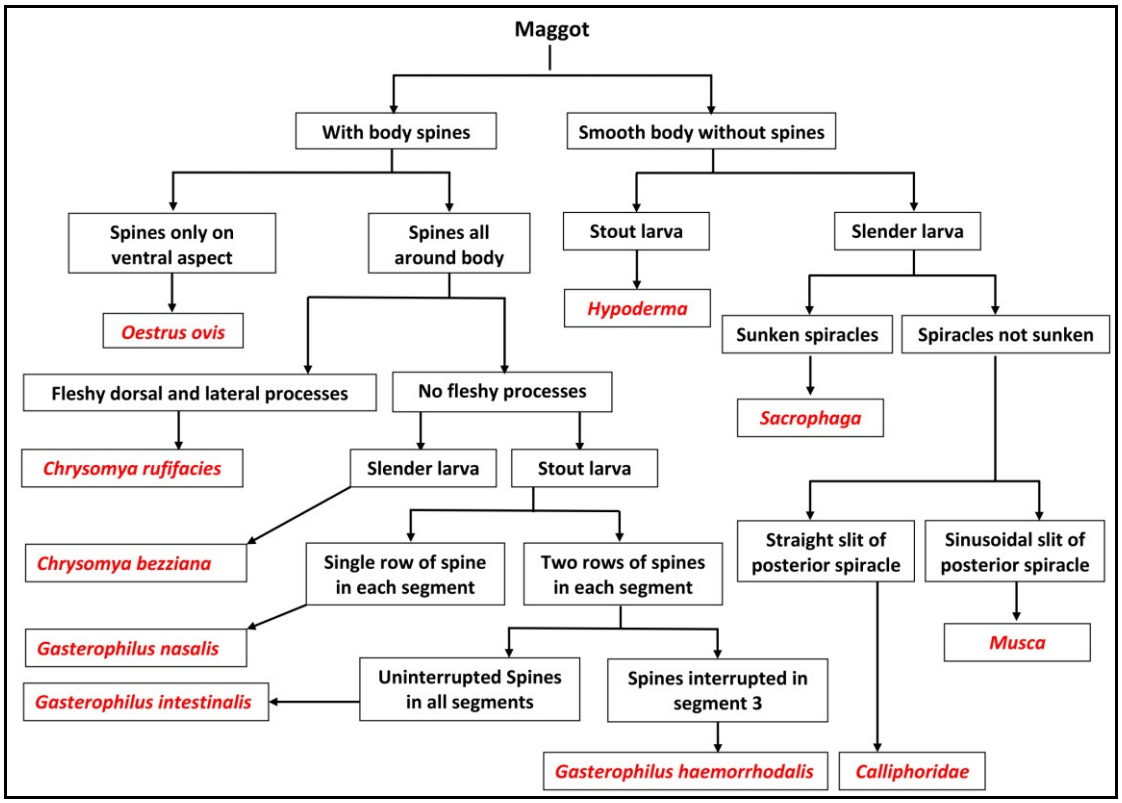

Fig 6. *Dichotomous, maggot identification key. (Based on the data from the School of Veterinary Sciences, University of Queensland) https://shire.science.uq.edu.au/bb/parasitology/maggots/mag got.html*

High levels of IgE, elevated C-reactive protein and increased erythrocyte sedimentation rate may be present.

Attempted development of serodiagnosis has not been successful because of antigenic cross reactivity between various species.[2] However, the exception is *Hypoderma*. It periodically releases hypodermin C, an antigen which can be diagnosed by enzyme-linked-immunosorbent serologic assay (ELISA) technique.[2] Polymerase chain reaction (PCR) aided testing of cytochrome oxidase-I (COI) of mitochondrial DNA is also used in the diagnosis of *Hypoderma*. Indirect haemagglutination test and double immuno-fluorescence test with crude antigenic extracts can detect the first and second instar larvae. But these techniques are less sensitive for third instar larvae. An intradermal injection test is used to diagnose *Gasterophilus* infestations in animals.[2,3]

Fine-needle aspiration cytology (FNAC) and tissue biopsy are usually not indicated. However, Pogany demonstrated that an unspecified species of larva could be aspirated from a neck mass using a 23G needle.[101] Obviously maggots with sharp body spines, such as the *Dermatobia,* can not be aspirated. Needle puncturing of maggots may leave them killed in deep burrows making their removal difficult and may cause leaking of toxic body fluids provoking anaphylaxis. Hence, FNAC cannot be recommended for routine clinical use.

Exact species identification of maggots extracted from lesions is not essential for the clinical management of myiasis. Further, required entomological expertise is not readily available in many resource limited centers. For these reasons, most of the reports on myiasis do not mention the infesting species. However, academically it is desirable to establish the taxonomic identity of the

parasite. Maggots are identified by their external morphology. (Fig. 3) Third instars are easier to identify than the first two instars which lack the characteristic morphological features. Hence, preserving the retrieved maggots without any structural alteration is essential. Formalin is not an ideal preservative as it causes shrinkage and hardening artifacts. The extracted worms are transported to entomology lab after being killed in hot (but not boiling) water and preserved in 70% alcohol. When the services of a trained entomologist is not available, the dichotomous Maggot Identification Key available online at the website of the University of Queensland[102] can be of great help to practicing pediatric surgeons. (Fig. 6)

As identification of adult flies is easier than that of the larval forms, some entomologists recommend maggot culturing on raw meat or Robertson cooked meat medium allowing them to mature in the laboratory.[85] More recently, molecular diagnostics are applied for accurate identification of the maggot species.[3]

TREATMENT

When left untreated, myiasis may spontaneously resolve when the larvae mature into pupae and leave the host. Further, maggots are also therapeutically used in healing chronic ulcers (*vide infra*). Therefore, one may wonder if it is essential to treat naturally occurring WM as a disease. It is to be emphasized that all naturally occurring maggots should be removed from wounds because of the uncertainty of the species involved and because of the risk of superadded bacterial infection and tissue damage.[103] It is to be remembered that not all maggots are beneficial.[104] Some of the obligate parasites may cause extensive tissue damage, hemorrhage and death of the host.[84,51,52] Wild maggots may also transmit infections like tetanus, gas gangrene and synergistic necrotizing fasciitis.[104] Therefore, all clinical myiasis should be treated as a disease. [103]

Manual (Mechanical) Removal

The best method of removing maggots is gentle manual picking with forceps.[105,106] Alternatively gargling, syringing, rinsing, sternutatories, purgatives (polyethylene glycol) and mouth washes can be appropriately used in removing surface larvae. Removal of worms from the deep dermis is often aided by squeezing with a wooden spatula. Optical magnification (e.g. handheld lens, dermascope or operating microscope) is helpful, especially in cavity myiasis. But, photophobic larvae frequently hide in deep burrows and are not easily accessible. Usually multiple session are required for complete removal of all the worms. Maggots may also resist removal by firmly anchoring to the host tissues by using oral hooklets and body spines. Forced extraction results in rupturing of maggots and incomplete removal. Left over dead maggots may cause anaphylatic shock or foreign body reaction. *Dermatobia* is very resistant to manual extraction due to innumerable stiff body spines.[107] Their attempted removal is not only painful but also unsuccessful with the risk of rupturing the larva. Tiny cruciate incisions are often used to remove them furuncle.

