ORIGINAL INVESTIGATION

Wound Myiasis in Urban and Suburban United States

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Background: The epidemiologic characteristics of human myiasis in the United States remain undefined.

Objective: To describe the most common clinical conditions associated with human myiasis and the causative maggot species.

Methods: Multicenter, prospective observational study of urban and suburban patients who were infested with maggots.

Results: Forty-two cases of US-acquired myiasis were collected from 20 participating centers. Most infestations occurred within preexisting wounds. No cases of tissue invasion were recorded. Host age averaged 60 years, with a male-female ratio of 5.5:1. Homelessness, alcoholism, and peripheral vascular disease were frequent cofactors. Two patients (5%) were hospitalized at the time of their infestation. The most common species was *Phaenicia sericata* (green blowfly; family: Calliphoridae). Other blowflies, flesh flies (Sarcophagidae), and humpbacked flies (Phoridae) also were identified. In 6 cases, 2 coinfesting species were identified.

Conclusions: Results of this prospective study of myiasis differ significantly from those of our analysis of previously published reports and suggest that most cases of human myiasis are caused by noninvasive blowflies laying eggs in preexisting wounds. Five percent of infestations were nosocomially acquired and not necessarily associated with patient neglect.

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A YOUNG man who fell overboard while drinking and boating was brought to the hospital with deep, infected lacerations of the foot and ankle caused by his boat's propeller. Despite antibiotic therapy, repeated surgical debridements, and attempted revascularization, the necrotic foot could not be salvaged. After learning that maggots had been noted in the wound at the time of amputation, the patient sued the hospital, the doctors, and the county for negligence, alleging that hospital personnel had allowed maggots to infest his wound and cause the loss of his foot.

An elderly, intubated, comatose woman was transferred from her nursing home to the local hospital for management of her acute pneumonia. Several days into her hospitalization, her son found maggots in her mouth, prompting litigation against the nursing home in which she had resided the previous week.

In both cases, determination of the maggots' responsibility for the clinical outcome and the timing of the infestation were pivotal factors in determining the defendants' culpability. In both cases, the existence of maggots was cited as a priori evidence of medical negligence. Yet in neither case were the maggots saved; their identity, natural history, and pathogenic potential were unknown. The court may not be the ideal venue for determining the pathophysiology of myiasis (maggot infestations), but most of us on the wards or in the clinics appear unprepared or unwilling to make this assessment ourselves. Unlike almost any other clinical specimen, maggots are often discarded (in haste and with disgust), rather than submitted to the clinical laboratory for analysis.

Maggots are the larvae of flies (**Figure 1** and **Figure 2**). Because of their immaturity, it is more difficult to differentiate the various species of maggots than it is to speciate adult flies. Species identification can be crucial, however, in determining the natural history and pathogenic potential of an infestation. Species identification helps classify maggots as obligatory or facultative parasites. Obligatory myiasis-causing larvae infest living hosts and tend to be more invasive than the facultative parasites, which favor dead hosts or the necrotic tissue of living hosts.[2,3] Rarely, maggots can be found in the human intestinal or urinary tract.[4-6] This usually results when eggs or larvae have been swallowed with food or when larvae have wandered accidentally into these areas. Such situations should be called *pseudomyiasis*,[7] since the maggots are not living parasitically.

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PATIENTS AND METHODS

PROSPECTIVE STUDY

Emergency department and infection control supervisors from over 100 academic, public, and Department of Veterans Affairs medical centers throughout the continental United States were invited to submit maggots and clinical data from their patients with myiasis. The participating clinicians at 20 centers were provided with containers of sterile liver-agar rearing medium,[15] vials of preservative (70% ethanol or formaldehyde), and forms for recording relevant clinical data. Some larvae were placed live into the rearing containers; the remainder were submitted in the vials of preservative. These were mailed back to us along with the completed clinical questionnaires.

Upon receipt, preserved specimens were transferred to Kahle solution,[16] and live larvae were reared to adulthood in our insectary, according to previously published methods.[17] Preserved larvae and adult flies were identified on the basis of morphologic features.[18-21] Subsequently, specimens were submitted to Steven Heydon, PhD, of the Bohart Museum of Entomology (University of California, Davis) for collaborative identification and vouchering (storage in a research and reference collection).

Lukin[14] used blood-agar bacterial culture media to transport the larvae he collected after determining that the blowfly *Lucilia cuprina* (Weidemann) survived on this substrate for at least 36 hours. The liver-agar transport rearing medium used in our study has been shown to support the complete and normal development of another blowfly, *Phaenicia sericata* (Meigen).[15] This medium also supports the complete metamorphosis of flesh flies (Sarcophagidae: *Neobellieria* [or *Sarcophaga*] *bullata* [Parker]), small fruit flies or vinegar flies (Drosophilidae: *Drosophila melanogaster* [Meigen]), and hump-backed flies (Phoridae; species unidentified). Most second instar common houseflies (Muscidae: *Musca domestica* [Linnaeus, 1768]) and lesser houseflies (Muscidae: *Fannia canicularis* [Linnaeus]) have survived for at least 2 days on this medium (90% and 60% survival, respectively), but only 2 of 20 *F canicularis* and no *M domestica* specimens have reached adulthood (unpublished data). A satisfactory artificial medium has never been found for rearing botfly larvae, although the second and third instars should survive for a few days after removal from their live hosts.[22]

LITERATURE REVIEW

The 671 publications on human myiasis indexed between 1960 and 1995[13] were reviewed. Of the 400 English language articles indexed, 72 articles described 137 cases of US-acquired myiasis[4-6,11,23-90] (**Figure 3**). Clinical details, host characteristics, and entomological data from each article were recorded in our database for subsequent analysis.

