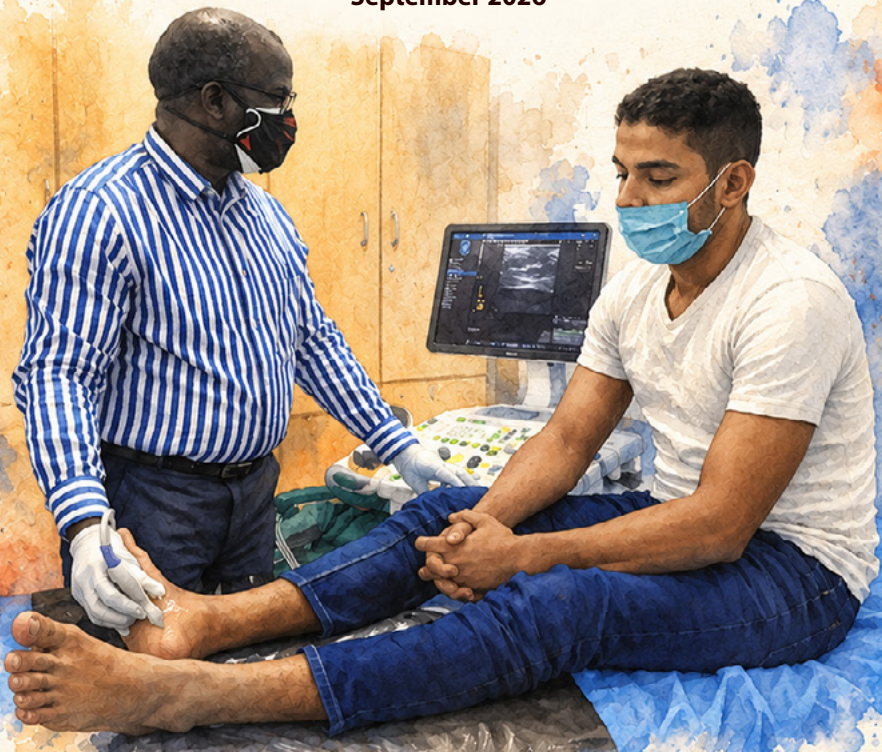




WHO Collaborating Center on Mycetoma & Skin NTDs
Excellence & Leadership
Mycetoma Imaging Diagnosis
An Advanced Clinical Imaging Training Manual
for Healthcare Providers

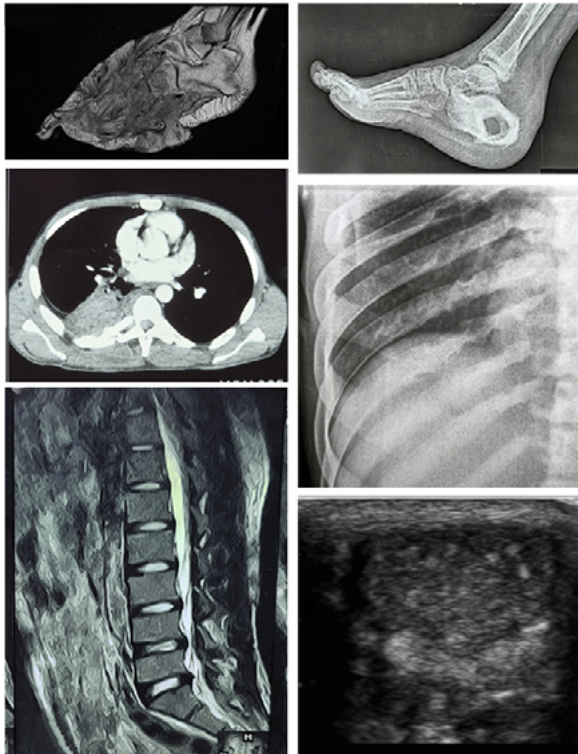
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Mycetoma Imaging Diagnosis

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Preface

Mycetoma remains one of the world's most neglected tropical diseases, imposing a profound physical, socio-economic, and psychological burden on vulnerable individuals across endemic regions. Characterised by its insidious onset, progressive subcutaneous swelling, sinus tract formation, and purulent discharge containing fungal or bacterial grains, the condition presents a unique diagnostic and therapeutic challenge. Because physical examination alone cannot reliably delineate disease extent along body planes or track therapeutic response, diagnostic imaging is the indispensable backbone of modern clinical management.

This training manual, ***Mycetoma Imaging Diagnosis: An Advanced Clinical Imaging Training Manual for Healthcare Providers***, was conceived to bridge the persistent gap between advancements in radiologic science and point-of-care clinical practice. In endemic, resource-limited field settings, the early differentiation between fungal mycetoma (*eumycetoma*) and bacterial mycetoma (*actinomycetoma*) is a critical clinical imperative. Initiating the wrong therapeutic regimen, administering long-term antifungals for a bacterial infection or prolonged antibiotics for a fungal mass inevitably leads to therapeutic failure, numerous drug adverse reactions, disease progression, unnecessary surgical mutilation, or avoidable amputation.

To address these challenges, this manual provides a structured, multi-modality diagnostic framework designed for radiologists, clinicians, surgeons, infectious disease specialists, general practitioners, and point-of-care health workers. Bridging field-level diagnostics and advanced tertiary care.

Accurate diagnostic imaging does more than confirm a diagnosis; it protects patient mobility, guides limb-sparing surgical intervention, provides an objective measure of therapeutic response, and ultimately restores dignity to individuals suffering from this debilitating disease.

This manual fulfils part of the Mycetoma Research Centre mandate as a WHO Collaborating Centre by enhancing clinical management and driving better health outcomes for affected patients.

It is our hope that this manual serves as a practical, empowering resource for clinicians and health workers on the front lines of mycetoma care, advancing early diagnosis and transforming patient outcomes across endemic commu-



nities.

The Authoring Committee

Mycetoma Imaging Diagnosis Initiative

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Acknowledgments

The development of ***Mycetoma Imaging Diagnosis: An Advanced Clinical Imaging Training Manual for Healthcare Providers*** has been a collaborative endeavour driven by a shared commitment to advancing patient care, early diagnosis, and clinical research in neglected tropical diseases. We extend our deepest gratitude to the many individuals, institutions, and clinical teams whose expertise, dedication, and steadfast support made the publication of this manual possible.

First and foremost, our profound appreciation goes to the patients, their families, and the endemic communities whose resilience in the face of mycetoma continues to inspire our research, diagnostic innovations, and clinical outreach efforts. Their bravery underscores the urgency of improving point-of-care diagnostics and ensuring equitable access to healthcare.

Finally, we express our appreciation to the global health advocates and field healthcare workers who work tirelessly in remote health centers across the Mycetoma Belt. Their dedication to applying these imaging protocols at the bedside transforms scientific research into life-saving clinical practice.

Target Audience

This training manual is designed to serve a broad, multidisciplinary spectrum of healthcare professionals involved in the diagnosis, treatment and long-term management of mycetoma across both resource-limited field settings and tertiary academic medical centres:

- **Point-of-Care Health Workers & Clinical Officers:** Frontline rural practitioners operating in endemic regions who require practical skills in performing and interpreting point-of-care ultrasonography (POCUS) for rapid bedside triage.
- **Radiologists & Diagnostic Imaging Technologists:** Specialists seeking standardised, multi-modality diagnostic criteria and reporting frameworks for plain radiography, ultrasound, CT and MRI scans evaluation of complex soft tissue and bony lesions.
- **Orthopaedic & General Surgeons:** Surgical teams requiring precise pre-operative cross-sectional mapping to determine anatomical boundaries, deep fascial integrity, neurovascular contiguity, and clear surgical margins for limb-sparing interventions.
- **Infectious Diseases & Tropical Medicine Specialists:** Physicians managing long-term antimicrobial regimens who rely on objective, interval imaging metrics to monitor therapeutic response and detect disease recurrence.
- **Medical Educators & Clinical Trainees:** Academic faculty, residents, and fellows in radiology, surgery, and tropical medicine utilising this resource as a clinical training curriculum.

Scope of the Manual

Mycetoma Imaging Diagnosis: An Advanced Clinical Imaging Training Manual for Healthcare Providers encompasses a comprehensive, multi-modality diagnostic framework tailored to the unique clinical realities of endemic regions across the global Mycetoma Belt. The scope includes:

- 1. Field-Level Triage & Bedside Diagnostics:** Early aetiological differentiation between fungal (*eumycetoma*) and bacterial (*actinomycetoma*) infections using high-frequency linear ultrasound and POCUS protocols in low-resource settings.
- 2. Skeletal Assessment & Staging:** Standardised staging (Stages I–IV) of osseous involvement, cortical erosion, periosteal reactions, and bone remodelling on conventional plain radiography and CT scan.
- 3. Advanced Cross-Sectional Characterisation:** High-resolution multi-detector CT for complex bony architecture evaluation and multi-sequence MRI for multi-planar soft tissue, dural, and neurovascular mapping.
- 4. Specialised Anatomical Presentations:** Detailed imaging features of rare and high-risk presentations, including craniofacial/skull, pelvic, and chest and abdominal cavities mycetoma.
- 5. Standardised Clinical Reporting Protocols:** Implementation of structured, multi-modality reporting templates to eliminate diagnostic ambiguity and facilitate interdisciplinary communication.
- 6. Therapeutic Response & Pre-Operative Planning:** Objective imaging algorithms for tracking response to prolonged medical therapy and executing pre-operative margin mapping for surgical resection.

Key Learning Objectives

Upon completing this training manual, healthcare providers will be able to:

- **Differentiate Aetiology at the Bedside:**

Identify the pathognomonic 'hyper-reflective echoes' sign and acoustic shadowing criteria on US to rapidly distinguish eumycetoma from actinomycetoma without reliance on delayed culture results.

- **Classify Radiographic Bone Disease:**

Systematically evaluate plain radiographs to stage skeletal destruction from localised soft tissue swelling (Stage I) through diffuse cortical collapse and pathological fracture (Stage IV).

- **Execute Advanced Pre-Operative MRI Mapping:**

Delineate precise 3D tissue boundaries, differentiate true bone marrow involvement from reactive oedema, and evaluate deep fascial and neurovascular encasement to define a 10- 15 mm surgical safety margin.

- **Analyse High-Resolution CT for Bony Pathology:**

Detect early cortical micro-geodes, endosteal erosion, sequestra, and 3D calvarial/skull base integrity to guide surgical curettage or segmental bone resection.

- **Utilise Standardised Reporting Templates:**

Formulate structured imaging reports for US, X-ray, CT, and MRI to ensure clear, reproducible documentation across multidisciplinary care teams.

- **Monitor Longitudinal Treatment Response:**

Apply objective imaging criteria to distinguish active infection from quiescent post-treatment fibrosis, preventing premature drug discontinuation or delayed detection of treatment failure.

Module 1

Mycetoma Clinical Foundations

Mycetoma: Epidemiology, Pathophysiology, and Clinical Reality

Mycetoma is a chronic, progressive, and severely disabling granulomatous inflammatory disease of the subcutaneous tissues that, if left untreated, relentlessly spreads to involve the skin, deep muscle compartments, fascial planes, and underlying bones. Recognised by the World Health Organization (WHO) as a neglected tropical disease (NTD) in 2016.

The disease is classified into two distinct aetiological forms: Eumycetoma, caused by true fungi; *Madurella mycetomatis*, the most commonly reported causative microorganism; and Actinomycetoma, caused by aerobic actinomycetes (bacteria), including *Streptomyces somaliensis*, *Actinomadura madurae*, and *Nocardia brasiliensis*. Infection occurs via minor local trauma, such as thorn pricks, splinters, or abrasions, which introduce environmental organisms into the subcutaneous tissue. Agricultural workers, pastoralists, and rural labourers who walk barefoot are disproportionately affected.