Several chemical agents have been used either to to facilitate manual removal of maggots or to kill them. They include asphyxiants, vermifuges, baits, larvicides and paralyzers.

Asphyxiants

Maggots are highly photophobic that burry their head-end deep inside the tissues. However, they keep their rear-end spiracles exposed for breathing. Blocking their atmospheric access make them suffocated and cause them move out of burrows seeking fresh air.[2] This property of maggots is exploited in treating them. Liquid paraffin is the ideal agent as it not only asphyxiates the worms but also lubricates their removal from burrows. Alternatively, covering the area with an adhesive tape or ointments (e.g. Polymyxin B) can be used. Occlusion of the punctum for 24 hr may be

required to achieve the desired effect. It is important to avoid tight occlusion which may kill the worms instead of making them just uncomfortable. A dead worm can never be extracted from arbores-cent burrows. Intense inflammatory reaction evoked by a dead worm may actually be more troublesome than the presence of live worms.

Vermifuges

Mild chemical irritants are ideal as they cause maggots to move out of burrows. Turpentine oil is the oldest known vermifuge which is still being used in modern medicine. It was first recommended in 1870 by Center who experimented with 20 different chemicals.[18] Calomel is said to be more effective and less painful than turpentine as they neutralize ASEM in addition to causing worm irritation.[19] Natives of Bengal use extract of the plant *Ocimum sanctum* (Holy Basil or Tulasi).[19]

Paralyzers

Drugs like lignocaine, 15% chloroform in olive oil and ether temporarily paralyze the maggots and facilitate their manual extraction.[107] Lignocaine has the added advantage of reducing pain to the host. Although these agents do not kill the worms, the stupefied maggots may remain in deep tunnels thus become inaccessible for manual picking. Liquid nitrogen may stiffen the larvae facilitating their easy extraction.

Laser Destruction

Although manual removal of wild maggots is always desirable, the only exception is ocular myiasis. Subretinal and vitreous maggots are often killed with laser and left in situ without any active efforts to remove them. This is supplemented with drugs to suppress inflammation (topical steroids and mydriatics). Only those maggots floating in the visual axis require surgical removal. Rarely affected eye may need to be enucleated to prevent sympathetic ophthalmia and intracranial extension of the infestation.

Larvicides

Larvicidal chemicals are generally not preferred for the following reasons: (1) They leave behind dead maggots in deep burrows provoking strong inflammatory reaction; (2) Sudden release of large amount of toxins from the killed maggots may precipitate anaphylactic shock; (3) The chemical agents, when absorbed into the host circulation, may cause systemic toxicity; (4) They pollute the environment; (5) Insects are known to develop resistance to pesticides. However, larvicides are occasionally used in aggressive maggots such as *Dermatobia*, *Wohlfahrtia, Cochliomyia*, *Chrysomya* and *Oestrus ovis*. They are also indicated when the maggots are wandering inaccessibly in deeper tissues or when their removal is deemed to cause more damage to the host tissues.

Several pesticides including organo-phosphorus compound have been successfully used in animals and human adults. (Table 7) However, their safety and efficacy in children are not yet well stablished. Among the slow-acting larvicides, ivermectin has been extensively studied.[2,108-111] It causes release of gamma-amino-butyric acid which is toxic to maggots. Ivermectin is used as topical paste (1% solution in propylene glycol applied for 2 hr), oral tablet (15 μg/kg per day; maximum 400μg/kg) or as subcutaneous local injection around the lesion. Topical ivermectin has the risk of converting WM into migratory myiasis by repelling the maggots into deeper tissues. Oral ivermectin is ideal for migratory myiasis although they have the disadvantage of leaving behind the dead larvae in the host tissues. Rarely, spontaneous external emigration of worms with oral ivermectin has been reported. At the oral dosage of 200 μg/kg (single dose) ivermectin kills 99% of WM.[2] Topical trichlorphon kills larvae within 28-52 hr of application while ivermectin does so at 50-64 hr.[2] Mesalazine, albendazole, mebendazole, and levamizole are other alternatives to oral ivermectin. They are specifically used in intestinal myiasis. In a case of rectal myiasis due to *Fannia canicularis* levamizole

Table 7. Drugs and chemical used in the treatment of maggots

Rapid Larvicides (mostly of topical use)[2]
- Chlorfenvinphos*
- Chlorpyrifos*
- Closantel * (oral, topical, IM)[2]
- Coumaphos*
- Crotoxyphos *
- Crufomate *
- Cyromazine*
- DDT *
- Decamethrine *
- Diazinon*
- Dichlofenthion*
- Dichlorvas*
- Fenchlorphos*
- Fenthion *
- gamma-BHC*
- iodofenphos*
- Lufenuron *
- Milbemycin*
- Moxidectin *
- Phenylbutazone
- Phosalone*
- Propoxur*
- Rafoxanide * (oral or IV Use) [2]
- Temephos *
- Tetrachloroethylene (oral)[85]
- Thymol (enema)[85]
- Toxaphene (Camphechlor)*
- Trichlorphon * (topical)

Slow larvicides (systemic or topical use)
- Abamectin* (subcutaneous)
- Albendazole †
- Avermectin*
- Clindamycin †
- Decamethrin*
- Doramectin* (subcutaneous)
- Ivermectin † (oral, topical, subcutaneous, IV)
- Levamizole
- Milbemycin*
- Moxidectin*

(Continued)

Vermifuges (Topical use)
- Carbolic acid[18]
- Hydrogen peroxide
- Mercurials [18]
- Phenol
- Potassium permanganate
- Povidone iodine
- Sodium hypochlorite
- Tobacco juice [18]
- Turpentine oil [18]