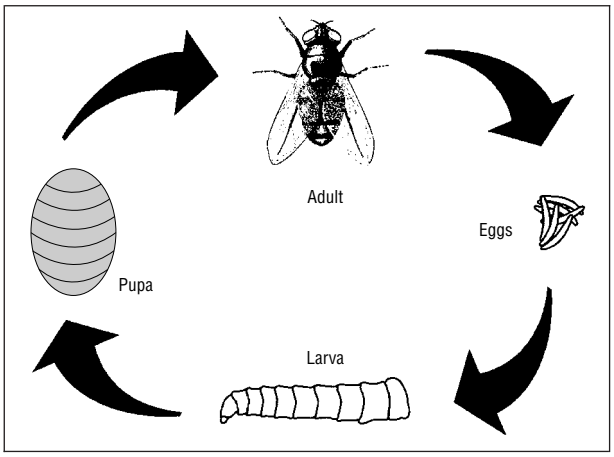

Figure 1. *Life cycle of* Phaenicia sericata*, the green blowfly, depicting the 4 stages of metamorphosis: egg, larva (maggot), pupa, and adult. Some flies (ie, Sarcophagidae) deposit live larvae, not eggs (adapted from Sherman et al[1]; Copyright Ronald A. Sherman, MD; reprinted with permission).*

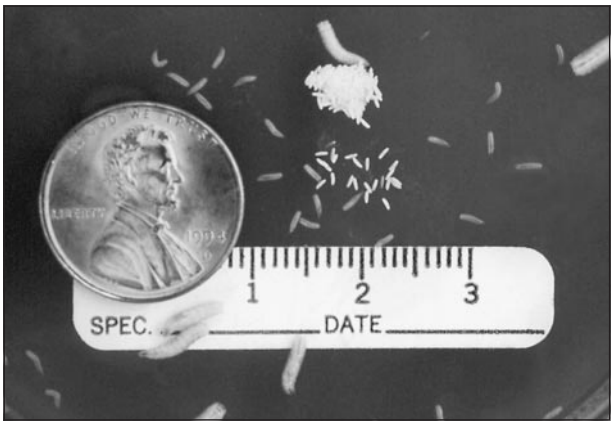

Figure 2. Phaenicia sericata *eggs and larvae on sheep blood agar culture plate. The relative sizes of the first, second, and third instars can be compared on the centimeter scale.*

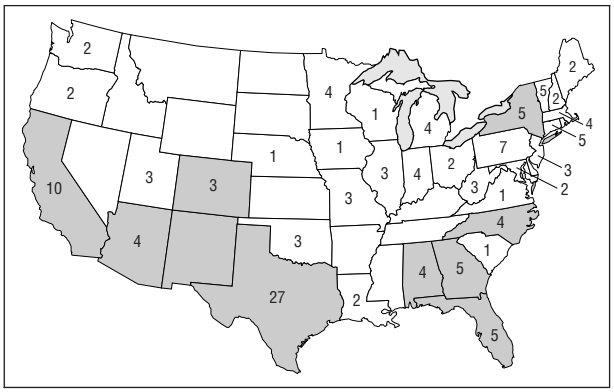

Figure 3. *Geographic distribution of US-acquired myiasis cases reported between 1960 and 1995.[4-6,11,23-90] Shaded states are those with centers participating in the current study.*

Species identification also allows the consultant to estimate the timing and circumstances of a maggot infestation. For example, blowflies (Calliphoridae) lay eggs that might not hatch for 8 to over 80 hours. Flesh flies (Sarcophagidae), on the other hand, are larviparous; they deposit live larvae that begin feeding and growing almost immediately.

Tropical obligate parasites include the human botfly (Cuterebridae: *Dermatobia hominis* [Linnaeus Jr]) and the tumbu fly (Calliphoridae: *Cordylobia anthropophaga*

Table 1. Clinical Syndromes of 42 Patients With Myiasis Arranged by Causative Species*