Foot eumycetoma lesion with numerous active sinuses, discharge and black grains

The clinical hallmark of early mycetoma is an indolent, painless subcutaneous nodule or firm mass. Because early lesions do not impair daily labour or cause systemic constitutional symptoms, patients in resource-limited rural

settings rarely seek medical attention at onset. Over months to years, the infection breaches fascial boundaries through direct local extension, producing the classic diagnostic triad: massive painless swelling, multiple active and healed draining sinus tracts, and a purulent discharge containing characteristic grains, which are microscopic colonies of the causative organism.



**Foot actinomycetoma with multiple healed
and active sinuses and discharge**

While no anatomical region is immune, cases are documented in the head, neck, chest, abdominal wall, gluteal region, and spine. The lower extremities, particularly the foot and ankle, account for over of all reported cases. Upper extremities, especially the hands and forearms, are the second most common sites due to occupational handling of contaminated soil and vegetation.



**Advanced inguinal actinomycetoma
spreading from an amputated foot lesion
spreading to anterior abdominal wall**



**Advanced actinomycetoma involving
anterior left hemithorax, axilla, neck with
cervical spinal cord affection**

As the disease advances, fungal hyphae or bacterial filaments form the grains surrounded by an intense polymorphonuclear neutrophil reaction and chronic granulomatous tissue, leading to progressive fibrosis, destruction, and deformities. Fungal eumycetoma tends to remain encapsulated longer, forming

localised fluid-filled cavities, whereas bacterial actinomycetoma spreads more aggressively along fascial planes and tissues, inducing rapid periosteal reaction and bone destruction.



**Surgical specimen showing multiple grains containing cavities
surrounded by intense fibrous tissue**

The human and socio-economic toll of late-stage mycetoma is catastrophic. Structural deformities, joint ankylosis, muscle atrophy, and secondary bacterial infections frequently lead to permanent physical disability, loss of livelihood, stigma, and forced surgical amputation. Early clinical identification, combined with non-invasive imaging techniques to map anatomical spread and differentiate fungal from bacterial aetiology, remains the single most critical factor in preserving body function and achieving therapeutic cure.

The Clinical Diagnostic Challenge

- **Insidiousness & Clinical Latency:** The initial painless subcutaneous nodule often persists for months or years without disturbing daily activities. Because pain occurs only during secondary bacterial superinfections or bone invasion, patients in rural, resource-limited settings rarely seek medical attention in the early stages.



Multiple left foot painless swellings of early eumycetoma

- **Classic Diagnostic Triad:** By the time patients present to specialised centers, the disease has progressed to its classic triad:
 1. Firm, painless subcutaneous swellings.
 2. Multiple draining sinus tracts that intermittently discharge purulent or serosanguineous fluid containing fungal or bacterial grains.
 3. Structural deformity and destruction of surrounding soft tissue, fascia, and bone structures.

The Three Fundamental Clinical Questions

Effective mycetoma management relies on precisely identifying the causative pathogen. To direct clinical decision-making, comprehensive imaging and laboratory testing must swiftly address three core questions:

Aetiological Classification

- **Eumycetoma (Fungal):**

Most commonly caused by *Madurella mycetomatis*. Requires long-term systemic azole antifungal therapy for a variable duration between 6–12 months, often followed by localised surgical excision.

- **Actinomycetoma (Bacterial):**

Caused by species such as *Streptomyces somaliensis*, *Actinomadura madurae*, or *Nocardia brasiliensis*. Managed primarily with combination antibiotic regimens. Surgery is generally not required as the response is reasonable.

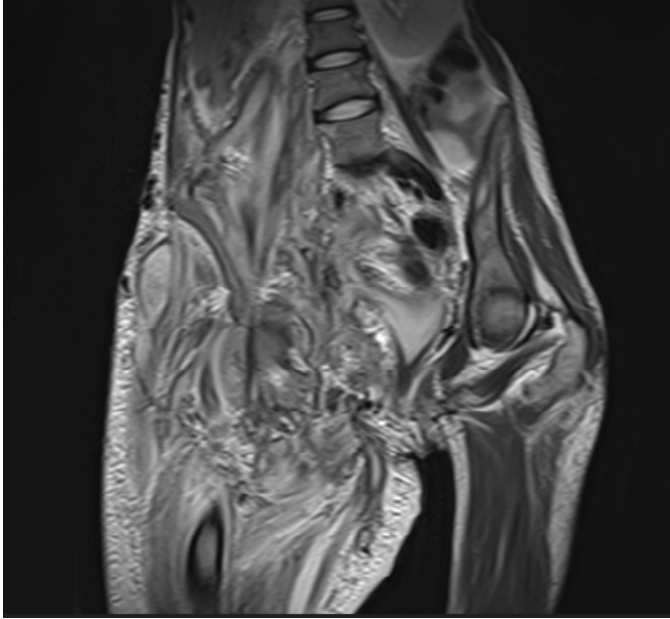
- **Clinical Significance:**

Administering antifungals for a bacterial infection or vice versa delays effective treatment and risks toxicities, unnecessary surgical interventions, and financial hardship. Non-invasive imaging (specifically Point-of-Care Ultrasound) provides immediate bedside differentiation before culture verification.

Anatomical Extension & Compartmental Mapping

- **Soft Tissue & Fascial Barriers:**

Mycetoma does not respect typical anatomical boundaries. It traverses deep fascial planes and muscular compartments through direct local invasion.



MRI scan showing massive thigh and inguinal actinomycetoma spreading intra-abdominally

- **Neurovascular & Joint Involvement:**

Defining the precise relationship between the mycetoma granulomatous mass and major neurovascular bundles (e.g., the posterior tibial artery and the sciatic nerve) determines whether limb-sparing surgery is feasible.

- **Osseous & Joint Contiguity:**

Radiographs and MRI identify early periosteal reaction, bone affection, subperiosteal erosions, and intra-articular extension, factors that distinguish localised medical management from extensive debridement or amputation.

Treatment Response & Longitudinal Monitoring

- **Inaccuracy of Physical Inspection:**

Clinical induration, hyperpigmentation, and healed scar tissue persist long after clearance of active bacterial or fungal infection, rendering clinical palpation unreliable for assessing therapeutic efficacy.

- **Imaging Biomarkers of Response:**

Non-invasive imaging monitors true therapeutic efficacy through specific parameters:

- **Regression:** Decreasing size and count of hypoechoic fluid cavities on ultrasound; reduction in high T2/STIR hyperintensity on MRI.
- **Encapsulation:** Formation of thick, continuous fibrotic rims around lesions, signalling disease containment.
- **Progression:** Persistent or expanding osteolytic changes, new cortical breaches, or recurrence of the pathognomonic “Dot-in-Circle” sign on MRI during therapy.

Limitations of Physical Examination & Necessity of Imaging

Differentiation of Fungal from Bacterial Mycetoma:

Clinical examination alone cannot reliably differentiate fungal from bacterial types.

- **Underestimation of Deep Spread:**

Clinical inspection measures surface involvement but fails to identify deep subcutaneous and muscular infiltration, interosseous extension, or bone invasion.

- **Role in Surgical Planning:**

Imaging provides good delineation of lesion margins for adequate surgical excision with clear margins, reducing local recurrence rates following surgery.

- **Role in Staging & Treatment Duration:**

Accurate baseline imaging may be used to establish a disease staging system, providing an objective reference point for deciding when medical therapy can be safely discontinued.

Diagnostic Modality Selection Matrix

Modality	Primary Diagnostic Indication	Clinical Strengths	Limitations & Barriers
Ultrasonography (US)	First-line point-of-care screening.	High spatial resolution for soft tissue.	Limited acoustic penetration in deep cortical bone.
	Organism type discrimination: eumycetoma vs actinomycetoma.	Portable, low cost. Immediate differentiation of mycetoma type.	Operator-dependent.
Conventional Radiography (X-Ray)	Assessment of cortical integrity, periosteal reaction, and gross bone destruction.	Universally available. Fast, low cost. Excellent baseline for skeletal monitoring.	Poor soft tissue contrast. Insensitive to early bone marrow invasion.
Magnetic Resonance Imaging (MRI)	Comprehensive staging. “Dot-in-Circle” sign identification. Surgical margin planning.	Superior soft tissue contrast. Multi-planar imaging. Precise bone marrow and fascial mapping.	High cost. Limited availability in rural endemic foci. Contraindications (implants/metal).

Modality	Primary Diagnostic Indication	Clinical Strengths	Limitations & Barriers
Computed Tomography (CT)	Fine cortical bone detail. Bone cavity identification. Surgical planning for complex resections.	Excellent 3D osseous visualisation. Fast acquisition.	Radiation exposure. Soft tissue resolution inferior to MRI.

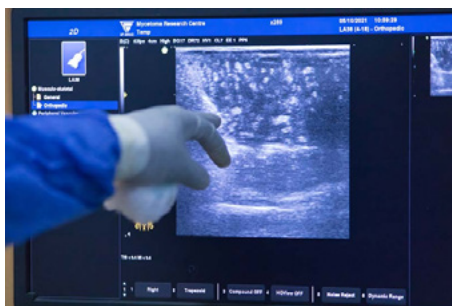
Module 2

Point-of-Care Ultrasonography Protocol

Point-of-care ultrasonography (POCUS) has transformed mycetoma management in endemic, resource-limited settings by enabling rapid, bedside differentiation between eumycetoma, actinomycetoma, and non-mycetoma lesions, without waiting weeks for culture results, surgical biopsies, or histopathological reports.

Mycetoma Ultrasound Characteristics

The mycetoma grains, capsule, and the accompanying inflammatory granuloma have characteristic ultrasonic appearances. Ultrasound imaging can differentiate between eumycetoma, actinomycetoma, and other non-mycetoma lesions. The grains produce numerous sharp, bright hyperreflective echoes consistent with the black grains in eumycetoma lesions. Fungal grains contain a dense extracellular matrix rich in melanin, proteins, and cross-linked chitin-glucan walls, creating high acoustic impedance that reflects ultrasound waves and leaves a dark shadow behind. Also, there are multiple thick-walled cavities with absent acoustic enhancement. In actinomycetoma lesions, the findings are similar, but the grains are less distinct. This may be due to their smaller size and consistency, the individual embedding of the grains or the absence of cement substances in a few.



Mycetoma ultrasonic appearance consistent of numerous sharp, bright hyperreflective echoes and hypoechoic thick-walled cavities with absent acoustic enhancement

Clinical Utility of Ultrasonography

1. Immediate Bedside Decision-Making:

Allows clinicians to initiate appropriate targeted antifungal therapy vs combination antibiotics on the day of presentation.

2. Non-Invasive & Safe:

Eliminates invasive biopsy risks in remote rural health centres lacking adequate surgical facilities.

3. Anatomical Mapping & Surgical Guidance:

Maps lesion depth, muscular compartment involvement, and contiguity to bone or major vessels before surgical intervention.

4. Therapeutic Monitoring:

Provides an objective baseline to track cavity shrinkage, reduction in grain counts, or fibrotic encapsulation during long-term therapy.

5. Field survey and epidemiological study

It is the most suitable tool for field early detection and management, as well as for epidemiological studies.



Ultrasound examination at field survey for early case detection and management



Standard Ultrasound Scan Protocol

- **Transducer Choice:**

High-frequency linear array probe (**7.5–15 MHz**) for superficial lesions, soft tissue, and small joints

Low-frequency convex probe (**3.5–5 MHz**) for deep abdominal, pelvic, or retroperitoneal extensions.

- **Patient Positioning:**

Comfortable, fully supported positioning with the affected anatomical region fully exposed. Apply abundant acoustic gel to avoid direct pressure on tender areas.