Paralyzing Agents (Topical use)
- Chloroform[31]
- Ether
- Ethyl chloride
- Lignocaine
- Liquid nitrogen

Worm asphyxiants (Topical use)
- Butter
- Chewing gum[54]
- Dipping affected part in water
- Hydrocolloid dressing[54]
- Nail polish[54]
- Olive oil
- Paraffin wax or oil
- Pine oil
- Resins or glues[54]
- Sealing with cello tapes
- Vaseline (petrolatum jelly)

Baits
- Bacon
- Lard[54]

Agents of Unknown mechanism
- Calomel
- Mesalazine[90]
- Nitrofurazone 0.2% (Topical)
- Polymyxin B (Topical)
- Warm water immersion[54]

Compiled from: Hall,[2] Cedello,[54] Center[18]
** These agents are extrapolated from veterinary and adult practices. Pediatric experience with them is almost non-existent. Their safety in children is yet to be studied.*
† The 3 are given together as triple therapy
BHC - Benzene hexachloride, DDT - Dichloro-diphenyl-trichloro-ethane

was useful when albendazole was ineffective.[90] A triple therapy of oral ivermectin (15 mg/kg/d for 3 days) followed by clindamycin (300 mg t.i.d for 5 days) and albendazole (400 mg b.i.d for 3 days) has been used successfully.[48,111] However, it must be emphasized that pediatric experience with these larvicidal agents is very limited.

Baits

Bacon therapy, a form of baiting, is known to ancient Indians (*vide supra*). In 1993, Brewer et al from Massachusetts General Hospital 'rediscovered' it [14,17] without any reference to Sushruta who described exactly the same technique 3000 years ago. Within 3 hr of applying raw bacon fat the worms attracted by the smell will come out which then can be manually removed.[112] On careful analysis of the published descriptions, the modern bacon therapy appears to act more like an asphyxiant rather than as a bait.

Surgical debridement

Flies are principally attracted towards necrotic wounds. Hence, it is logical to do complete surgical debridement both as therapy and prophylaxis. However, this is inappropriate if vital organs are involved.

Antibiotics

Bacterial infections not only attract gravid flies but also can occur as a complication of myiasis. Therefore, concomitant administration of broad spectrum antibiotics and tetanus prophylaxis are indicated in all patients with myiasis.[113]

COMPLICATION

It is not clear as to whether all the complications of myiasis are attributable to the larvae or to the predisposing necrotic wounds.[53] For example, tetanus is a well known complication of myiasis; but it may just be due to the original trauma. Complications of myiasis may be general or site and species specific. There are some evidences to say that complications are becoming infrequent with modern treatment. For example, palatal perforation in nasal myiasis fell from 12% in 1980 to 2.5% in 2004.[27] Site specific complications are already described above in respective subsections.

Maggots transmit several helminthic, viral and bacterial diseases. Eggs of *Ascaris, Enterobius* and *Trichuris* remain undigested in the gut of *Lucilia sericata*.[114] Diseases like typhoid, pasturella, kala azar, shigella, anthrax and polio are known to be transmitted by maggots.[114]

Prions are infectious protein particles that cause serious neurodegenerative diseases like spongiform encephalopathy, Creutzfeldt–Jakob disease and Kuru. It is suspected that maggots may be vectors and reservoirs for horizontal transmission of prions.[115] In fact, prion has been isolated from *Sarcophaga carnaria* maggots and adult *Drosophila melanogaster*.[115] Prion proteins replicate inside the maggots' nervous system using the larval DNA. It remains to be confirmed if children with myiasis develop neurodegenerative diseases in adult life.

PREVENTION

Prophylaxis of wound myiasis includes eradication of flies and preventing their access to wounds. Spraying insecticides and proper garbage disposal will largely control breeding of flies. Pine oil repels gravid flies.[2] Biological larvicides such as *Tolypocladium niveum* (a fungus), *Bacillus thuringiensis* (a bacteria) and *Macrocheles muscaedomestica* (a mite) are used to kill maggots in garbage.[2] Genetic control by the laboratory bred sterile male flies is shown to be effective in reducing fly-population.

Children should be prohibited from sleeping out door and playing nude without undergarments. Contact with farm animals should be restricted and monitored. Drying clothes in bright sunlight and ironing them with hot press are effective against *Cordylobia*.[75]

Anti-maggot vaccines were tried with great enthusiasm. Maggots are too large to be affected by the host phagocytes. But, host antibodies can kill them by binding the peritrophic membrane in the larval gut, when they feed on the host serum.[2] However, the attempts of vaccine development were not successful due to antigenic cross reactivity.[2] The third stage instars also develop defense mechanism against the host immune cells and antibodies. Recently, Hypodermin A&B the digestive enzymes of *Hypoderma* are found to be suitable target antigens for vaccine production.

Livingston topically applied a jelly made of ground maggots to prevent myiasis. Its effectiveness is attributed to the ASEM present in the paste. But, this was soon discarded as the paste evoked more allergic reactions and inflammation.

PROGNOSIS

Recurrent infestation is reported in 15% of nasal myiasis and it increases to 80% when associated with suppurative rhinitis.[19] About 1% of nasal myiasis,[4] 8% of otomyiasis,[64] and 5% of ophthal momyiasis[68] cause death by meningitis. Cerebral myiasis has the highest mortality of 50%.[80] Death may not be exclusively attributed to the presence of maggots.[53] Rather, the original suppurative condition that predisposes to myiasis and secondary bacterial infection should also be accounted. Interestingly, maggot infested wounds are less often associated with systemic sepsis, a phenomenon attributed to bacteriostatic properties of the ASEM.

MAGGOT THERAPY

Maggot therapy (MT, also known as larval therapy or biosurgery) is a form of iatrogenic WM.[38,116-118] Among the several species of maggots (Table 8), *Lucilia sericata* has been extensively studied as a therapeutic agent.[24] Interestingly, it is a serious pest causing fatality in farm animals.[2] Maggots are said to promote the healing of chronic wounds by 3 different mechanisms: (1) Enhancing wound debridement, (2) Microbial disinfection and (3) Promoting cellular proliferation. Each of these goals is achieved by several physical and chemical properties of maggots.