Species Identification	Clinical Syndrome and Anatomical Site	Patient Age, y	Patient Sex	Underlying Illnesses	Location, City, State
Calliphoridae					
Phaenicia sericata	Wound myiasis (chronic toe wounds)	70	M	None	Loma Linda, Calif
P sericata	Wound myiasis (leg)	53	M	CADz, Afib, CHF, PVDz, COPD, alcoholism‡	Long Beach, Calif
P sericata	Wound myiasis (feet and ankles)	61	M	PVDz, COPD, alcoholism, smoking‡	Long Beach, Calif
P sericata	Wound myiasis (toes)	71	M	PVDz, CADz, COPD, CVA, prostate CA	Long Beach, Calif
P sericata	Wound myiasis (chronic foot and ankle wounds)	61	M	PVDz, COPD‡	Long Beach, Calif
P sericata	Wound myiasis (chronic foot and ankle wounds)	61	M	PVDz, COPD‡	Long Beach, Calif
P sericata	Wound myiasis (chronic leg and foot wound)	63	M	PVDz‡	Los Angeles, Calif
P sericata	Wound myiasis (chronic leg and thigh wound)	63	M	None	Oakland, Calif
P sericata	Soiled clothing (perineum, vagina)	49	F	Alcoholism	Orange, Calif
P sericata	Wound myiasis (site unspecified)†	35	M	MVA with femur ORIF and splenectomy, intubated	Orange, Calif
P sericata	Wound myiasis (chronic foot wound)	73	M	Gouty arthritis	Orange, Calif
P sericata	Wound myiasis (chronic wound, site unspecified)	78	M	None	Torrance, Calif
P sericata	Aural myiasis (lacerated ear, soiled clothing)	54	M	Cocaine and alcohol abuse‡	Torrance, Calif
P sericata	Wound myiasis (chronic foot and ankle wound)	50	M	PVDz, HTN	Denver, Colo
P sericata	Wound myiasis (chronic leg wound)	63	M	Alcoholism‡	Denver, Colo
P sericata	Wound myiasis (chronic ankle wound)	87	F	Diabetes, PVDz	Denver, Colo
P sericata	. . .	. . .	. . .	. . .	Albuquerque, NM
P sericata	Wound myiasis (chronic wound, toe)	63	M	Diabetes, PVDz, CADz, liver disease	Albuquerque, NM
P sericata	Wound myiasis (chronic wound, foot)	62	M	PVDz‡	Albuquerque, NM
P sericata	Wound myiasis (chronic wound, leg)	41	M	None‡	New York, NY
P sericata	Wound myiasis (chronic wound, legs and feet)	51	M	CVA, alcoholism‡	New York, NY
P sericata	Wound myiasis (chronic post surgical ankle wound)†	46	F	HTN, asthma, alcoholism	New York, NY
P sericata	Wound myiasis (chronic wound, leg)	75	M	PVDz‡	New York, NY
P sericata	Wound myiasis (foot wound with necrotic toes)	84	M	CADz, CHF, GI bleeding	Dallas, Tex
Phaenicia cuprina	Wound myiasis (chronic wound, lateral malleolus)	62	F	PVDz	Phoenix, Ariz
Phaenicia species	Wound myiasis (chronic wound, leg)	63	M	Diabetes, PVDz, CA, TB	Torrence, Calif
Phaenicia species	Wound myiasis (neck fistula)	49	M	Oropharyngeal CA, status posttracheotomy, alcoholism	Long Beach, Calif
Phaenicia species	Clinical condition of leg not specified	. . .	M	. . .	New York, NY
Phormia regina	Wound myiasis (chronic wound, leg)	52	M	Alcoholism without hepatic dysfunction‡	New York, NY
P regina	Wound myiasis or soiled skin (ankle)	46	M	Alcoholism‡	New York, NY
Lucilia illustris	. . .	. . .	. . .	. . .	Durham, NC
Sarcophagidae					
Bercaea haemorrhoidalis	Wound myiasis (site unspecified)	. . .	M	. . .	Albuquerque, NM
Gymnoprosopa species	Wound myiasis (chronic leg wound)	. . .	F	Alcoholism‡	Phoenix, Ariz
Phoridae					
Megaselia species	Wound myiasis (pressure ulcer, leg)	46	F	PVDz, CA‡	Los Angeles, Calif
Megaselia species	Wound myiasis (chronic leg wound)	66	M	PVDz, CADz	Oakland, Calif
Mixed infestations					
P sericata and *P regina*	Wound myiasis (chronic ankle wound)	50	M	‡	Los Angeles, Calif
P sericata and *P regina*	. . .	. . .	. . .	. . .	New York, NY
P sericata and *P regina*	Wound myiasis (pretibial trauma wound)	64	M	COPD, alcoholism	Albuquerque, NM
P sericata and *P regina*	Wound myiasis (recurrent facial CA, status postresection)	78	M	CA	Albuquerque, NM
P sericata and *B haemorrhoidalis*	. . .	61	M	. . .	Loma Linda, Calif
P sericata and *B haemorrhoidalis*	Wound myiasis (toe wound)	60	M	Alcoholism, smoking, dementia	Long Beach, Calif
Specimens unidentifiable	Wound myiasis (chronic toe wound)	56	M	Diabetes	Torrance, Calif

*CADz indicates coronary artery disease; Afib, atrial fibrillation; CHF, congestive heart failure; PVDz, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; CVA, cerebral vascular accident; CA, cancer; MVA, motor vehicle accident; ORIF, open reduction and fixation; HTN, hypertension; GI, gastrointestinal; and TB, tuberculosis. Ellipses indicate data not available.

†Nosocomial infestations.

‡Homeless hosts.