- **Probe Protection**

Use a probe cover with a glove to avoid damage from the thick skin, sinuses, and cross-infection.

Systematic Scanning Sweep:

1. **Superficial Epidermal/Dermal Layer:**

Assess sinus tracts and local fluid collections.

2. **Subcutaneous Fat & Fascial Planes:**

Map the extent of granulomatous cavities and capsule formation.

3. **Muscular & Neurovascular Bundles:**

Evaluate muscle fibre displacement, intramuscular cavities, and vascular displacement.

4. **Cortical Bone Interface:**

Inspect for cortical disruption, irregular periosteal reactions, and acoustic breaches.

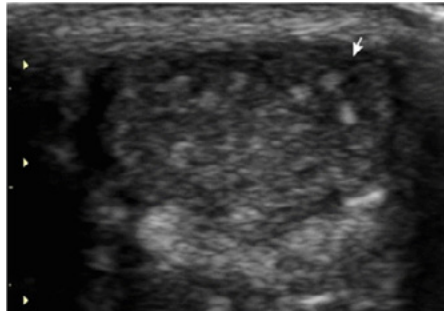
Pathognomonic Sonographic Features

Characteristic	Eumycetoma	Actinomycetoma
Acoustic Profile	Distinct, individual, or clustered hyper-reflective (bright white) echoes embedded within localised hypoechoic (dark) fluid-filled cavities.	Fine, less dense, hyper-reflective echoes distributed throughout hypoechoic granulomatous tissue.
Acoustic Shadowing	<i>Present.</i> <i>Prominent posterior acoustic shadowing occurs behind the hyper-reflective grains due to high acoustic absorption by thick fungal walls and surrounding cement matrix (Madurella mycetomatis).</i>	Absent or Minimal. Bacterial grains (Streptomyces somaliensis, Actinomadura madurae) do not produce strong posterior acoustic attenuation, allowing sound waves to pass through.
Cavity Architecture	Well-defined, thick-walled, hypoechoic cavities, often showing thick fibrous septations.	Ill-defined, poorly demarcated hypoechoic areas representing diffuse inflammatory exudate and micro-abscesses without distinct fibrous capsules.
Grain Appearance	Bright, distinct hyperechoic echoes.	Fine, faint, multi-reflective echoes.
Cavity Size & Shape	Larger (> 5 mm), well-defined hypoechoic cavities.	Smaller (< 5 mm), ill-defined micro-abscesses.

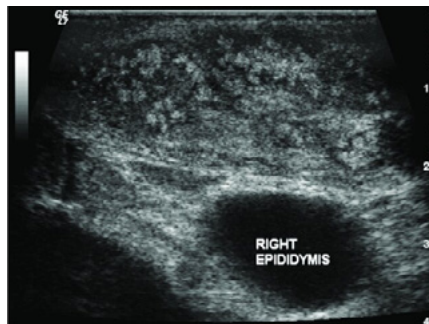


Grain Distribution	Sharp, aggregated central hyperreflective dots.	Fine, widely dispersed, delicate reflections.
Lesion Boundary	Thick, sharp inflammatory walls.	Diffuse, infiltrative, poorly demarcated margins

Mycetoma Ultrasound Appearance



Foot actinomycetoma Lesion



Scrotal eumycetoma

Module 3

Conventional Radiography (X-Ray)

Conventional plain radiography remains the essential, low-cost baseline modality for evaluating skeletal involvement, staging disease severity, and guiding long-term management in mycetoma. While initial soft tissue changes manifest on X-rays as localised swelling or soft tissue density, progressive infection induces characteristic bone changes ranging from soft tissue swelling and periosteal reaction to extensive osteolysis, cortical erosion, and bone destruction.

Radiographs cleanly categorise skeletal pathology into distinct stages, such as external cortical indentations (Scalloping), intra-osseous “moth-eaten” cavities, and widespread bone expansion, osteoprosis or pathological fractures, allowing clinicians to differentiate the slow, osteosclerotic bone remodelling typical of eumycetoma from the rapid, diffuse osteolytic destruction characteristic of actinomycetoma.

Furthermore, plain radiography provides an indispensable, easily reproducible benchmark to monitor bone healing and remineralisation during extended antimicrobial therapy, rule out concurrent traumatic fractures, and determine whether conservative medical management remains viable or if surgical debridement or bone resection is necessary.

Recommended Standard Projections

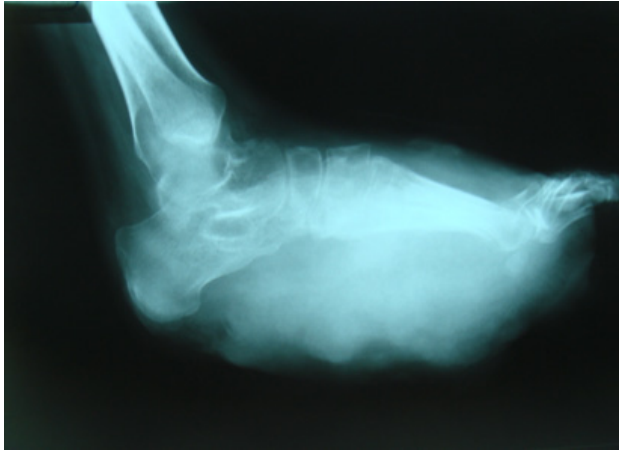
- **Feet & Hands:** Anteroposterior (AP), Lateral, and Oblique views.
- **Long Bones & Joints:** AP and Lateral views including one joint above and one joint below the lesion.
- **Pelvis & Trunk:** AP Pelvis, dedicated oblique projections for iliac wings or sacrum.

Radiological Findings in Mycetoma

A series of radiological changes were observed in mycetoma, including:

1. Soft Tissue Appearance:

The lesions appear as soft tissue, and some contain calcification.



X-ray showing the ankle joint region with massive periosteal reactions presenting as a sun-ray appearance and numerous bone cavities.

2. Cortical Scalloping:

The expanding soft-tissue mass directly invades the bone cortex, producing characteristic cortical scalloping before aggressive periosteal reactions develop.



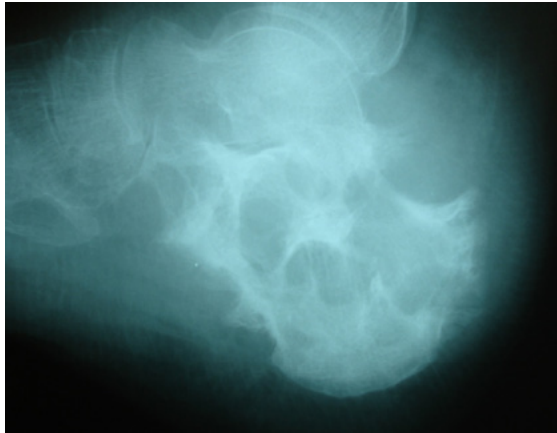
Foot X-Ray showing soft tissue shadow, with calcification and scalloping

3. Periosteal Reactions:

New bone formation, presenting as a Codman triangle, sun-ray appearance or cortical thickening.



X-ray showing the ankle joint region with massive periosteal reactions presenting as a sun-ray appearance and numerous bone cavities.



Calcaneus X-ray showing soft tissue shadow, numerous bone cavities and periosteal reaction



Foot X-ray showing soft tissue shadow, Codman triangle periosteal reaction

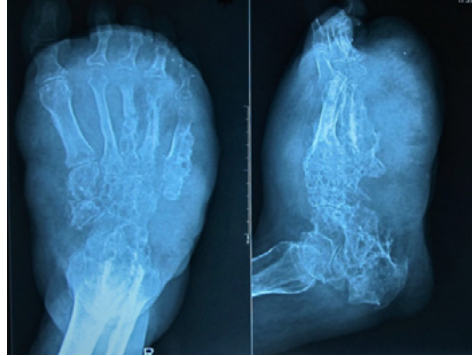
1. Bone Cavities:

Bone cavities are a characteristic feature of advanced mycetoma. They are usually multiple round, osteolytic cavities within the bone matrix. In eumycetoma, these cavities tend to be larger (greater than 1cm), fewer, with edge sclerosis reflecting slower, localised bone destruction.

In actinomycetoma, they are typically smaller (2 to 5 mm), numerous, and poorly defined.



X-Ray of hand eumycetoma showing larger cavities with edge sclerosis



X-Ray of advanced foot actinomycetoma showing massive soft tissue shadow, periosteal reaction, Codman triangle, numerous small, ill-defined cavities with osteoprosis.

Radiological Staging System for Bone Involvement

- **Stage I: Soft Tissue Swelling Only**

Preservation of subcutaneous fat planes; no periosteal or cortical bone abnormalities.

- **Stage II: Early Bone Involvement (Periostitis)**

Cortical scalloping, smooth or spiculated periosteal reaction; early cortical thickening adjacent to soft tissue mass.





Hand X-Ray showing massive soft tissue shadow, sun-ray periosteal reaction and bone cavitation.

- **Stage III: Cortical Erosion & Cavity Formation**

Multiple round, well-circumscribed lytic lesions (cavities) within cortical and subcortical bone; preservation of joint spaces.



Stage III

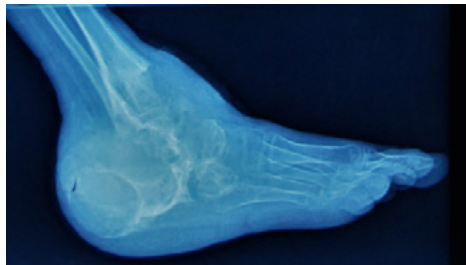
Massive advanced actinomycetoma foot X-Ray showing numerous small ill-defined cavities with massive periosteal reactions and soft tissue shadow.



X-Ray of the leg eumycetoma showing multiple large cavities, cortical thickening of the tibia, and soft tissue shadow.

- **Stage IV: Advanced Osseous Destruction & Deformity**

Diffuse osteoporosis, multi-cavitary bone loss, moth-eaten appearance, pathological fractures, cortical collapse, and joint ankylosis or disorganisation.



Stage IV advanced mycetoma foot

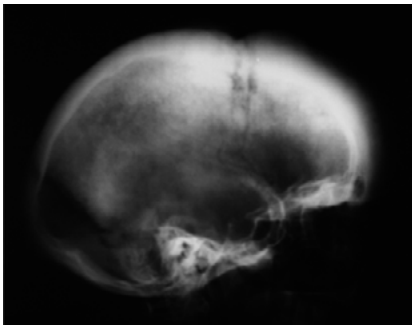
Foot X-Ray showing big multiple cavities with sclerotic edges affecting the lower tibia and fibula, and tarsal bones and pathological fracture of the lower third of the tibia.

Differential Radiographic Features: Eumycetoma vs Actinomycetoma

Features	Eumycetoma	Actinomycetoma
Bone cavities	Few.	Numerous.
	Relatively large cavities (typically in diameter).	Small, lytic cavities (typically in diameter).
	With distinct sclerotic margins.	Poorly demarcated, creating a classic “moth-eaten” appearance.
	The bone attempts to wall off the fungal infection, preserving overall structural alignment until late stages.	Marked diffuse osteopenia. Aggressive periosteal reactions are common.

Skull Mycetoma Radiological Appearance

A skull X-ray in cranial mycetoma typically shows massive thickening of the skull tables and generalised osteoblastic (bone-forming) changes with a purely sclerotic appearance and loss of normal trabeculation. There is marked widening and heavy density of the inner and outer skull tables.



Mycetoma Skull X-Ray showing dense sclerosis

Module 4

Advanced Cross-Sectional Imaging (MRI & CT)

Advanced cross-sectional imaging via Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) serves as the definitive multi-planar modality for establishing total anatomical extent, bone involvement, and surgical feasibility in complex mycetoma cases.