Table 8. Commonly used medicinal maggots

Calliphora vicina
Chrysomya rufifacies
Lucilia caesar
Lucilia cuprina
Lucilia illustris
Lucilia sericata *
Musca domestica
Phormia regina
Protophormia terraenovae
Wohlfahrtia nuba †

** Most commonly used species*
† When necrotic tissues are exhausted, they notoriously start feeding on healthy tissue

Wound Debridement

Medicinal maggots (MM) with body spines, while crawling, scrub the wound that loosens necrotic debris and breaks biofilm (a layer of coagulum under which bacteria thrive protected from the attacks of immune cells and antibiotics). By breaking biofilms, MM improve antibiotic penetration. ASEM contain proteolytic enzymes such as the matrix metallo-proteinase(MMP), trypsin-like and chymotrypsin-like serine protease, leucin-amino-peptidase, carboxy-peptidase and collagenase that are resistant to human wound protease inhibitors. These digestive enzymes liquefy necrotic tissue and biofilms which are subsequently consumed by the MM. Each maggot is estimated to eat up 25-30 mg of necrotic debris in 24 hr.[24, 38] Being a facultative maggot *Lucilia* does not cause any damage to the viable host-tissue. MM do not affect the functioning of host immune cells or inflammatory repairs.

Infection Control

The natural habitat of maggots is decaying matters and feces. Hence, they are endowed with natural protection against bacteria. This is attributed to the antibacterial chemicals in ASEM such as the urea, calcium carbonate, ammonium bicarbonate, lucifensin, diptericin, allantoin, calcium picrate, picric acid, phenyl-acetaldehyde and phenyl-acetic acid. Deoxy-ribonuclease (DNAse) present in ASEM not only facilitates breaking of biofilms, but also inhibits bacterial proliferating. Aelloferons in ASEM are capable of inhibiting even viruses and protozoa like *Leishmania*. ASEM also alkalinizes the wound pH and make it hostile for bacteria. By all these mechanisms, MM significantly reduce the microbial population of the wound.

Epithelial Proliferation

Physical crawling of larvae stimulates the electrical potential of the repairing cells and releases epithelial growth factors. Chemicals in ASEM such as the cysteine, glutathione, sulphydryl radicals and haemolymph are shown to stimulate the growth of fibroblasts, endothelial cells, angiogenic cells and neural cells. They also promote fibroblast migration, vascular perfusion, tissue oxygenation and phagocyte maturation. ASEM inhibits generation of superoxide and release of myeloperoxidase from activated neutrophils, thereby down-regulates inflammation. This is further enhanced by increased synthesis of cyclic AMP in neutrophils. Although MM subdue host inflammation, they do not affect phagocytosis or apoptosis. Cytokines like IFNγ and IL-10 in ASEM promote healing. MMP in the ASEM has positive influence over hemostasis, thrombosis, keratinocyte migration, collagen degradation and tissue remodeling. They also increase epithelial growth factor and interleukin-6-stimulated fibroblasts. ASEM causes macrophages and neutrophils to switch from their original pro-inflammatory role to pro-angiogenic function. ASEM inhibits complement activation and breaks down C3 and C4 proteins.[38]

Techniques of Maggot Application

The number of MM required for therapy varies between 5 and 600 according to the size of the wound.[117,118] There are two different methods of applying MM to the wound: In *free-range therapy* they are directly applied to crawl on the wound. However, this is not well received as children are terrified by creeping worms. In *biobag method* MM are not directly applied to the wound. Rather they are kept in nylon bags with tiny pores of 100-400 micron size. These biobags, when applied to the wound, allow seepage of ASEM, thus providing the benefits of chemical action.[119] Several studies have shown that biobag method is less effective than free-range therapy as it deprives the benefits of physical action of maggots.

Demerits of Maggot Therapy

Anxiety and repulsion of patients, foul smell of the ASEM and aesthetic unacceptability are the major demerits of MT. Further, the duration of treatment is very prolonged, that two cycles of 48-72 hr therapy sessions per week for 3-4 weeks is needed for complete wound debridement. The beneficial effects of maggots are short lived, that they need to be applied as 'maintenance therapy' even after achieving complete debridement until the wound heals completely. Some of the randomized controlled trials have questioned the very benefits of MT.[120]

Although MT inhibit *Pseudomonas* and Gram positive organisms (*Staphylococcus aureus* and Group A&B *Streptococcus*), they actually increase the population of gram negative bacteria (*Escherichia coli* and *Proteus*). This is probably due to the reduced competition from Gram positive bacteria. MM in fact develop symbiosis with *Proteus* in their gut to facilitate synthesis of bacteriostatic chemicals in ASEM.

MT is contraindicated near body cavities, orifices and fistulae where physical removal of maggots at the completion of therapy will be difficult. Other

contraindications of MT include life endangering or limb threatening infections, acute gangrene, and wounds close to great vessels.[38] Ammonia present in ASEM may get absorbed and cause toxicity especially in children with liver impairment.

Pediatric Experience with Maggot Therapy

Although extensively studied in adults with leg ulcers, MT is very rarely used in children.[121-123] In 1931, William Baer used wild maggots to treat more than 100 children with osteomyelitis and soft tissue wounds.[12,23] Subsequently the enthusiasm with MT was dampened by the availability of broad-spectrum antibiotics and by the entomophobia of children. Recently, few case reports have appeared in the pediatric literature.[121-123]

EPILOGUE

Although there are several randomized controlled trials (RCT) on 'maggot therapy' there are none on the 'therapy of maggots'. It is difficult to design an RCT because of the heterogeneity of the involved larval species. Most of our understanding about myiasis is derived from veterinary practice. Global warming, climate change and international travels are expected to change the clinical pattern and incidence of myiasis. Growing resistance of flies to insecticides may, in future, significantly affect the treatment and its outcome.[3]

REFERENCES

[1] Zumpt F. Myiasis in man and animals in the Old World. Butterworths, London, 1965.

[2] Hall M, Wall R. Myiasis of humans and domestic animals. Adv Parasitol 1995; 35: 257-334.

[3] Hall MJ, Wall RL, Stevens JR. Traumatic Myiasis: A neglected disease in a changing world. Annu Rev Entomol. 2016; 61: 159-76.

[4] Francesconi F, Lupi O. Myiasis. Clin Microbiol Rev. 2012 Jan; 25(1): 79-105.

[5] Caumes E, Carrière J, Guermonprez G, Bricaire F, Danis M, Gentilini M. Dermatoses associated with travel to tropical countries: a prospective study of the diagnosis and management of 269 patients presenting to a tropical disease unit. Clin Infect Dis. 1995 Mar; 20(3): 542-8.