Figure 4. Phaenicia sericata *larvae crawling from the neck tumor fistula (just anterior to sternomastoid muscle) of a patient in a nursing home. This patient probably acquired his infestation while at home on pass. Contrast and brightness have been adjusted using Corel Photopaint V.8 (Corel Corp, Ottawa, Ontario).*

[Blanchard]). Larvae of these flies burrow through the intact skin of man and animals, feeding for several weeks on the tissue and exudate within their subcutaneous furuncle. Obligate parasites in North America include the rodent, sheep, and horse botflies (Cuterebridae and Oestridae), which occasionally lay their eggs in the eyes, nose, sinuses, or skin of humans. The New World screwworm (Calliphoridae: *Cochliomyia hominivorax* [Coquerel], also known as *Cochliomyia americana* and *Callitroga americana* in older literature) is an obligate parasite of cattle and other livestock. This maggot occasionally infests human wounds as well. Eggs are usually laid at the site of a wound, and the larvae invade through the wound bed into the adjacent healthy tissue. Its species name, meaning "human-eater," was coined in 1858 by the French entomologist Charles Coquerel after he received clinical specimens from physicians who associated this maggot with the death of hundreds of Devil's Island prisoners.[8] As a result of intensive eradication efforts during the 1950s and 1960s, *C hominivorax* is no longer established in North America.[8,9] Livestock in the United States is now infested with this parasite only rarely when the fly has been imported accidentally.

Most North American blowflies (family: Calliphoridae) are facultative parasites, laying their eggs on corpses or in decomposing animal or plant matter more commonly than on a living host. Many of these flies tend not to invade living tissue—a feature exploited by practitioners of maggot debridement therapy.[10]

Myiasis can be classified according to the anatomic site of infestation (aural myiasis, ophthalmomyiasis, cutaneous myiasis, etc) or on the basis of clinical syndrome (ie, furuncular cutaneous myiasis, migratory cutaneous myiasis, wound myiasis). Scott[11] divided the 111 cases in his review (32 cases of which had not previously been published) into 11 clinical types; wound ("traumatic") myiasis represented only 4.5% of his cases.

Seeking to better understand the epidemiologic characteristics and clinical manifestations of human myiasis, we reviewed the literature. Several case series and retrospective reviews were published 40 to 50 years ago by James,[3] Hall,[12] and Scott.[11] Since that time, hundreds of case reports have been published in the medical literature, with over 250 new clinical reports indexed during the last 10 years alone.[13] Consisting predominantly of case reports, the human myiasis literature is subject to reporter biases. Only a single prospective study of human myiasis has ever been published, and that study was limited to the Australian city of Brisbane.[14] The epidemiologic characteristics of myiasis in North America remain obscure.

The present study addresses the hypothesis that the epidemiologic characteristics of North American myiasis may be much different than the current literature suggests. Maggots were collected from patients at participating centers, reared to adult flies when possible, and identified. Patients' clinical conditions were recorded. The results of this survey were compared with the findings of our literature review.

RESULTS

Of the 20 centers that participated in this study, 12 centers submitted 45 cases. Three cases were excluded from our analysis because they did not meet the definition of US-acquired myiasis: one human botfly (*Dermatobia hominis*) that was removed from a traveler returning from Brazil; a gravid fly (family: Sarcophagidae) that was captured on an intensive care unit staff dining table; and an adult fly (probably Calliphoridae) that was found and killed on an unconscious inpatient.

The remaining 42 cases were categorized by species and clinical syndrome (**Table 1**). Thirty-two (75%) of the infestations occurred on lower-extremity wounds, such as venous stasis ulcers, diabetic neurovascular ulcers, pressure ulcers, nonhealing surgical wounds, or traumatic wounds. Nine of these wounds were surrounded by cellulitis of unknown duration.

Patients' ages ranged from 35 to 87 years (mean, 60 years; median, 51 years), with a male-female ratio of 5.5:1. Two (5%) of the patients were hospitalized at the time of their infestation. A thorough investigation of one of these patients—a 35-year-old in the medical intensive care unit who had been in a motor vehicle accident—demonstrated no evidence of medical neglect. No follow-up data were available on the other nosocomial infestation. Myiasis of a nursing home resident's draining neck tumor (**Figure 4**) was determined to have occurred at his home (while the resident was away from the nursing home on a weekend pass). Therefore, this infestation was not classified as nosocomial, even though it was discovered after readmission to the nursing home. At least 16 of the patients were homeless; the clothing of 10 (62%) of these homeless individuals was soiled at the time they presented to the emergency department. Of the 35 patients whose medical histories were known, 17 (49%) had peripheral vascular disease, coronary ar-

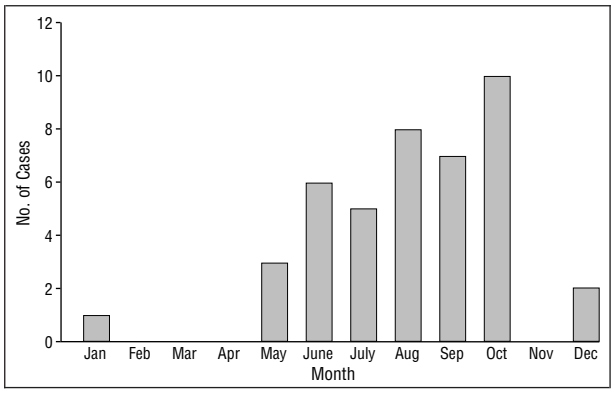

Figure 5. *Monthly distribution of 42 US-acquired myiasis cases.*

tery disease, cerebral vascular accidents, or some other manifestations of circulatory compromise. Thirteen patients (37%) were alcoholics, 5 (14%) had solid tumors, and 4 (11%) had diabetes. None of the patients had hematopoietic tumors, nor had they received immunosuppressive agents.