MRI is the modality of choice for soft-tissue characterisation, utilising T1- and T2-weighted sequences. Short Tau Inversion Recovery (STIR) sequences to identify the pathognomonic “Dot-in-Circle” sign—where high-signal-intensity granulomatous cavities (“circles”) enclose central hypointense fungal or bacterial grain aggregates (“dots”), while precisely delineating neurovascular, muscular compartment, and early bone marrow invasion before overt cortical destruction occurs.

Conversely, high-resolution CT excels at depicting skeletal pathology, offering superior visualisation of cortical erosion, periosteal reaction, sequestra, and “moth-eaten” osteolytic cavities, particularly in intricate bony structures such as the tarsal bones, pelvis, and skull base.

Together, these cross-sectional techniques eliminate the depth underestimation inherent to physical examination, guide limb-sparing surgical margins, differentiate soft-tissue mass effects from true joint extension, and provide an objective radiologic baseline for monitoring therapeutic response or disease recurrence.

Magnetic Resonance Imaging (MRI) Protocol & Signs

MRI is the gold standard for soft tissue mapping, fascial boundary assessment, and deep marrow evaluation. Furthermore, it is essential for disease staging and management decision-making.

A. Recommended MRI Sequences

- **T1-Weighted (T1W) Axial & Sagittal:**

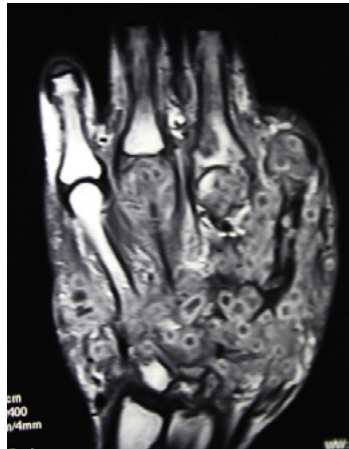
Demonstrates anatomical boundaries, subcutaneous fat replacement, and bone marrow signal modification (low signal intensity replacing bright fat).

- **T2-Weighted (T2W) & Fat-Suppressed (STIR/T2-FS) Multi-planar:**

Highlights active inflammatory fluid collections, granulomas, sinus tracts, and soft-tissue oedema (high signal intensity).

- **T1-Weighted Post-Contrast (Gadolinium) with Fat Saturation:**

Delineates thick peripheral granuloma wall enhancement, necrotic non-enhancing cores, and active sinus tracts.



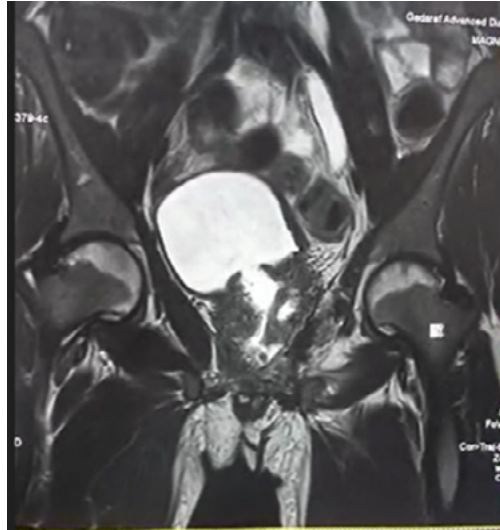
MRI of a massive hand mycetoma showing the typical Dot-in-Circle sign

B. The Pathognomonic “Dot-in-Circle” Sign

The **“Dot-in-Circle”** sign is the pathognomonic MRI feature of mycetoma, highly specific for both fungal and bacterial forms.

The **“Circle”**: Smaller (< 5 mm), ill-defined micro-abscesses.

The **“Dot”**: Central tiny hypointense (dark) rounded dot within the circle on both T1W and T2W sequences representing the aggregate grain of fungal mycelia or bacterial colonies.



MRI showing pelvic/perineal soft-tissue mass, displacing the rectum to the right and the rectovesical fistula due to massive advanced perineal eumycetoma extending deep into the pelvic cavity.

Computed Tomography (CT) Applications

Computed Tomography (CT) serves as the primary cross-sectional imaging modality for evaluating subtle osseous destruction, periosteal changes, and complex surgical anatomy in mycetoma. While MRI provides superior contrast for soft-tissue compartments, multi-detector CT with high-resolution bone algorithms excels at identifying early cortical scalloping, microcavities, endosteal erosion, sequestrum formation, and sclerotic bone remodelling often before these changes become clearly visible on conventional plain radiography.

In anatomically complex regions such as the tarsal bones, pelvis, skull base, or spine, 3D CT reformations provide precise multi-planar mapping of cortical integrity and bony architecture, allowing surgeons to distinguish between localised cortical destruction requiring targeted curettage and extensive structural collapse necessitating segmental resection or stabilisation.

Additionally, intravenous contrast-enhanced CT reliably maps hypervascular inflammatory margins, deep soft-tissue abscesses, and retroperitoneal or neu-

rovascular structures, offering a rapid, widely accessible alternative when MRI is contraindicated or unavailable in resource-limited diagnostic settings.



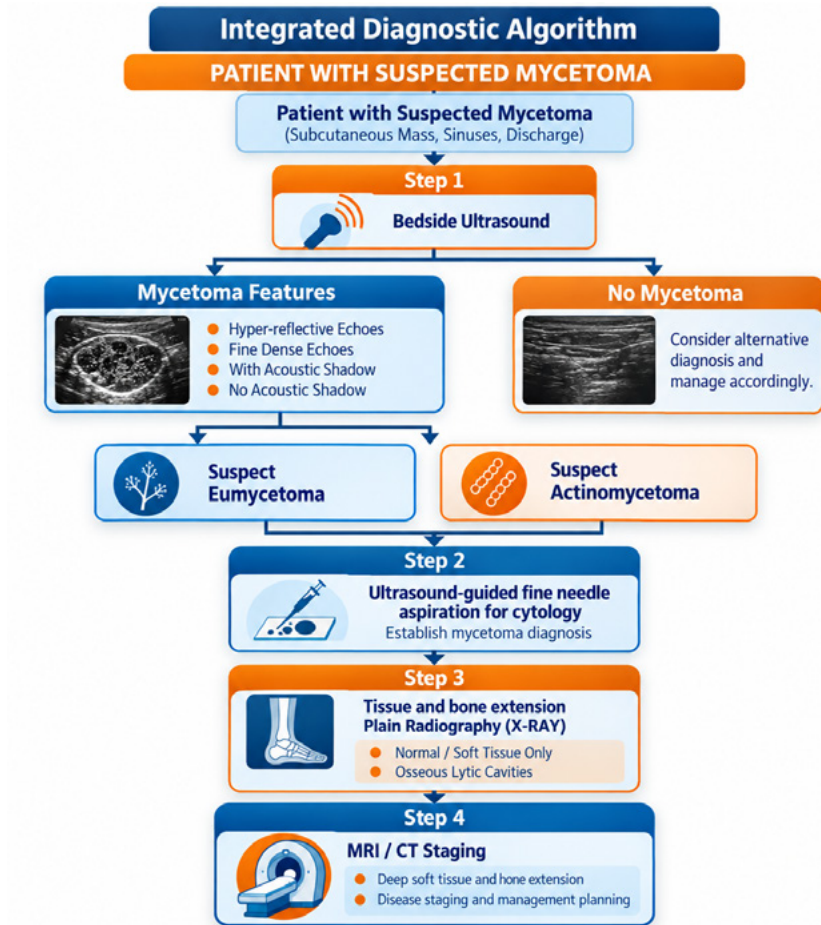
The skull and facial bones CT scan of actinomycetoma showed radiological features inconsistent with bone fibrous dysplasia.

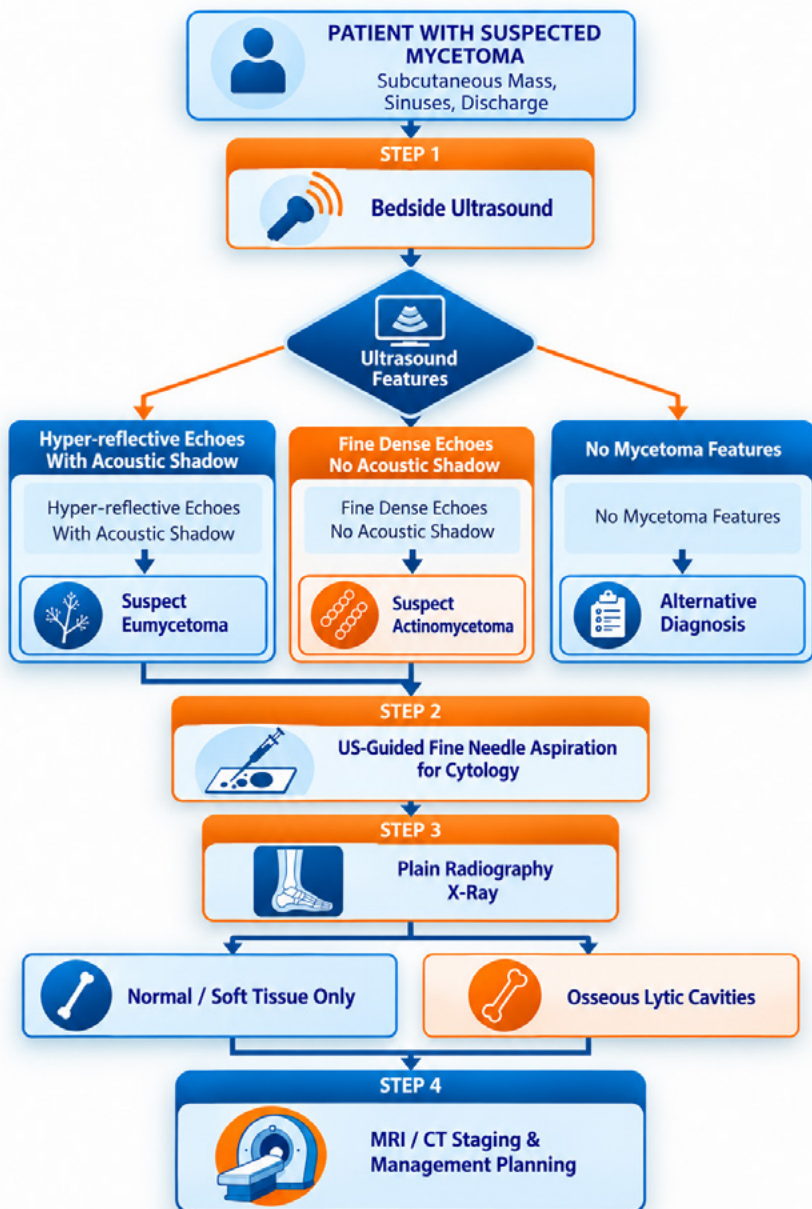
- **Primary CT Indications:**

- » Identification of dense bone sequestra (necrotic bone fragments) within granulomatous cavities.
- » Evaluation of complex anatomical regions (pelvis, spine, calvarium) where cortical bone structure is intricate.
- » 3D volumetric reconstruction for surgical planning and prosthetic custom fit before major reconstructive surgery.

Module 5

Diagnostic Workflows & Case Studies







Clinical Case Scenarios

Case 1: Early Foot Eumycetoma (US-Driven Diagnosis)

- **Presentation:** A 24-year-old agricultural worker presents with a 6-month history of a painless swelling on the plantar aspect of the right foot. No sinus tracts or active discharge are present.
- **US Findings:** High-frequency linear scan reveals multiple well-defined hypoechoic cavities within the subcutaneous tissue, with central hyperreflective bright echoes. The underlying cortical bone interface of the metatarsals is smooth and intact.
- **Radiographs:** Plain AP/Lateral X-rays show soft tissue swelling without periosteal reaction or bone lytic lesions (Stage I).
- **Clinical Decision:** Eumycetoma diagnosed at an early stage. Patient initiated on systemic antifungal therapy (e.g., Itraconazole) for 6 months, followed by wide surgical excision, and continued on antifungal therapy for 6 months or until cure is achieved.