[6] Diaz JH. The global epidemiology, public health outcomes, management, and prevention of reemerging ectoparasitic diseases. *Trop Med Health 2008;* 36(1): 1-10

[7] Pechter EA, Sherman RA. Maggot therapy: the surgical metamorphosis. Plast Reconstr Surg. 1983 Oct; 72(4): 567-70.

[8] Sherman RA, Hall MJ, Thomas S. Medicinal maggots: an ancient remedy for some contemporary afflictions. Annu Rev Entomol. 2000; 45: 55-81.

[9] Collier R. Medicinal maggots cross border at a crawl. CMAJ. 2010 Feb 9; 182(2): E123-4.

[10] Hall M, Donovan S. Forensic entomology: what can maggots tell us about murders? Biologist (London). 2001 Dec; 48(6): 249-53.

[11] Greenberg B. Flies through history. In: Greenberg B (ed). Flies and Disease - Vol 2. Princeton University Press, New Jersy, 1973. pp 2-18.

[12] Whitaker IS, Twine C, Whitaker MJ, Welck M, Brown CS, Shandall A. Larval therapy from antiquity to the present day: Mechanisms of action, clinical applications and future potential. Postgrad Med J. 2007 Jun; 83(980): 409-13.

[13] Parke EC. Flies from meat and wasps from trees: Re-evaluating Francesco Redi's spontaneous generation experiments. Stud Hist Philos Biol Biomed Sci. 2014 Mar; 45: 34-42.

[14] Bhishagratna KKL. An English translation of the Sushruta Samhita. Vol-3 - Uttara-Tantra. S.L.Bhaduri, Calcutta. 1916. pp 108, 115, 132, 137.

[15] Aswani KV, Abdul Shukkoor MM, Rajasree G. Extraction of *Krimi* (maggots) in *Dushtavrana* (non-healing ulcer) by *Susrutha's* concept of *Mamsaachadana:* A rare case report. Int J Ayush CaRe. 2021 Oct-Dec; 5(4):247-252.

[16] Deb D, Das K. Maggot therapy or *Krimi Utpattikara Chikitsa*: A review of history and clinical applications. Int Ayurvedic Med J (online). March 2023. DOI: 10.46607/iamj09p7032023

[17] Brewer TF, Wilson ME, Gonzalez E, Felsenstein D. Bacon therapy and furuncular myiasis. JAMA. 1993 Nov 3; 270 (17): 2087-8.

[18] Center W. A case of Peenash. Ind Med Gaz. 1870 Feb 1; 5(2):38-39.

[19] Bosmia AN, Zimmermann TM, Griessenauer CJ, Shane Tubbs R, Rosenthal EL. Nasal myiasis in Hinduism and contemporary otorhinolaryngology. J Relig Health. 2017 Aug; 56(4): 1263-1281.

[20] Mazzarello P. Achilles and the maggots. Nature.1999 Nov 18; 402(6759): 237.

[21] Agnelli S, King RB. Aural myiasis in ancient Rome: Celsus and the ear maggots. J Laryngol Otol. 2023 Dec; 137(12): 1345-1348.

[22] Manring MM, Calhoun JH. Biographical sketch: William S. Baer (1872-1931). Clin Orthop Relat Res. 2011 Apr; 469(4): 917-9.

[23] Baer WS. The treatment of chronic osteomyelitis with the maggot (larva of the blow fly). J Bone Joint Surg. 1931 July; 13(3): 438-475. {Reprinted: Clin Orthop Relat Res. 2011 Apr; 469(4): 920-44.}

[24] Sherman RA. Mechanisms of maggot-induced wound healing: what do we know, and where do we go from here? Evid Based Complement Alternat Med. 2014; 2014: 592419.

[25] Shamloul G, Khachemoune A. Reappraisal and updated review of maggot debridement therapy in chronic lower extremity ulcers. Int J Dermatol. 2023 Jul; 62(7): 962-968.

[26] Syam K, Joiya SA, Khan S, Unnikrishnan PN. Maggot debridement therapy for chronic leg and foot ulcers: A review of randomized controlled trials. Adv Skin Wound Care. 2021 Nov 1; 34(11): 603-607.

[27] Arora S, Sharma JK, Pippal SK, Sethi Y, Yadav A. Clinical etiology of myiasis in ENT: a reterograde period-interval study. Braz J Otorhinolaryngol. 2009 May-Jun; 75(3): 356-61.

[28] Hope FW. On insects and their larvae occasionally found in the human body. Trans Entomolo Soc London 1837; 2: 256-271.

[29] McGraw TA, Turiansky GW. Cutaneous myiasis. J Am Acad Dermatol. 2008 Jun; 58(6): 907-29.

[30] Sherman R. Putting wild maggots on your head is not "maggot therapy," but it does suggest pre-existing pathology. Plast Reconstr Surg. 2007 Nov; 120(6):1737-1738.

[31] Doss B. Maggots in nose or so-called Vermes Nasi. Ind Med Gaz. 1874 Apr 1; 9(4): 96.

[32] Hunter JM. Bot-fly maggot infestation in Latin America. Geogr Rev. 1990 Oct; 80(4): 382-398.

[33] James MT. The flies that cause myiasis in man. US Dept of Agriculture. Pub.no. 631. Washington. 1947. pp 1–175.

[34] Bishopp FC. Flies which cause myiasis in man and animals: Some aspects of the problem. J Economic Entomol 1915 June; 8(3), 317-329.

[35] Patton WS. Notes on the myiasis-producing Diptera of man and animals. *Bull Entomol Res*. 1921; 12(3): 239-261.

[36] Chan JC, Lee JS, Dai DL, Woo J. Unusual cases of human myiasis due to Old World screw-worm fly acquired indoors in Hong Kong. Trans R Soc Trop Med Hyg. 2005 Dec; 99(12):914-8.

[37] Sarwar M. Typical flies: Natural history, lifestyle and diversity of Diptera. In: Sarwar M (ed.) Life cycle and development of Diptera. Intech Open 2020. DOI: 10.5772/intechopen.91391 {accessed on 10 Sep 2024}

[38] Wollina U, Karte K, Herold C, Looks A. Biosurgery in wound healing - the renaissance of maggot therapy. J Eur Acad Dermatol Venereol. 2000 Jul; 14(4): 285-9.

[39] Rodrigues FT, D'Acri AM, Lessa CSS, Aguiar VM. Profile of pediatric patients with myiasis treated at a tertiary hospital in Rio de Janeiro. An Bras Dermatol. 2021 May-Jun; 96(3):369-372.