Specimens submitted by routine mail service arrived approximately 4 days after they were removed from patients (excluding one specimen that was submitted nearly 3 weeks later). In 4 cases, maggots submitted live arrived dead as a result of suffocation; their rearing containers had been hermetically resealed. In all but 2 cases, maggots received alive were reared successfully to adult-

Table 2. Myiasis Acquired in the United States Arranged by Species and Clinical Syndromes, 1960-1995[3-5,10,22-89]

	No. of Cases									
	Cutaneous						Respiratory			
Causative Species	Furuncular	Migrating	Wound	Soiled Skin	Ophthalmic	Aural	Lower	Upper	Nasal	Sinuses
Calliphoridae										
Phaenicia sericata	. . .	. . .	5	. . .	. . .	1	. . .	. . .	2	. . .
Phaenicia cuprina	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cochliomyia hominivorax	. . .	. . .	14	. . .	. . .	. . .	. . .	1	1	. . .
Cochliomyia macellaria	. . .	. . .	1	. . .	1	. . .	. . .	. . .	. . .	. . .
Phormia regina	. . .	. . .	5	1	. . .	2	. . .	. . .	. . .	. . .
Calliphora vomitoria	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Calliphora vicina	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Unspecified	. . .	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .
Sarcophagidae										
Wohlfahrtia opaca	3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Wohlfahrtia vigil	2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sarcophaga crassipalpis?	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sarcophaga species	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Unspecified	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Calliphoridae or Sarcophagidae	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Cuterebridae										
Dermatobia hominis	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cuterebra species	. . .	25	. . .	. . .	7	. . .	1	. . .	. . .	. . .
Cuterebra buccata?	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Cuterebra cuniculi	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Unspecified	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Oestridae										
Hypoderma lineatum	. . .	3	. . .	. . .	2	. . .	. . .	. . .	. . .	. . .
Hypoderma bovis	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Oestrus ovis	. . .	. . .	. . .	. . .	8	. . .	. . .	. . .	. . .	. . .
Cuterebridae or Oestridae	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Gastrophilidae										
Gasterophilus species	. . .	. . .	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .
Phoridae										
Megaselia species	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	1
Muscidae										
Muscina stabulans	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Musca domestica	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Scenopinidae										
Scenopinus species	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Drosophilidae										
Drosophilia species	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Piophilidae										
Piophila species	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Maggot found but not identified	. . .	. . .	12	. . .	2	. . .	. . .	. . .	. . .	. . .
Maggot-like organism seen	. . .	. . .	1	. . .	3	. . .	. . .	. . .	. . .	. . .
No maggot found	. . .	. . .	. . .	. . .	5	. . .	. . .	. . .	. . .	. . .
Total, No. of Presentations (% of Total Syndromes)	**5** (3.6)	**30** (21.9)	**44** (32.1)	**1** (0.7)	**33** (24.1)	**4** (2.9)	**2** (1.5)	**1** (0.7)	**3** (2.2)	**1** (0.7)

hood and identified. The 2 exceptions were *P sericata* and a species unidentifiable from the larva itself.

The most common species, isolated from 71% (30/42) of the patients, was the green blowfly *P* (also known as *Lucilia*) *sericata* (Table 1). Blowflies were isolated from 37 patients, flesh flies (Sarcophagidae) were identified in 4, and humpbacked flies (Phoridae; also called *cemetery flies* or *scuttle flies*) were isolated from 2 patients. The wounds of 6 patients were infested simultaneously with 2 different species of flies. Of the 47 identified species recovered, 41 (87%) were blowflies. Most infestations collected during this 3-year study occurred between late spring and early autumn (**Figure 5**).

Gastrointestinal	Genitourinary	Perineal	Total, No. (%)
			41 (29.0)
...	...	...	**8** (5.8)
1	...	...	**1** (0.7)
...	...	...	**16** (11.7)
...	...	...	**2** (1.5)
1	...	1	**10** (7.3)
...	...	...	1 **(0.7)**
1	...	...	**1** (0.7)
1	...	...	**2** (1.5)
			11 (8.0)
...	...	...	**3** (2.2)
...	...	...	**2** (1.5)
...	...	...	**1** (0.7)
3	...	...	**4** (2.9)
...	...	...	**1** (0.7)
...	...	...	**1** (0.7)
			37 (27.0)
...	...	...	**1** (0.7)
...	...	...	**33** (24.1)
...	...	...	**1** (0.7)
...	...	...	**1** (0.7)
...	...	...	**1** (0.7)
			14 (10.2)
...	...	...	**5** (3.6)
...	...	...	**1** (0.7)
...	...	...	**8** (5.8)
...	...	...	**1** (0.7)
...	...	...	**1** (0.7)
			3 (2.2)
...	...	1	**3** (2.2)
			2 (1.5)
1	...	...	**1** (0.7)
...	...	...	**1** (0.7)
...	1	...	**1** (0.7)
1	...	...	**1** (0.7)
1	...	...	**1** (0.7)
...	...	...	**14** (10.2)
...	...	...	**4** (2.9)
...	...	...	**5** (3.6)
10 (7.3)	**1** (0.7)	**2** (1.5)	**137** (100)