Case 2: Advanced Pelvic Actinomycetoma (MRI Staging)

- **Presentation:** A 42-year-old pastoralist presents with extensive indurated swelling involving the right gluteal region, the lower abdominal wall, and the upper thigh, with multiple purulent sinus tracts.
- **Radiographs:** AP Pelvis radiograph reveals diffuse, moth-eaten osteolysis of the iliac wing with marked periosteal spiculation (Stage IV).
- **MRI Findings:** Multi-planar T2-Weighted and STIR sequences demonstrate extensive hyperintense signal infiltrating the gluteus maximus and iliopsoas muscle, and extending into the pelvic retroperitoneum. Widespread pathognomonic "Dot-in-Circle" signs are visible throughout the gluteal muscle beds. T1 post-contrast images confirm thick ring-enhancement surrounding necrotic collections.
- **Clinical Decision:** Advanced pelvic actinomycetoma. Given the extensive involvement of deep muscle groups and pelvic bones, surgical resection is contraindicated. Patient started on combined intensive antibacterial therapy (Amikacin plus Trimethoprim-Sulfamethoxazole). Ultrasound and MRI scheduled at 6-month intervals to monitor reduction in cavity size and resolution of the "Dot-in-Circle" sign.

Self-Assessment & Review Questions

1. Which ultrasound feature definitively differentiates *Eumycetoma* from *actinomycetoma*?
2. Describe the anatomical structures represented by the “Dot” and the “Circle” in MRI T2-weighted sequences.
3. Why does *actinomycetoma* produce a “moth-eaten” radiographic appearance in bone compared to the large, well-demarcated geodes seen in *Eumycetoma*?

Module 6

Standardised Reporting Templates & Longitudinal Imaging Protocols

Structured Reporting Templates for Clinical Documentation

To reduce clinical ambiguity among radiologists, clinicians, surgeons, and infectious disease specialists, mycetoma imaging reports should follow a standardised, structured reporting template that systematically captures key diagnostic, aetiological, and anatomical parameters.

Unstructured narrative reports frequently omit critical operational details such as exact fascial plane integrity, neurovascular contiguity, or specific acoustic and signal features, leading to delayed or misdirected management.

A standardised template enforces consistent documentation across all imaging modalities, explicitly requiring clinicians to record the presence or absence of pathognomonic markers, such as the MRI “Dot-in-Circle” sign, grain acoustic behaviour (e.g., hyperreflective echos on ultrasound to differentiate eumycetoma from actinomycetoma, precise lesion dimensions in three planes, muscle compartment infiltration, and radiologic bone staging (Stage I–IV).

By establishing a uniform diagnostic language, structured reporting minimises inter-observer variability, streamlines multidisciplinary surgical planning, and provides an accurate, reproducible quantitative baseline for longitudinal monitoring during extended medical therapy.



Ultrasound Imaging Reporting Template

Patient Name & ID:

Age

Gender: [M] [F]

Date of Exam: [YYYY / MM / DD]

Lesion site:

Transducer Type: [] Linear (7.5–15 MHz) [] Convex (3.5–5 MHz)

Soft Tissue Architecture

Lesion Depth	[] Subcutaneous [] Fascial [] Intramuscular [] Subperiosteal
Cavity Count	[] Single [] Multiple localised [] Diffuse multi-cavitary
Cavity Size	[] <2 cm [] 2- 5 cm [] > 5cm
Capsule Definition	[] Well-demarcated- Thick-walled [] Poorly demarcated - Diffuse

Grain Acoustic Characterisation

Echo Pattern	[] Hyper-reflective bright echoes [] Fine dense micro-echoes
Acoustic Shadowing	[] Present (Strong Attenuation) -> Eumycetoma suspected [] Absent / Minimal -> Actinomycetoma suspected
Grain Aggregation	[] Clustered [] Dispersed [] Absent/Fluid only

Bone & Fascial Interface

Deep Fascia	[] Intact [] Disrupted / Invaded
Cortical Bone Surface	[] Smooth & Continuous [] Irregular / Cortical Breach



Diagnostic Impression

☐	Sonographic pattern strongly suggestive of Eumycetoma
☐	Sonographic pattern strongly suggestive of Actinomycetoma
☐	Inconclusive / Non-mycetoma soft tissue collection

Sonographer Name:

Clinician Signature:

Magnetic Resonance Imaging (MRI) Reporting Template

Date of Scan:

Patient Name:

Age:

Gender: [M] [F]

Referring Physician: Dr

Clinical Indication: Suspected / Established Mycetoma.

Clinical Duration: [Months / Years]

Lesion site:

Examination Protocol

- Sequences Acquired: Multi-planar T1-Weighted (T1W), T2-Weighted (T2W), Short Tau Inversion Recovery (STIR) / T2-Fat Saturated, and Post-Contrast T1W Fat-Saturated (T1W+C) images in [Axial / Sagittal / Coronal] planes.
- Contrast Agent: [Gadolinium-based agent, Dose e.g., 0.1 mmol/kg] | [Not Administered]

1. Soft Tissue & Subcutaneous Involvement

Subcutaneous and Soft Tissue Involvement	
Anatomic Region	[e.g., Plantar aspect of forefoot / Midfoot / Calvarium / Gluteal]
Maximum Dimensions	AP x TR x CC cm.
Subcutaneous & Fascial Extent	[Confined to subcutaneous fat / Breaches deep fascia]
Muscle Compartments Involved	[Specify muscles, e.g., Abductor hallucis, Flexor digitorum brevis / Free]

Pathognomonic MRI Signs	
"Dot-in-Circle" Sign	[Present] [Absent]
"Circle" Characterisation (T2/STIR)	[Multiple hyperintense rounded cavities, [size: <5 mm / >5 mm]]
"Dot" Characterisation (T1/T2)	[Central hypointense dots present] [absent]
Post-Contrast Pattern	[Thick rim-enhancing granulomas] [Diffuse hypervascular enhancement]

2. Neurovascular & Tendon Sheath Contiguity

Neurovascular Bundles	[Preserved / Encasement / Compression]
Specific Structures	[e.g., Posterior tibial nerve / Plantar arteries / Sciatic nerve]
Tendon Sheaths & Synovium	[Uninvolved / Tenosynovial thickening / Fluid effusion]
Specific Tendons	[e.g., Flexor hallucis longus, Tibialis posterior]

3. Skeletal & Joint Integrity

Bone Marrow Signal (T1/STIR)	[Normal / Geographic marrow oedema / Marrow replacement]
Bones Involved	[Specify individual bones, e.g., 1st Metatarsal]

Cortical Integrity	[Intact / Extrinsic Cortical Scalloping / Cortical Breach / Sequestra]
Lytic Cavities	Absent / Present: Size <5 mm (Bacterial pattern) / >5 mm with sclerotic margin (Fungal pattern)]
Joint Extension	[Intact joint spaces / Intra-articular effusion / Cartilage erosion / Joint ankylosis]
Affected Joints	[e.g., Tarsometatarsal / Talonavicular / Interphalangeal]

4. Radiological Mycetoma Staging (Skeletal & Soft Tissue)

[]	Stage I	Soft tissue involvement only; no bone marrow or cortical changes.
[]	Stage II	Soft tissue mass with cortical scalloping or periosteal reaction; no deep marrow replacement.
[]	Stage III	Soft tissue mass with localised bone marrow involvement and intra-osseous cavities (<3 bones).
[]	Stage IV	Advanced multi-compartmental soft tissue involvement with extensive bone destruction / multiple cavities (≥ 3 bones) / joint ankylosis.



Impression

Aetiological Pattern Suggestion:

[] Eumycetoma Pattern:

Large cavities (>5 mm), well-demarcated thick walls, sharp central low-signal dots, localised bone geodes with sclerotic borders.

[] Actinomycetoma Pattern:

Small microabscesses (<5 mm), diffuse, poorly demarcated infiltrative margins, and widespread bone involvement without thick capsular borders.

Anatomic Extent:

Granulomatous lesion involving [Specific anatomical compartments], measuring [X x Y x Z] cm, with [Invasion / Preservation] of the deep fascia and neuro-vascular bundles.

Skeletal Status:

[Radiological Stage I / II / III / IV], with involvement of [Bones/Joints].

Surgical Margin Considerations:

Recommended surgical-free margin boundary should clear [Specific tissue landmark] by at least 10–15 mm.

Radiologist Signature: [Dr. Name, MD]

Date / Time: [DD/MM/YYYY - HH:MM]

Module 7

Longitudinal Imaging Protocol for Monitoring Treatment Response

Evaluating therapeutic response in mycetoma remains a major clinical challenge because clinical physical examination, marked by persistent tissue induration, hyperpigmentation, and dense fibrotic scarring, frequently misrepresents active disease status long after the causative bacterial or fungal pathogens have been cleared.

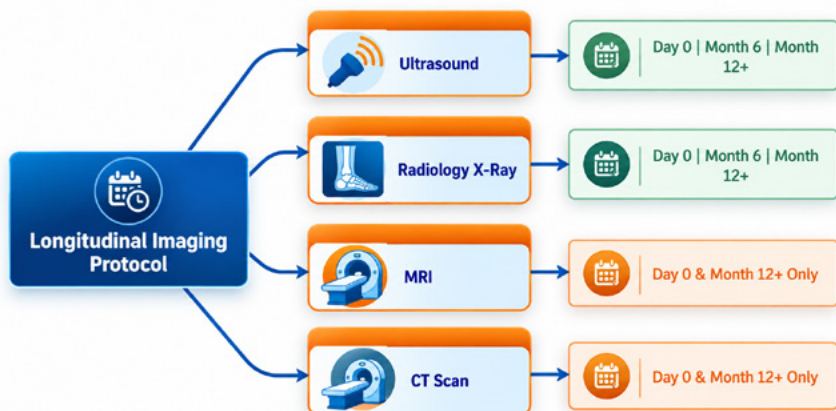
To overcome these clinical limitations, regular, structured imaging intervals using ultrasound and Magnetic Resonance Imaging (MRI) serve as the essential backbone for monitoring treatment efficacy.

Serial ultrasonography directly tracks disease resolution by demonstrating a progressive reduction in hypoechoic granulomatous cavities, disappearance of pathognomonic central grain echoes, and shrinkage of localised fluid collections. Similarly, follow-up MRI quantitatively measures the regression of high T2-weighted and STIR signal hyperintensity, clearing of marrow oedema, and thickening of encapsulating fibrotic rims around healing lesions.

By providing reproducible, non-invasive benchmarks, interval cross-sectional imaging prevents the premature discontinuation of antimicrobial regimens, helps clinicians distinguish quiescent post-treatment fibrosis from active disease relapse, and enables timely identification of therapeutic failure or drug resistance before catastrophic bone destruction ensues.

Longitudinal Imaging

Imaging technique	Timeline		
	Baseline Day 0	Mid-Treatment (Month 6)	End of Treatment (Month 12+)
Ultrasound	+	+	+
Radiology X-Ray	+	+	+
MRI	+		+
CT scan	+		+



Radiological Signs of Treatment Success (Positive Response)

- **Ultrasound:** Significant reduction or total disappearance of hypoechoic fluid cavities; reduction in hyper-reflective grain echoes; transformation of fluid collections into hyper-echoic fibrous scar tissue.
- **Plain Radiography:** Halting of lytic bone destruction; sclerosis and re-calcification around cortical cavities; bone remodelling and stabilisation of periosteal reaction.