[40] Azarmi S, Akbarzadeh K, Ekrami A, Sheikh Z, Dehghan O. Scalp myiasis associated with soft tissue sarcoma lesion: a case report and review of relevant literature. BMC Infect Dis. 2024 Jan 5; 24(1): 51.

[41] Bapat SS. Neonatal myiasis. Pediatrics. 2000 Jul; 106(1): E6.

[42] Lindquist DA, Abusowa M, Hall MJ. The New World screw worm fly in Libya: a review of its introduction and eradication. Med Vet Entomol. 1992 Jan; 6(1):2-8.

[43] Gabaj MM, Beesley WN. American screwworm fly in Libya. Vet Rec. 1989 Feb 11; 124(6):152.

[44] Beckett SD, Spradbery JP, Green PE, Urech R and James P. Old World screw-worm fly: Risk of entry into Australia and surveillance requirements. A report for Animal Health Australia, Canberra (November, 2014)

[45] Singh A, Singh Z. Incidence of myiasis among humans-a review. Parasitol Res. 2015 Sep;114(9):3183-99.

[46] Seif AI, Kholeif HA, Koura EA, El-Alfi NM. Experience with traumatic myiasis among patients with septic wounds. J Trop Med. 1992 Dec; 2 (1): 115–19.

[47] Singh I, Gathwala G, Yadav SP, Wig U, Jakhar KK. Myiasis in children: the Indian perspective. Int J Pediatr Otorhino laryngol. 1993 Jan; 25(1-3): 127-31.

[48] Jain A, Taneja S. Oral myiasis affecting pediatric patients: a systematic review. J Stomatol Oral Maxillofac Surg. 2022 Jun; 123(3): e32-e36.

[49] Jain S, Audhya A; Madhupriya; Nagpure PS. Aural myiasis in a 1-day-old neonate. Indian J Med Sci. 2008 Apr; 62 (4): 164-6.

[50] Goldman L. Pyodermic myiasis in children: observations with special reference to torsalo. Am J Dis Child. 1945 May; 69(5): 280-282.

[51] Bozorgmehr R, Rezaei MM, Jafarabadi K, Alibeik N, Rahi mian N, Ahmadinejad M. A rare case of carotid artery injury during maggot debridement therapy for locally advanced parotid gland carcinoma. Int J Surg Case Rep. 2023 Oct; 111: 108844.

[52] Steenvoorde P, Oskam J. Bleeding complications in patients treated with maggot debridement therapy. Int J Low Extrem Wounds. 2005 Mar; 4(1): 57-8.

[53] Sherman RA, Bjork R. Association does not mean causation, especially when it concerns maggots. Wounds. 2018 Dec; 30(12):382.

[54] Cedillo MRQ, Leon-Urena H, Contreras-Ruiz J, Arenas R. The value of Doppler ultrasound in diagnosis in 25 cases of furunculoid myiasis. Int J Dermatol. 2005 Jan; 44(1): 34-7.

[55] Al-Juaid A, Al-Zahrani W. Furuncular Myiasis in a Child: A Case Report and Literature Review. Saudi J Med Med Sci. 2017 Jan-Apr;5(1):77-79.