LITERATURE REVIEW

Four hundred English-language articles on the topic of myiasis were referenced in *Index Medicus* between 1960 and 1995, and included 72 reports describing 137 unique cases of US-acquired human myiasis (**Table 2**).[4-6,11,23-90] Many reports omitted clinical details such as age, sex, and the underlying illnesses of the patients. Eight (11%) of the authors failed to identify the maggots that they found, and 5 (7%) never actually found a maggot. Thus, maggots from 23 (17%) of the patients reported to have US-acquired myiasis were either never seen or not identified. Wound myiasis, ophthalmomyiasis, and invasive cutaneous myiasis were the most frequently reported clinical manifestations, with *C hominivorax* (screwworm fly), *O ovis* (sheep botfly), and *Cuterebra* species (rodent botflies) being the most commonly described causative species, respectively. The most commonly reported maggots overall were *Cuterebra* species (37/137 [27%]), followed by presumed or unidentified maggots (23/137 [17%]). Eight (6%) of the reported infestations were acquired in a hospital or nursing home. Several cases of accidental gastrointestinal or urinary myiasis were reported. In addition, cases of myiasis were reported that were probably acquired accidentally, but the presented information was insufficient to determine whether or not the larvae were living off the host. Both of these groups have been included in our analysis of US-acquired myiasis reports.

Thirty-seven of the English-language publications on myiasis that were indexed between 1960 and 1995 reported on 47 patients who were infested in tropical countries and later diagnosed and/or treated in the United States.[91-127] Most of these patients presented with furuncular myiasis (**Table 3**).

COMMENT

The clinical manifestations of myiasis and the causative species identified in our study differ significantly from those reported in the literature (**Table 4**). Thirty-five (83%) of our cases were simple wound myiasis; the majority of species were identified as noninvasive blowflies, especially the green blowfly, *P sericata*. By contrast, the literature between 1960 and 1995 identified only 8.9% of 236 cases as caused by nonscrewworm Calliphorid flies. Of the 45 cases of wound myiasis reported during these 36 years, nearly one third were attributed to *C hominivorax*; only 13 cases were caused by all other blowflies combined. It is no wonder that recent reviews of human myiasis continue to overlook *Phaenicia* and other noninvasive blowfly species.[128]

These prospective findings should more closely represent the true pattern of myiasis in urban and suburban North America. Of course, the study is limited by the location and clinical practice of its participants. The major deficiency of this study is the absence of participating centers from Northern and Midwestern communities. We might have encountered patients infested with the larvae of sheep, horse, or rodent botflies had we successfully recruited facilities in more agrarian regions.

Table 3. Myiasis Acquired Outside the United States, but Diagnosed Within the United States, and Reported 1960-1995[90-126]

Causative Species	Region of Acquisition, No. of Cases							
	Africa	Southeast Asia	Middle East	Canada	Mexico	Central America	South America	Caribbean
Calliphoridae								
Cochliomyia hominivorax	1	. . .	. . .	. . .	. . .	2	1	. . .
Cordylobia anthropophaga	6	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sarcophagidae	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cuterebridae								
Dermatobia hominis	. . .	. . .	. . .	. . .	. . .	17	5	9
Cuterebra species	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .
Oestridae								
Oestrus ovis	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .
Stratiomyidae								
Hermetia species	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Maggot found but not identified	1	1	. . .	. . .	1	. . .	. . .	. . .
Total, No. (%)	**9** (19)	**1** (2)	**1** (2)	**1** (2)	**1** (2)	**19** (40)	**6** (13)	**9** (19)

Most of our patients were homeless. Homelessness may have increased their exposure to flies and to refuse frequented by flies. Also, their soiled bandages and clothing probably attracted gravid flies. Most of our patients—especially those with wound myiasis—had diabetes or peripheral vascular disease. These conditions are known to be associated with chronic wounds. They are unlikely to be independent risk factors for myiasis, but this cannot be determined from the present study.

The high incidence between late spring and early fall (Figure 5) is consistent with earlier reports of myiasis in man[61] and animals.[129] All 3 wintertime infestations occurred in California, which has a temperate climate.

The scarcity of *P sericata* in earlier reports is not simply a manifestation of geographical distribution, since these and the other blowflies are found in abundance throughout the United States. Noninvasive wound myiasis clearly has been underreported. Our results resemble those of the prospective study in Australia conducted by Lukin,[14] in which he collected maggots from the wounds of patients in Brisbane during a 17-month period. Maggots from 12 of his 14 cases were identified; 10 (83%) of those were blowflies (Calliphoridae: *P cuprina*). All infestations occurred within preexisting wounds. Six infestations (43%) were nosocomial, occurring in hospital rooms with unscreened windows that likely had been opened. Lukin's patients were not adversely affected by the maggots. Seven of the patients with myiasis of their foot or ankle wounds subsequently required amputations; all of these patients had diabetes and/or peripheral vascular disease.

Mandatory reporting would have simplified the collection of data, but myiasis is not a reportable disease. In order to consider this study in the context of myiasis cases that were voluntarily submitted elsewhere for identification, senior officers were contacted at the Centers for Disease Control and Prevention, the Armed Forces Institute of Pathology, and the US Department of Agriculture. During the past 14 years, only a handful of cases have been submitted for identification to these centers; most of these maggots were invasive and non-US acquired (**Table 5**).