- **MRI:** Disappearance of the pathognomonic “Dot-in-Circle” sign; replacement of hyperintense T2/STIR fluid signals with hypointense T1/T2 fibrous signal; marked decrease in post-contrast ring enhancement.

Radiological Signs of Treatment Failure or Disease Relapse

- **Ultrasound:** Expansion of existing fluid cavities or emergence of new hypoechoic foci containing fresh hyper-reflective grains; breakdown of previously fibrous barriers.
- **Plain Radiography:** Progression of bone erosion, new cavity formation, or sudden cortical collapse despite ongoing medical therapy.
- **MRI:** Persistent or expanding areas of high T2/STIR signal; recurrence of central hypointense dots within fluid spheres; persistent deep muscular or bone marrow enhancement on post-contrast sequences.

Module 8

Differential Diagnosis & Pitfalls

Radiological Differentiation from Mimickers

Mycetoma can clinically and radiologically simulate several infectious, inflammatory, and neoplastic conditions.

Differential Diagnosis Matrix			
Condition	Ultrasound Profile	Plain X-Ray	MRI Features
Mycetoma	Cavities. Hyper-reflective acoustic shadow.	Soft tissue mass. Periosteal reaction. Cavities.	"Dot-in-Circle" sign.
Chronic Bacterial Osteomyelitis	Diffuse fluid collection. Thick periosteal Abscess. No grains.	Cortical thickening. Broad bone sequestrum. Involucrum.	Cortical thickening. Broad bone sequestrum. Involucrum.

Soft Tissue Sarcoma	Solid mass. Increased vascular flow on Colour Doppler.	Soft tissue mass.	Soft tissue mass. Direct bone erosion without cavities.
Tuberculosis	Cold abscess. Necrotic lymph. hyperechoic calcified.	Marked joint space narrowing. Juxta-articular os- teopenia.	Dactylitis. Arthritis. Nodes. Debris without shadow. Subchondral ero- sions.
Foreign Body Granulomas	Retained wooden splinters or thorns can produce bright hy- per-reflective echoes with acoustic shadow- ing.		
Osteogenic Sarcoma	Soft tissue mass.	Periosteal reaction. Pathological frac- ture.	

Common Diagnostic Pitfalls & Avoidance Strategies

1. Mistaking Scar Tissue for Active Disease on Ultrasound

- **Pitfall:** Dense fibrous scar tissue from prior surgery can mimic hyper-reflective acoustic patterns.
- **Avoidance:** Look specifically for fluid-filled (hypoechoic) cavities surrounding the bright echoes. Scar tissue lacks hypoechoic fluid rims and does not demonstrate hyper-reflective echoes typical of fungal grains.



2. Underestimating Deep Bone Involvement on Plain X-Rays:

- **Pitfall:** Early bone marrow infiltration occurs well before 30–50% of bone mineral density is lost, the threshold required for lytic lesions to become visible on conventional X-rays.
- **Avoidance:** If a patient presents with a deep-seated mass adjacent to bone but plain X-rays appear normal, perform US to inspect the cortical interface or request an MRI/CT scan.

3. Misinterpreting Foreign Body Granulomas:

- **Pitfall:** Retained wooden splinters or thorns can produce bright hyper-reflective echoes with acoustic shadowing on ultrasound, mimicking eumycetoma grains.
- **Avoidance:** Foreign bodies usually present as a single linear hyperechoic structure rather than multiple spherical clusters distributed across distinct hypoechoic fluid cavities.

Module 8

Surgical Mapping & Interventional Radiology Guidance

Pre-Operative Surgical Margin Mapping

When wide local excision, surgical debridement, conservative resection or amputation is indicated, incomplete excision carries a high risk of local recurrence. Imaging serves as the ultimate roadmap for defining safe surgical margins.

Pre-Operative MRI Mapping		
Sequence	Planes	Primary Surgical Objective
1-Weighted (T1W)	Axial & Coronal/Sagittal	Baseline anatomical layout, bone marrow fat assessment. Neurovascular fat plane clearance.
T2-Weighted (T2W)	Axial & Coronal/Sagittal	Identification of “Dot-in-Circle” sign, capsule. Fast Spin Echo (FSE). Integrity and peripheral fibrous wall thickness.

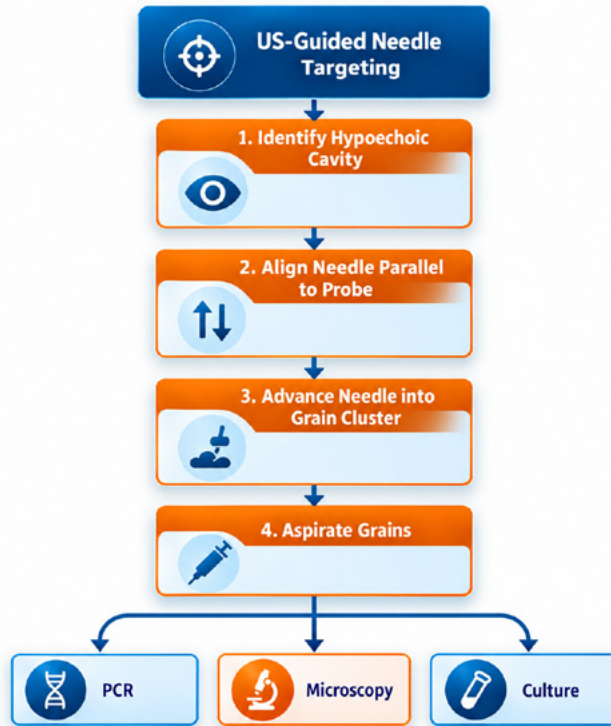
STIR / T2 Fat-Sat	Axial & Coronal	Maximum sensitivity for occult tissue oedema. Muscle micro-abscesses. Early marrow disease.
T1 Fat-Sat + Contrast (Gadolinium)	Multipplanar 3D Acquisition	Delineation of hypervascular inflammatory margins vs non-enhancing necrotic/ granulomatous core.
Mark 10–15 mm Clear margin		

- **Skin Marking Under US:**

In resource-constrained settings lacking MRI, the sonographer uses a high-frequency linear probe to trace the outermost boundaries of hypoechoic cavities directly onto the patient’s skin with indelible ink, adding a **10–15 mm safety margin** around the lesion.

- **Image-Guided Fine-Needle Aspiration & Biopsy (FNAC/Core Biopsy)**

Directing needle placement using real-time US significantly improves diagnostic yield compared to blind palpation-guided aspiration.



Step-by-Step Interventional Technique:

1. **Sterile Preparation:** Clean the skin site with chlorhexidine/povidone-iodine and place a sterile sheath over the linear transducer.
2. **Cavity Target Selection:** Identify a well-defined hypoechoic cavity containing abundant hyper-reflective grain echoes. Avoid avascular necrotic center-points lacking grains.
3. **In-Plane Needle Visualisation:** Insert a 21G–22G needle (for fine-needle aspiration) or 14G–16G core biopsy needle using the **in-plane technique**, keeping the entire needle shaft and tip visible under continuous real-time ultrasound monitoring.
4. **Sample Harvesting:** Guide the needle tip directly into the grain cluster within the cavity. Apply gentle negative pressure to aspirate intact



grains for direct microscopy, fungal/bacterial culture, and molecular PCR verification.

Further Reading

Further Reading

Mycetoma Management Standard Operating Procedures (SOP)

https://mycetoma.edu.sd/?page_id=%205896

Publications

5. Fahal AH, Hassan MA. Mycetoma. Br J Surg. 1992; 79(11): 1138-1141. PMID: 1467883.
6. Fahal AH, Suliman SH, Gadir AFA, EL Hag IA, EL Amin FI, Gumaa SA, Mahgoub ES. Abdominal wall mycetoma: an unusual presentation. Trans R Soc Trop Med Hyg. 1994; 88(1):78-80. PMID: 8154012.
7. Fahal AH, Suliman SH. Clinical presentation of mycetoma. Sudan Med J. 1994; 32: 46-66.
8. Fahal AH, El Hassan AM, Abdelalla AO, Sheikh HE, Cystic mycetoma: an unusual clinical presentation of *Madurella mycetomatis*. Trans R Soc Trop Med Hyg. 1998; 92:6-67.
9. Fahal AH, EL Toum EA, EL Hassan AM, Gumaa SA, Mahgoub ES. A preliminary study on the ultrastructure of *Actinomadurella pelletieri* and its host tissue reaction. J Med Vet Mycol. 1994; 32: 343-348. PMID: 7844700.
10. EL Hassan AM, Fahal AH, EL Hag IA, Khalil EAG. The pathology of mycetoma: Light microscopic and ultrastructural features. Sudan Med J. 1994; 32: 23-45.
11. Fahal AH, Hassan MA, Sanhoury M. Surgical treatment of mycetoma. Sudan Med J. 1994; 32: 98-104.
12. Fahal AH, EL Toum EA, EL Hassan AM, Gumaa SA, Mahgoub ES. Host

- tissue reaction to *Madurella mycetomatis*: New classification. *J Med Vet Mycol*. 1995; 33: 15-17.
13. EL Hag IA, Fahal AH, Khalil EAG. Fine needle aspiration cytology of mycetoma. *Acta Cytologica*. 1996; 40(3): 461-46.
 14. Fahal AH, Omer SM, El Razig SA, Ali ABE, Mahdi EMA, Mahgoub ES. Thyroid function in mycetoma patients. *East Afr Med J*. 1995; 72(7): 454-456. PMID: 7498029.
 15. Fahal AH, Azziz KAA, Suliman SH, Galib HV, Mahgoub ES. Dual infection with mycetoma and tuberculosis. *East Afr Med J*. 1995; 72(11): 749-750. PMID: 8904072.
 16. Mohamed ARO, Fahal AH, Venge V. Immunoglobulin and inflammatory markers profile in mycetoma. *East Afr Med J*. 1996; 73(4): 212 (Letter). PMID: 8698027.
 17. Fahal AH, Yagi HI, EL Hassan AM. Mycetoma induced palatal deficiency and pharyngeal plexus dysfunction. *Trans R Soc Trop Med Hyg*. 1996; 90: 676-677. PMID: 9015514
 18. Fahal AH, Sheikh HE, EL Hassan AM. Pathological fracture in mycetoma. *Trans R Soc Trop Med Hyg*. 1996; 90: 675-676. PMID: 9015513.
 19. Fahal AH, Sharfi AR, Sheikh HE, EL Hassan AM. Internal fistula formation: an unusual complication of mycetoma. *Trans R Soc Trop Med Hyg*. 1996; 89: 550-552.
 20. Fahal AH, Sadig ME, Suliman SH, EL Razig SA, Mahgoub ES. Lack of association between ABO blood groups and Rh factor and the tendency to develop mycetoma. *East Afr Med J*. 1996; 11: 769. (Letter). PMID: 8997873
 21. Fahal AH, EL Hag IA, Gadir AFA, EL Lider AR, Baraka OZ, EL Hassan AM. The blood supply and vasculature in mycetoma. *J Med Vet Mycol*. 1997; 35: 101-106. PMID: 9147269
 22. Fahal AH, Sheikh HE, EL Lider MA, Homeida MA, EL Arabi YE, Mahgoub ES. Ultrasonic imaging in mycetoma. *Br J Surg*. 1997; 78: 765-766.