[56] Boruk M, Rosenfeld RM, Alexis R. Human botfly infestation presenting as peri-auricular mass. Int J Pediatr Oto rhinolaryngol. 2006 Feb; 70(2): 335-8.
[57] Fernandes LF, Pimenta FC, Fernandes FF. First report of human myiasis in GoiaS state, Brazil: frequency of different types of myiasis, their various etiological agents, and associated factors. J Parasitol. 2009 Feb; 95 (1): 32-8.
[58] Sharma SB, Gupta R. Newborn umbilical cord stump myiasis: Report of an earliest presentation. J Indian Assoc Pediatr Surg. 2023 Jan-Feb; 28(1): 86-87.
[59] Barolia DK, Singh AP, Tanger R, Gupta AK. Umbilical myiasis in a human neonate treated with turpentine oil. J NTR Univ Health Sci 2020 Apr-June; 9 (2):143-5.
[60] Ogbalu OK, Eze CN, Manuelrb B. A new trend of omphalitis complicated with myiasis in neonates of the Niger Delta, Nigeria. Epidemiology (Sunnyvale) 2016; 6(2): 231. doi:10.4172/2161-1165.1000231
[61] Ogbalu OK, Achufusi TD, Orlu EE, Bawo DS, Adibe CH, Kumbe L, Azuonwu O, Amadi E. Human myiasis in neonates and children of the Niger Delta wetlands and South East Nigeria. J Cosmetic Dermatol Sci Appl. 2011 Dec; 1: 171-176. {DOI:10.4236/jcdsa.2011.14026}
[62] Ruiz-Zapata JD, Figueroa-Gutiérrez LM, Mesa-Franco JA, Moreno-Gutierrez PA. Umbilical myiasis by *Cochliomyia hominivorax* in an infant in Colombia. Front Med. 2020 Jan 22; 6: 292.
[63] Sharma H, Dayal D, Agrawal SP. Nasal myiasis: review of 10 years experience. J Laryngol Otol. 1989 May; 103(5): 489-91.
[64] Yuca K, Caksen H, Sakin YF, Yuca SA, Kiriş M, Yilmaz H, Cankaya H. Aural myiasis in children and literature review. Tohoku J Exp Med. 2005 Jun; 206(2): 125-30.
[65] Ogbalu OK, Achufusi TG, Adibe C. Incidence of multiple myiases in breasts of rural women and oral infection in infants from the human warble fly larvae in the humid Tropic-Niger Delta. Int J Dermatol. 2006 Sep; 45(9): 1069-70.
[66] Kamboj M, Mahajan S, Boaz K. Oral myiasis misinterpreted as salivary gland adenoma. J Clin Pathol. 2007 Jul; 60(7): 848.
[67] Huang YL, Liu L, Liang H, He J, Chen J, Liang QW, Jiang ZY, He JF, Huang ML, Du Y. Orbital myiasis: A case report and literature review. Medicine (Baltimore). 2020 Jan; 99(4): e18879.
[68] Blejter J. Tracheostomy wound myiasis in a child: case report and review of the literature. Case Rep Pediatr. 2012; 2012: 317862.
[69] Demir AD, Iraz M, Ipek DNS. Urogenital myiasis caused by *Psychoda albipennis* in a child. Turk Ped Arch 2015; 50: 65-8
[70] Kataria U, Siwach S, Gupta S. Myiasis in female external genitalia. Indian J Sex Transm Dis AIDS. 2013 Jul; 34(2): 129-31.
[71] Singh A, Kaur J. Occurrence of human urogenital myiasis due to neglected personal hygiene: a review. Trans R Soc Trop Med Hyg. 2019 Jan 1; 113(1): 4-10.
[72] Jesuyajolu DA, Jesuyajolu P. Furuncular myiasis affecting the glans penis of a young boy caused by the larvae of *Cordylobia anthropophaga* (the tumbu fly): a case report. Pan Afr Med J. 2022 May 27; 42: 75.
[73] Passos MR, Barreto NA, Varella RQ, Rodrigues GH, Lewis DA. Penile myiasis: a case report. Sex Transm Infect. 2004 Jun; 80(3): 183-4.
[74] Wakid MH, Sharafeldein YS, Almakki AA, Alidrisi DA, Bashinim AA. Scrotal Myiasis in a Child Due to Cordylobia anthropophaga. Cureus. 2024Apr30;16(4): e59417.
[75] Egbuchulem KI, Ogundipe HD, Olulana DI, Ojediran TO. A rare finding of distal penile furuncular myiasis in a child of a Nigerian health care worker. Ann Ib Postgrad Med. 2023 Aug; 21(2): 103-105.
[76] Rath BK, Das PK. Urogenital myiasis. Indian Pediatr. 2000 Jul; 37(7): 797-8.
[77] Lageju N, Neupane D, Jaiswal LS, Phuyal U. Pin-tract myiasis after external bone fixation: A case report and review of literature. Int J Surg Case Rep. 2022 Jun; 95: 107247.
[78] Saluja HK, Jadhav S. Diaphyseal tibial osteosarcoma with myiasis. Cureus. 2022 Dec 20; 14(12): e32718.
[79] Kalelioglu M, Akturk G, Akturk F, Komsuoglu SS, Kuzeyli K, Tigin Y, Karaer Z, Bingol R. Intracerebral myiasis from Hypoderma bovis larva in a child. Case report. J Neuro surg. 1989 Dec; 71(6): 929-31.
[80] Ramon-Cuellar JF, Mejía-Cordovez JA, Quinones-Ossa GA, Leal-Isaza JP, Vargas-Osorio MP, Ramirez-Munoz JD, Ordonez-Rubiano EG, Ramirez AP, Amarillo DG, Hakim-Daccach F. Cerebral myiasis, an unexpected intraoperative finding - A case report and systematic review. World Neurosurg. 2024 Jun; 186: 138-144.
[81] Curzi C, Bartoletti V, Canova G, Giordan E. A severe case of brain myiasis: treatment rationale and review of literature. Asian J Neurosurg. 2021 Sep14; 16(3): 582-586.
[82] Pouillaude JM, Dupont J, Gilly R, Lapras C. Intracerebral myiasis in a child. Pediatr Radiol. 1980 Nov; 10(2):121-3.
[83] Labbe A, Desvignes V, Meyer M, Campagne D, Cohen F, Dechelotte P. Meningite a Hypoderma bovis. A propos d'un nouveau cas pediatrique [Hypoderma bovis meningitis. Apropos of new pediatric case]. Ann Pediatr (Paris). 1983 Apr; 30(4): 277-80.
[84] Rossi MA, Zucoloto S. Fatal cerebral myiasis caused by the tropical warble fly, Dermatobia hominis. Am J Trop Med Hyg. 1973 Mar; 22(2): 267-9.
[85] Udgaonkar US, Dharamsi R, Kulkarni SA, Shah SR, Patil SS, Bhosale AL, Gadgil SA, Mohite RS. Intestinal myiasis. Indian J Med Microbiol. 2012 Jul-Sep; 30(3): 332-7.
[86] Chen XQ, Zhang KL, Shan QW. Bloody diarrhea caused by intestinal myiasis in an infant: A case report and review