The true frequency of myiasis in the United States cannot be estimated from this study alone. Study cases represent only a small portion of the myiasis cases health care workers are likely to encounter myiasis. Furthermore, even at participating centers, many cases went unreported. At least 5 myiasis cases were not submitted by the author's own institutions, including 3 cases acquired in the hospital. Scott[130] estimated that about 7000 cases of myiasis occur annually in the United States, but there are no known data to support this claim. Lukin[14] states that many cases of myiasis go unreported as a result of "cultural, social, and medicopolitical reasons." Another reason why relatively few cases of blowfly wound myiasis appear in the American literature may be that few health care providers consider noninvasive myiasis to be worthy of reporting.

Confounding matters, invasive myiasis can be overdiagnosed by medical staff with an incomplete understanding of fly biology. Preexisting wounds may be misidentified as maggot-induced wounds, or genitourinary myiasis may be diagnosed when the patient or examining clinician finds maggots in the rectum or vagina without realizing that the maggots subsisting on a nearby wound or on stool or soiled underclothes may simply have sought refuge within the cavernous anatomy after being disturbed. Finding maggots in the rectum or vagina is not itself proof of primary infestation at that site, nor is it proof of consequent injury. Reports of genitourinary[46] or rectal[131] myiasis should be considered incomplete if not inaccurate when they are not supported by physical findings. Furthermore, continued reporting of myiasis without finding a maggot—let alone identifying it—adds little benefit to our understanding of myiasis and should be discouraged.

Greenberg[61] listed the features contributing to 2 published nosocomial infestations, stating that "the following factors intersected to result in myiasis: (1) a helpless and debilitated patient; (2) blood and/or odors of decomposition; (3) nursing neglect; and (4)

Clinical Manifestations, No. of Cases						Total, No. (% of Total Species)
Furuncular	Wound	Other Cutaneous	Ophthalmic	Aural	Gastrointestinal	
1	1	. . .	. . .	2	. . .	**4** (8)
6	. . .	. . .	. . .	. . .	. . .	**6** (12)
. . .	. . .	. . .	. . .	. . .	. . .	**0**
31	. . .	. . .	. . .	. . .	. . .	**31** (67)
1	. . .	. . .	. . .	. . .	. . .	**1** (2)
. . .	. . .	. . .	1	. . .	. . .	**1** (2)
1	. . .	. . .	. . .	. . .	. . .	**1** (2)
1	. . .	. . .	1	. . .	1	**3** (6)
41 (87)	**1** (2)	**0** (0)	**2** (4)	**2** (4)	**1** (2)	**47** (100)

Table 4. Discrepancies Between Published Cases and the Present Study*

	No. (%)	
	Literature Review (n = 114)	Prospective Study (n = 47)
Species		
Calliphoridae	41 (36.0)	41 (87)
Phaenicia species	9 (7.9)	34 (72)
Phormia regina	10 (8.8)	6 (13)
Calliphora species	2 (1.8)	0 (0)
Lucilia species	0 (0)	1 (2)
Cochliomyia species	18 (15.8)	0 (0)
Unspecified	2 (1.8)	0 (0)
Sarcophagidae	11 (9.6)	4 (8)
Wohlfahrtia species	5 (4.4)	0 (0)
Sarcophaga species	5 (4.4)	0 (0)
Bercaea haemorrhoidalis	0 (0)	3 (6)
Gymnoprosopa species	0 (0)	1 (2)
Unspecified	1 (0.9)	0 (0)
Cuterebridae	37 (32.5)	0 (0)
Cuterebra species	35 (30.7)	0 (0)
Dermatobia hominis	1 (0.9)	0 (0)
Unspecified	1 (0.9)	0 (0)
Oestridae	14 (12.3)	0 (0)
Oestrus ovis	8 (7.0)	0 (0)
Hypoderma species	6 (5.3)	0 (0)
Gastrophilidae	1 (0.9)	0 (0)
Gasterophilus species	1 (0.9)	0 (0)
Phoridae	3 (2.6)	2 (4)
Megaselia species	3 (2.6)	2 (4)
Muscidae	2 (1.8)	0 (0)
Muscina stabulans	1 (0.9)	0 (0)
Musca domestica	1 (0.9)	0 (0)
Scenopinidae	1 (0.9)	0 (0)
Scenopinus species	1 (0.9)	0 (0)
Drosophilidae	1 (0.9)	0 (0)
Drosophilia species	1 (0.9)	0 (0)
Piophilidae	1 (0.9)	0 (0)
Piophila species	1 (0.9)	0 (0)
Calliphoridae or Sarcophagidae	1 (0.9)	0 (0)
Cuterebridae or Oestridae	1 (0.9)	0 (0)
Two or more species	(n = 137) 0 (0)	(n = 42) 6 (14)

Table 4. Discrepancies Between Published Cases and the Present Study* (cont)