PMID: 9278658

23. Ahmed AOA, Fahal AH, Abugroun EAM, Zijlstra E, Belkum A van, Verbrugh HA. Unexpected high prevalence of secondary bacterial infection in mycetoma. *J Clin Microbiol.* 1998; 36(3): 850-851.
24. Fahal AH, Sharfy ARA. Vulval mycetoma: a rare cause of bladder outlet obstruction. *Trans R Soc Trop Med Hyg.* 1998; 92: 652-653. PMID: 10326112.
25. Ahmed AO, Mukhtar MM, Kools-Sijmons M, Fahal AH, de Hoog S, van den Ende BG, Zijstara, ED, Verburgh H, Abugroun ESA, EL Hassan AM, van Beklum A. Development of a species-specific PCR RFLP procedure for the identification of *Madurella mycetomatis*. *J Clin Microbiol.* 1999; 37(10):3175-8. PMID: 10488173.
26. Fahal AH. The management of mycetoma. *Post-Grad -Caribbean.* 2000;16(4):229-232.
27. EL Hassan AM, Fahal AH, Ahmed AO, Ismail A, Veress B. The immunopathology of actinomycetoma lesions caused by *Streptomyces somaliensis*. *Trans R Soc Trop Med Hyg.* 2001; 95(1); 89-92. PMID: 11280076
28. Ahmed AOA, Adelmann D, Fahal AH, Verbrugh HA, Van Belkum A, De Hoog S. Environmental occurrence of *Madurella mycetomatis*, major agent of human eumycetoma in Sudan. *J Clin Microbiol.* 2002 40(3): 1031-1036. PMID: 11880433.
29. Ahmed AOA, van Vianen W, ten Kate M, van de Sande WWJ, Van Belkum A, Fahal AH, Verbrugh HA, Bakker-Woudenberg IAJM. A murine model of *Madurella mycetomatis* eumycetoma. *FEMS Immunol Med Microbiol.* 2003; 37: 29-36. PMID: 12770757..
30. Ahmed AOA, van de Sande W, Van Belkum A, Verbrugh HA, Fahal AH, van Belkum A. *Madurella mycetomatis* strains from mycetoma lesions in Sudanese patients are clonal. *J Clin Microbiol.* 2003; 41(10):4537-41 PMID: 14532179.
31. Abd Bagi ME, Fahal AH, Sheikh HE, Abdul Wahab O, Taifoor MK, Osman

- EM. High incidence of pathological fractures in mycetoma. *Trans R Soc Trop Med Hyg.* 2003; 97(5):582-4. PMID: 15307432
32. Fahal AH. Mycetoma thorn on the flesh: Review article. *Trans R Soc Trop Med Hyg.* 2004; 98(1):3-11. Review.
 33. Ahmed AO, van de Sande WW, van Vianen W, van Belkum A, Fahal AH, Verbrugh HA, Bakker-Woudenberg IA. In vitro susceptibilities of *Madurella mycetomatis* to itraconazole and amphotericin B assessed by a modified NCCLS method and a viability-based 2,3-Bis(2-methoxy-4-nitro-5-sulfophenyl)-5-[(phenylamino)carbonyl]-2H-tetrazolium hydroxide (XTT) assay. *Antimicrob Agents Chemother.* 2004; 48(7):2742-6. PMID: 15215141.
 34. Ahmed AO, van Leeuwen W, Fahal A, van de Sande W, Verbrugh H, van Belkum A. Mycetoma caused by *Madurella mycetomatis*: a neglected infectious burden. *Lancet Infect Dis.* 2004; 4(9):566-74. Review. PMID: 15336224
 35. EL Hassan AM, Fahal AH, Veress B. Cell phenotypes, immunoglobulins, and complement in lesion of eumycetoma caused by *Madurella mycetomatis*. *Sud J Dermatol* 2006; 4 (1):2-5.
 36. van de Sande WW, Fahal A, Verbrugh H, van Belkum A. Polymorphisms in genes involved in innate immunity predispose toward mycetoma susceptibility. *J Immunol.* 2007; 179(5):3065-74. PMID: 17709521.
 37. van de Sande WW, de Kat J, Coppens J, Ahmed AO, Fahal A, Verbrugh H, van Belkum A. Melanin biosynthesis in *Madurella mycetomatis* and its effect on susceptibility to itraconazole and ketoconazole. *Microbes Infect.* 2007; 9: 1114-1123. PMID: 17644456.
 38. van de Sande WW, Fahal A, Verbrugh H, van Belkum A. *Madurella mycetomatis* compounds cross-reactive with galactomannan are detectable in culture supernatant but not in serum. *J Med Microbiol.* 2007; 56: 869-70. PMID: 17510278.
 39. Ahmed AA, van de Sande WW, Fahal A, Bakker-Woudenberg I, Verbrugh H, van Belkum A. Management of mycetoma: major challenge

- in tropical mycoses with limited international recognition. *Curr Opin Infect Dis.* 2007; 20(2):146-51. PMID: 17496572.
40. van de Sande WW, Fahal AH, Riley TV, Verbrugh H, van Belkum A. In vitro susceptibility of *Madurella mycetomatis*, prime agent of Madura foot, to tea tree oil and artemisinin. *J Antimicrob Chemother.* 2007; 59(3):553-5 PMID: 17324961. .
 41. Hussein A, Ahmed AEM, Fahal AH, Mahmoud A, Sidig A, Awad K, Ahmed EM. Cervical cord compression secondary to mycetoma infection. *Sud J Pub Health.* 2007; 2(2): 112-115.
 42. Quintana ET, Wierzbicka K, Mackiewicz P, Osman A, Fahal AH, Hamid ME, Zakrzewska-Czerwinska J, Maldonado LA, Goodfellow M. *Streptomyces sudanensis* sp. nov., a new pathogen isolated from patients with actinomycetoma. *Antonie Van Leeuwenhoek.* 2008; 93(3):305-13. PMID: 18157699.
 43. Dejan Stojković, Marina Soković, Ana Džamić, Mihailo Ristić, Ahmed Fahal, Silvana Petrović, Ivana Djujić, Sami Khalid. In vitro Susceptibility of *Actinomyces madurae* Clinical Isolates to Turpentine Oil of *Pinus pinaster* and α -Pinene. *Arch. Biol. Sci., Belgrade.* 2008; 60 (4): 697-701.
 44. Abd El-Bagi MEB, Fahal AH. Mycetoma revisited. Incidence of various radiographic signs. *Saudi Med J.* 2009;30(4):529-33. PMID: 19370281.
 45. Yousif BM, Fahal AH, Yahia MY. The Cell Block Technique: A New Diagnostic Tool for Mycetoma. *Trans R Soc Trop Med Hyg.* 2010; 104(1):6-9.
 46. Fahal AH, Abu Sabaa. AH. Mycetoma in Children. *Trans R Soc Trop Med Hyg.* 2010; 104: 117–12. PMID: 19716573.
 47. Fahal, AH. Management of mycetoma. *Expert Rev Dermatol.* 2010; 5(1), 87–93.
 48. van de Sande WWJ, Fahal AH, Tavakol M, van Belkum A. Polymorphisms in catechol-O-methyltransferase and cytochrome p450 sub-family 19 genes predispose towards *Madurella mycetomatis*-induced mycetoma susceptibility. *Med Mycol.* 26.2.2010; 48(7):959-68. PMID:

20184498

49. van de Sande WW, Fahal AH, Bakker-Woudenberg IA, van Belkum A. *Madurella Mycetomatis* is not susceptible to the Echinocandin class of antifungal agents. *Antimicrob Agents Chemother*. 2010 June, 54(6):2738-2740. PMID: 20350944
50. Fahal AH. Continuing Professional Development in Medical & Health Professions. *International J Sud Research*, 2010; 1(1): 29-34.
51. Fahal AH, Rahman I A, El-Hassan AM, EL Rahman ME, Zijlstra EE. The efficacy of itraconazole in the treatment of patients with eumycetoma due to *Madurella mycetomatis*. *Trans R Soc Trop Med Hyg*. 2011; 105(3):127-32.
52. Alex van Belkum, Ahmed H. Fahal, Wendy W.J van de Sande. In Vitro Susceptibility of *Madurella Mycetomatis* to Posaconazole and Terbinafine. *Antimicrob Agents Chemother*. 2011; 55(4):1771-3.
53. Fahal AH, EL Sheik H, El Hassan AM. Venous Varicosity in Mycetoma. *Sudan Med J*. 2011; 47(1): 20-24.
54. Fahal AH. Mycetoma. Review article, *Khartoum Med J*. 2011; 4(1): 514-523.
55. de Klerk N, de Vogel C, Fahal AH, van Belkum A, van de Sande W. Fructose-bisphosphate aldolase and pyruvate kinase, two novel immunogens in *madurella mycetomatis*. *Med Mycol*. 2012; 50(2):143-51.
56. Kirby R, Sangal V, Tucker NP, Zakrzewska-Czerwinska J, Wierzbicka K, Herron PR, Chu CJ, Chandra G, Fahal AH, Goodfellow M, Hoskisson PA. Draft genome sequence of the human pathogen *Streptomyces somaliensis*, a significant cause of actinomycetoma. *J Bacteriol*. 2012 Jul;194(13):3544-5. doi: 10.1128/JB.00534-12. PMID: 22689234; PMCID: PMC3434723.
57. Zein HAM, Fahal AH, Mahgoub ES, EL Hassan T, Abdel Rahman ME. The Predictors of Cure, Amputation & Follow-up dropout among Mycetoma Patients as seen at The Mycetoma Research Centre, University of

- Khartoum. Trans R Soc Trop Med Hyg. 2012; 106(11):639-44.
58. Mhmoud NA, Ahmed SA, Fahal AH, de Hoog GS, Gerrits van den Ende AH, van de Sande WW. Pleurostomophora ochracea, a novel agent of human eumycetoma with yellow grains. J Clin Microbiol. 2012; 50(9):2987-94
 59. Mhmoud NA, Fahal AH, van de Sande WW. CD4+ T-lymphocytopenia in HIV-negative tuberculosis patients in Sudan. J Infect. 2012; 65(4):370-2.
 60. de Hoog GS, van Diepeningen AD, Mahgoub el-S, van de Sande WW. New species of Madurella, causative agents of black-grain mycetoma. J Clin Microbiol. 2012; 50(3):988-94.
 61. Fahal AH, Arbab MAR, EL Hassan AM. Aggressive Clinical Presentation of Mycetoma due to Actinomadura Pelletierii. Khartoum Med J. 2012; 5(1): 699-702.
 62. Mohamed, EW, Suleiman HS, Fadella, AI, Fahal, AH. Aggressive Perineal and Pelvic Eumycetoma: An unusual and challenging problem to treat. Khartoum Med J. 2012; (5)2:771-774.
 63. Kloezen W, Meis JF, Curfs-Breuker I, Fahal AH, van de Sande WW. In vitro antifungal activity of isavuconazole against Madurella mycetomatis. Antimicrob Agents Chemother. 2012 Nov;56(11):6054-6. doi: 10.1128/AAC.01170-12. Epub 2012 Sep 10. PMID: 22964246; PMCID: PMC3486573.
 64. Mohamed EW, Mohamed, ENA, Yousif, BM, Fahal, AH. Tongue Actinomycetoma due to Actinomadura madurae: A rare clinical presentation. J Oral Maxillofac Surg. 2012; 70(11):e622-4.
 65. El Shamy, ME, Fahal AH, Shakir MY, Homedia MMA. New MRI Grading System for the Diagnosis and Management of Mycetoma. Trans R Soc Trop Med Hyg. 2012; 106(12):738-42.
 66. Fahal AH, van de Sande WW. The Epidemiology of mycetoma. Current Fungal Infection Reports. 2012; 6(4): 320-326