of pediatric literature. J Trop Pediatr. 2021 Jul 2; 67(3): fmaa037.
[87] Aspock H. Rektale Myiasis durch Fannia canicularis (Linne) und *Muscina stabulans* (Fallen) [Rectal myiasis due to Fannia canicularis (Linne) and *Muscina stabulans* (Fallen)]. Dtsch Med Wochenschr. 1972 Aug 11; 97(32): 1174-5.
[88] North DE, Matteson KL, Helgerson SD, Richards F Jr, Stewart JM, Baum L, Catts EP. Intestinal myiasis in a baby attending a public health clinic. Nurse Pract. 1987 May; 12(5): 60-3.
[89] Rathi S, Pednekar K, Pathak A, Singh P. Screw-worm myiasis of prolapsed rectum. Indian Pediatr. 2014 Jan; 51 (1): 53-4.
[90] Karabiber H, Oguzkurt DG, Dogan DG, Aktas M, Selimoglu MA. An unusual cause of rectal bleeding: intestinal myiasis. J Pediatr Gastroenterol Nutr. 2010 Oct; 51(4): 530-1.
[91] Hasegawa S, Miwata H, Masuda S, Naruse H, Ozaki T. An infantile case of intestinal myiasis. Acta Paediatr Jpn. 1992 Feb; 34(1): 87-9.
[92] Nagakura K, Isozaki M, Shigeta M, Shimamura T, Tachi bana H, Kaneda Y, Kano R. A case report of intestinal myiasis. Tokai J Exp Clin Med. 1984 Dec; 9(5-6): 345-8.
[93] Zardi EM, Iori A, Picardi A, Costantino S, Petrarca V. Myiasis of a perineal fistula. Parassitologia. 2002 Dec; 44 (3-4): 201-2.
[94] Ahmed MJ, Miller A. Pulmonary coin lesion containing a horse bot, Gasterophilus. Report of a case of myiasis. Am J Clin Pathol. 1969 Oct; 52(4): 414-9.
[95] Mielke U. Nosocomial myiasis. J Hosp Infect. 1997 Sep; 37(1): 1-5.
[96] Espinoza-Gomez F, Rojas-Larios F, Cruz-Sanchez S, Rodri guez-Hernandez A, Delgado-Enciso I. Outbreak of nosocomial myiasis by Cochliomyia macellaria (Diptera, Calliphoridae) in a hospital in Colima, Mexico. Am J Trop Med Hyg. 2023 Sep 11; 109(4):748-751.
[97] Maleki-Ravasan N, Shayeghi M, Najibi B, Oshaghi MA. Infantile nosocomial myiasis in Iran. J Arthropod Borne Dis. 2012 Dec; 6(2): 156-63.
[98] Martinez-Rojano H, Huerta H, Hernandez-Triana LM, Ruiz Perez EF, Sámano R. Nosocomial myiasis caused by *Lucilia sericata* (Diptera: Calliphoridae) in a pediatric patient in Mexico. Case Rep Infect Dis. 2020 Jan 29; 2020: 1285459.
[99] Clyti E, Deligny C, Nacher M, Del Giudice P, Sainte-Marie D, Pradinaud R, Couppie P. An urban epidemic of human myiasis caused by *Dermatobia hominis* in French Guiana. Am J Trop Med Hyg. 2008 Nov; 79(5): 797-8.
[100] Bouer M, Rodriguez-Bandera AI, Albizuri-Prado F, Lobos A, Gubeling W, Wortsman X. Real-time high-frequency colour Doppler ultrasound detection of cutaneous *Derma tobia hominis* myiasis. J Eur Acad Dermatol Venereol. 2016 Dec; 30(12): e180-e181.
[101] Pogany P, Szucs E, Lichtenberger G, Vass L. Diagnosis of myiasis by fine needle aspiration cytology: a case report. Acta Cytol. 2008 Mar-Apr; 52(2): 228-30.
[102] https://shire.science.uq.edu.au/parasites/insects/maggots/maggots-identification.php (Accessed on 16 August 2024)
[103] Sherman RA, Jesus KD. Removing unwanted maggots. J Emerg Med. 2015 Feb; 48(2): 213.
[104] Sherman RA, Nguyen A, Dastpak V, Fonseca-Munoz A, Parizad N, Siavash M, Yusuf MA. Not all maggots are created equal; not all maggots are therapeutic. Clin Case Rep. 2024 Jul 17; 12(7): e9163.
[105] Elder JW, Grover CA. Wound debridement: lessons learned of when and how to remove "wild" maggots. J Emerg Med. 2013 Oct; 45(4): 585-7.
[106] Nayak SP, Reddy YL, Patil PH, Harugop AS, Narasimman DB, Neema K. Importance of an ENT surgeon in maggot removal, improper attempt leads to deadly complications: A case report. Indian J Otolaryngol Head Neck Surg. 2023 Jun; 75(2): 1204-1206.
[107] Nunzi E, Rongioletti F, Rebora A. Removal of *Dermatobia hominis* larvae. Arch Dermatol. 1986 Feb; 122(2): 140.
[108] Pereyra-Rodríguez JJ, Bernabeu-Wittel J, Conejo-Mir MD, Ruiz-Perez de Pipaon M, Conejo-Mir J. Treatment of cutaneous myiasis associated with scalp psoriasis in a 13-year-old girl with oral ivermectin. J Am Acad Dermatol. 2010 Nov; 63(5): 908-9.
[109] Duque FL, Ardila CM. Oral myiasis caused by the screwworm Cochliomyia hominivorax treated with subcutaneous ivermectin and creolin: report of six cases after trauma. Dent Traumatol. 2011 Oct; 27(5): 404-7.
[110] Clyti E, Nacher M, Merrien L, El Guedj M, Roussel M, Sainte-Marie D, Couppie P. Myiasis owing to *Dermatobia hominis* in a HIV-infected subject: Treatment by topical ivermectin. Int J Dermatol. 2007 Jan; 46(1): 52-4.
[111] Patel BC, Ostwal S, Sanghavi PR, Joshi G, Singh R. Management of malignant wound myiasis with ivermectin, albendazole and clindamycin (triple therapy) in advanced head-and-neck cancer patients: A prospective observational study. Indian J Palliat Care. 2018 Oct-Dec; 24(4): 459-464.
[112] Bernhard JD. Bringing on the bacon for myiasis. Lancet. 1993 Dec 4; 342(8884): 1377-8.
[113] Fox H, Seeger FH. Tetanus in a patient with a maggot-colonised head tumor. Anaesth Intensive Care. 2013 Mar; 41(2): 272-3.
[114] Greenberg B. Flies and Disease. Vol 2: Biology and disease transmission. Princeton University Press, New Jersey. 1973.
[115] Lupi O. Myiasis as a risk factor for prion diseases in humans. J Eur Acad Dermatol Venereol. 2006 Oct; 20(9): 1037-45.
[116] Morris D, Flores M, Harris L, Gammon J, Nigam Y. Larval therapy and larval excretions/secretions: A potential

treatment for biofilm in chronic wounds? A systematic review. Microorganisms. 2023 Feb 11; 11(2): 457.
[117] Fleischmann W, Grassberger M, Sherman R. Maggot therapy - A handbook of maggot-assisted wound healing. Georg Thieme Verlag, New York 2004.
[118] Stadler F. A Complete Guide to Maggot Therapy. Open Book Publishers, Cambridge 2022
[119] Grassberger M, Fleischmann W. The biobag - a new device for the application of medicinal maggots. Derma tology. 2002; 204(4): 306.
[120] Opletalova K, Blaizot X, Mourgeon B, Chêne Y, Creveuil C, Combemale P, Laplaud AL, Sohyer-Lebreuilly I, Domp martin A. Maggot therapy for wound debridement: a randomized multicenter trial. Arch Dermatol. 2012 Apr; 148(4): 432-8.
[121] Birdsong M, McIltrot KH, Ascenzi J. Pediatric maggot debridement therapy: A case study. J Pediatr Surg Nurs. 2014 April; 3(2): 60-64. DOI:10.1097/JPS.0000000000000021
[122] Orkiszewski M, Madej J, Kilian T. The use of maggot therapy in paediatric surgery: a case report. World Wide Wounds. Mar 2006. {Availabe from: http://www.worldwidewounds.com/2006/march/Orkiszewski/Use-Maggot-Therapy-Paediatric-Surgery.html} (Accessed on 15 September 2024)
[123] Perez-Acevedo G, Bosch-Alcaraz A, Torra-Bou JE. Larval therapy for treatment of chronic wounds colonized by multiresistant pathogens in a pediatric patient: A Case study. J Wound Ostomy Continence Nurs. 2022 Jul-Aug 01; 49(4): 373-378.

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Received 20 Sep 2024; Accepted 30 Sep 2024

Acknowledgements: None
Conflicts of Interest: None declared by the author
Source of Funding : None
Ethical concerns : None (Review of literature)

Citation: *Raveenthiran V. Maggot infestation (Myiasis) in children. Pediatr Surg Trop 2024; 1(4): 216-248.*