	No. (%)	
	Literature Review (n = 114)	Prospective Study (n = 47)
Syndromes		
	(n = 137)	(n = 37)†
Wound myiasis	45 (32.9)	35 (95)
Cutaneous, nonwound	35 (25.5)	1 (3)
Ophthalmomyiasis	33 (24.1)	0 (0)
Aural	4 (2.9)	1 (3)
Respiratory	7 (5.1)	0 (0)
Gastrointestinal	10 (7.3)	0 (0)
Genitourinary	1 (0.7)	0 (0)
Other	2 (1.4)	0 (0)
Patient Characteristics		
Age, y	29 [n = 112]‡	60 [n = 36]†
Male-female ratio	1.3:1 [n = 123]‡	5.5:1 [n = 39]†
Nosocomial, No. (%)	8 (5.8) [n = 137]	2 (5) [n = 42]
Homelessness, No. (%)	. . .	16 (44) [n = 36]†
Circulatory insufficiency, No. (%)	. . .	17 (49) [n = 35]†
Substance abuse, No. (%)	. . .	13 (37) [35]†
Diabetes, No. (%)	. . .	4 (11) [n = 35]†

*Ellipses indicate data not available.
†The number of patients is less than 42 because of missing data.
‡The number of patients is less than 137 because of missing data.

summer season." Since that time, many have misinterpreted his observations to suggest that nosocomial myiasis is diagnostic of poor patient care. Of the 2 nosocomial cases collected in the present study, at least 1 was investigated thoroughly and found not to be associated with any evidence of medical negligence. It is possible that nosocomial myiasis occasionally may need to be considered a risk of certain underlying diseases (ie, impaired consciousness, purulent infection, or malodorous secretions) and/or their treatments (ie, sedatives, drainage tubes, and respiratory and gastrointestinal intubation).

It is hoped that this study will prompt health care workers to improve the evaluation and treatment of

Table 5. Human Myiasis Specimens Submitted to the Centers for Disease Control and Prevention (CDC) and the National Veterinary Services Laboratory (NVSL)*

	CDC	NVSL
Years reviewed	1986-1998	1986-1998
Total No. of cases (cases per year)	21 (1.6)	12 (0.9)
No. of US-acquired cases (%)	6 (29)	7 (58)
Species Identification of Cases Acquired in the United States		
Sarcophagidae (unspecified), No. (%)	0	5 (71)
Phaenicia sericata, No. (%)	0	1 (14)
Phormia regina, No. (%)	0	1 (14)
Hermetia species, No. (%)	1 (17)	0
Unidentified, No. (%)	5 (83)†	0
Clinical Syndromes of Cases Acquired in the United States		
Gastrointestinal, No. (%)	2 (33)	0
Ophthalmic, No. (%)	1 (17)	1 (14)
Aural, No. (%)	1 (17)	2 (29)
Body orifices, unspecified, No. (%)	0	1 (14)
Cutaneous/subcutaneous, ie, no wound, No. (%)	2 (33)	1 (14)
Wound associated, No. (%)	0	2 (29)

*Animal and Plant Health Inspection Service (APHIS), US Department of Agriculture.

†Identification was impaired because 2 of these specimens were submitted as tissue sections; the others were preserved larvae.

patients with myiasis. No longer should patients be treated with disgust, and their maggots should not be hastily discarded. Instead, histories and physical examinations always must be comprehensive, and the condition of the patient's hygiene and clothing must be noted. All wounds should be thoroughly cleansed, and tetanus immunoprophylaxis should be updated as necessary. Follow-up within a week should be standard practice; antibiotics need to be prescribed only when indicated by signs of active bacterial infection. Before claiming that myiasis contributed to a patient's demise, other causes must be ruled out, and a mechanism by which the infestation led to the patient's death should be sought. Blood cultures should be obtained in order to support (but not prove) the theory that invasive myiasis may have led to sepsis. Blood ammonia levels should be drawn in order to demonstrate whether the maggot-induced ammonia toxicity seen in some animals[132] might also occur in humans with heavy maggot burdens.

The first maggot caught should be submitted to the clinical laboratory in alcohol or formaldehyde for analysis. (Superior methods for preserving larvae have been described[133] but may not be practical in the clinic or emergency department.) Half of the remaining larvae should be submitted preserved; the other half should be submitted alive. If the clinical laboratory is unable to identify the specimens, then they can be saved for future identification or submitted directly to an academic or governmental center of entomology, parasitology, vector control, or agriculture. The National Veterinary Services Laboratory (National Veterinary Services Laboratory, Animal and Plant Health Inspection Services–Veterinary Services, US Department of Agriculture, PO Box 844, Ames, IA 50010) regularly identifies flies and larvae collected from humans and animals throughout the country.

Identification of the maggot can be crucial in determining pathogenesis. As already discussed, the natural history of each species suggests its potential for invasiveness. Additionally, it may only be possible to determine the exact time and circumstances of an infestation by knowing the age and species of the maggots. Forensic pathologists and entomologists have learned to recognize in maggot-infested corpses the clues needed to explain many unsolved homicides.[134-137] With greater knowledge about human myiasis, we might someday recognize clues about the conditions of the living hosts.

The distribution of some invasive flies is changing; consequently, the epidemiologic characteristics of human myiasis may be changing. In their 1937 report of myiasis in man and animals, Knipling and Rainwater[138] reported that 44% of their human myiasis cases were caused by the screwworm *C hominivorax*. As a result of screwworm eradication, there have been no reports in the literature since 1973 of US-acquired human myiasis with *C hominivorax*. However, related species, such as *Chrysomyia megacephala* and *Chrys rufifacies*, now are spreading through parts of the United States.[139,140] Only by carefully evaluating our patients, recording our findings, and identifying the maggots will we be able to determine if such changes in fly ecology will bring about a return of invasive wound myiasis.

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