67. Mhmoud NA, Fahal AH, van de Sande WW. The association between the interleukin-10 cytokine and CC chemokine ligand 5 polymorphisms and mycetoma granuloma formation. *Med Mycol.* 2013; 51(5):527-33. doi: 10.3109/13693786.2012.745201
68. Fahal, AH, The Mycetoma Research Centre, University of Khartoum, Sudan: a success story that needs support. *IJSR.* 2013 3(1): 1-13.
69. Ibrahim AI, El Hassan AM, Fahal A, van de Sande WW. A histopathological exploration of the *Madurella mycetomatis* grain. *PLoS One.* 2013; 8(3):e57774. doi: 10.1371/journal.pone.0057774.
70. Suleiman AM, Fahal AH. Oral cavity eumycetoma: a rare and unusual condition. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2013; 115(4): e23-5.
71. Ehab AM Elagab, Maowia M Mukhtar, Ahmed H Fahal, Wendy WJ van de Sande. Peripheral Blood Mononuclear Cells of Mycetoma Patients React Differently to *Madurella mycetomatis* Antigens than Healthy Endemic Controls. *PLoS Negl Trop Dis.* 2013; 7(4): e2081. doi: 10.1371/journal.pntd.0002081.
72. Suleiman HS, EL Hassan LAM, Fahal AH. Long-Standing Gluteal Mass: An Uncommon Presentation of Tuberculosis. *Khartoum Med J* 2013; 6(1): 864–867.
73. Osman AH, Ezaldeen EA, Ali BM, Jacoub AO, Suleiman SH, Fahal AH. Poor Infusion Therapy Knowledge among Young Doctors in Two Tertiary Teaching Hospitals in Khartoum State. *Khartoum Med J* 2013; 6(1): 854–858.
74. van Hellemond JJ, Vonk AG, de Vogel C, Koelewijn R, Vaessen N, Fahal AH, van Belkum A, van de Sande WW. Association of eumycetoma and schistosomiasis. *PLoS Negl Trop Dis.* 2013 May 23;7(5):e2241. doi: 10.1371/journal.pntd.0002241.
75. van Belkum A, Fahal A, van de Sande WW. Mycetoma caused by *Madurella mycetomatis*: a completely neglected medico-social dilemma. *Adv Exp Med Biol.* 2013; 764:179-89.

76. Fahal AH, Elkhawad AO. Managing mycetoma: guidelines for best practice. *Expert Rev Dermatol* 2013; 8(3): 301-307.
77. GS de Hoog, S. Abdalla Ahmed, MJ Najafzadeh, DA Sutton, M. Saradeghi Keisari, AH Fahal, U. Eberhart, B. Stielow, GJ Verkley, Lian Xin, WWJ van de Sande. Phylogenetic findings suggest possible new habitats and routes of infection of human eumycetoma. *PLoS Negl Trop Dis*. 2013 May 16; 7(5):e2229. doi: 10.1371/journal.pntd.0002229.
78. Najwa A. Mhmoud, Ahmed H. Fahal, Wendy W. J. Van De Sande. The association between the interleukin-10 cytokine and CC chemokine ligand 5 polymorphisms and mycetoma granuloma formation. *Med Mycol* 2013, 51, 527–533.
79. Mhmoud N, Fahal A, Wendy van de Sande WJ. Polymorphisms of Interleukin-10 and CCL5 Genes in Tuberculosis. *Trop Med Int Health*. 2013; 18(9): 1119-1127. doi:10.1111/tmi.12141
80. Ezaldeen EA, Fahal AH, Osman A. Mycetoma herbal treatment: the Mycetoma Research Centre, Sudan experience. *PLoS Negl Trop Dis*. 2013 Aug 22;7(8):e2400. doi: 10.1371/journal.pntd.0002400. e Collection 2013.
81. Khamis, AAG, Ali BM, Jacoub AO, Suleiman SH, Fahal AH, Knowledge, Attitudes and Practices of Surgical Staff at Khartoum State towards the Hepatitis B virus infection. *Khartoum Med J* 2014;7(1): 932- 940.
82. Fahal AH, Shaheen S. Jones DH. Orthopaedic Aspects of Mycetoma: Instructional Review. *Bone Joint J* 2014; 96-B: 420–5. doi: 10.1302/0301-620X.96B3.31421.
83. Al Dawi AF, Mustafa MI, Fahal AH, EL Hassan AM, Bakhiet SM, Mahgoub ES, Mergani A, Mukhtar MM. The Association of HLA-DRB1 & HLA-DQB1 and the occurrence of Eumycetoma. *Khartoum Med J*. 2013; 6(3): 923 - 929
84. Geneugelij K, Kloezen W, Fahal AH, van de Sande WWJ. Active matrix metalloprotease-9 is associated with the collagen capsule surrounding the *M. mycetomatis* grain in mycetoma. *PLoS Negl Trop Dis* Pub-

lished: March 27, 2014 DOI: 10.1371/journal.pntd.0002754.

85. Wendy W. J. van de Sande, El Sheikh Maghoub, Ahmed H. Fahal, Michael Goodfellow, Oliverio Welsh, Ed Zijlstra. The Mycetoma Knowledge Gap: Identification of Research Priorities. PLoS Negl Trop Dis Published: March 27, 2014 DOI: 10.1371/journal.pntd.0002667.
86. Fahal AH, Mahgoub ES, EL Hassan ESM, EL Tayeb E, EL Hassan AM. Eye Eumycetoma: The Mycetoma Research Centre, Sudan Case Series & Literature Review. Infectious Diseases in Clinical Practice 6 June 2014, doi: 10.1097/IPC.0000000000000157.
87. Sarah Abdalla Ahmed, Wendy Kloezen, Frederick Duncanson, Ed Zijlstra, G. Sybren de Hoog, Ahmed H. Fahal, Wendy WJ van de Sande. *Madurella mycetomatis* is highly susceptible towards Ravuconazole. PLoS Negl Trop Dis June 19, 2014 DOI: 10.1371/journal.pntd.0002942
88. Najwa A Mhmoud, Ahmed H Fahal, El Sheikh Mahgoub, Wendy W J van de Sande. The combination of Amoxicillin-clavulanic acid and ketoconazole proved to be effective and safe for treatment of *Madurella mycetomatis* eumycetoma patients with secondary *Staphylococcus aureus* infection. PLoS Negl Trop Dis June 19, 2014 DOI: 10.1371/journal.pntd.0002959.
89. Wendy W. J. van de Sande, Ahmed H. Fahal, Michael Goodfellow, El Sheikh Maghoub, Oliverio Welsh, Ed Zijlstra. The merits and pitfalls of the currently used diagnostic tools in mycetoma. PLoS Negl Trop Dis July 03, 2014 DOI: 10.1371/journal.pntd.0002918
90. Ahmed SA, van de Sande WJ, Stevens DA , Fahal AH, van Diepeningen A, Menken SBJ, and de Hoog GS. Revision of agents of black-grain eumycetoma in the order Pleosporales. *Persoonia* 2014; 33: 141–154.
91. Samy AM, van de Sande WWJ, Fahal AH, Peterson AT. Mapping the Potential Risk of Mycetoma Infection in Sudan and South Sudan Using Ecological Niche Modeling. PLoS Negl Trop Dis 2014; 8(10): e3250. doi:10.1371/journal.pntd.0003250
92. Welsh O, Al-Abdely HM, Salinas-Carmona MC, Fahal AH (2014) Myce-

- toma Medical Therapy. PLoS Negl Trop Dis 8(10): e3218. doi:10.1371/journal.pntd.0003218. <http://www.plosntds.org/article/info:doi/10.1371/journal.pntd.0003218>
93. Fahal A, Mahgoub ES, EL Hassan AM, Abdel-Rahman ME, Alshambaty Y, Ed E Zijlstra. A New Model for Management of Mycetoma in the Sudan. PLoS Negl Trop Dis 2014, 8(10): e3271. doi:10.1371/journal.pntd.0003271
 94. Fahal AH. Mycetoma Comm Dermato J. 2014; 10: 15-17.
 95. Sarah A. Ahmed, Bert Gerrits van den Ende, Ahmed H. Fahal, Wendy W. J. van de Sande, GS. de Hoog. Rapid Identification of Black Grain Eumycetoma causative agents Using Rolling Circle Amplification. PLoS Negl Trop Dis. 2014 Dec 4;8(12):e3368. doi: 10.1371/journal.pntd.0003368. eCollection 2014 Dec.
 96. Ahmed AK, SH Suleiman, Fahal AH. Aggressive Uncontrolled Gluteal Eumycetoma Invading the Pelvic Cavity and the Spinal Cord: Unusual Clinical Presentation. Khartoum Med J. 2014; 7(2): 1005–1007.
 97. Kimberly Eadie, Ahmed Fahal, Wendy WJ van de Sande. In vitro activity of antiseptic solutions against *M. mycetomatis*, implications on eumycetoma management. Br J Dermatol. 2015;172(6):1657-9. doi: 10.1111/bjd.13570
 98. Ahmed SA, Kloezen W, Fahal AH, de Hoog GS, van de Sande WW. In Vitro Interaction of Currently Used Azoles with Terbinafine Against *Madurella mycetomatis*. Antimicrob Agents Chemother. 2015 Feb;59(2):1373-4. doi: 10.1128/AAC.04487-
 99. Ahmed SA, de Hoog GS, Stevens DA, Fahal AH and van de Sande WJ. "In Vitro Antifungal Susceptibility of Coelomycete Agents of Black Grain Eumycetoma to Eight Antifungals. Med Mycol. 2015; 53(3):295-301. doi: 10.1093/mmy/myu098
 100. Hay RJ, Fahal AH. Mycetoma: an old and still neglected tropical disease. Trans R Soc Trop Med Hyg. 2015; 109(3):169-70. doi:10.1093/trstmh/trv003.

101. Ahmed SA, van de Sande WW, Stevens DA, Fahal A, van Diepeningen AD, Menken SB, de Hoog GS. Revision of agents of black-grain eumycetoma in the order Pleosporales. *Persoonia*. 2014 Dec; 33:141-54. doi: 10.3767/003158514X684744.
102. Nenoff P, van de Sande WW, Fahal AH, Reinel D, Schöfer H. Eumycetoma and actinomycetoma - an update on causative agents, epidemiology, pathogenesis, diagnostics and therapy. *J Eur Acad Dermatol Venereol*. 2015; 29(10):1873-83. doi: 10.1111/jdv.13008
103. Ahmed SA, de Hoog GS, Stevens DA, Fahal AH, van de Sande WW. In vitro antifungal susceptibility of coelomycete agents of black grain eumycetoma to eight antifungals. *Med Mycol*. 2015; 53(3):295-301. doi: 10.1093/mmy/myu098.
104. Ahmed SA, Kloezen W, Fahal AH, de Hoog GS, van de Sande WW. In Vitro Interaction of Currently Used Azoles with Terbinafine against *Madurella mycetomatis*. *Antimicrob Agents Chemother*. 2015 Feb; 59(2):1373-4. doi: 10.1128/AAC.04487-14.
105. Fahal A, Mahgoub ES, EL Hassan AM, Jacoub AO, Hassan D. Head and Neck Mycetoma: The Mycetoma Research Centre Experience. *PLoS Negl Trop Dis* (2015) 9(3): e0003587. doi:10.1371/journal.pntd.0003587
106. Elfadil H, Fahal A, Kloezen W, Ahmed EM, van de Sande W. The In Vitro Antifungal Activity of Sudanese Medicinal Plants against *Madurella mycetomatis*, the Eumycetoma Major Causative Agent. *PLoS Negl Trop Dis* (2015) 9(3): e0003488. doi:10.1371/journal.pntd.0003488
107. Fahal AH, EL Hassan AM, Mahgoub ES, Rahman ME, Mycetoma in the Sudan: The Mycetoma Research Centre Update. *PLoS Negl Trop Dis*. 2015 Mar 27; 9(3):e0003679. doi: 10.1371/journal.pntd.0003679. eCollection 2015 Mar.
108. Hala Taha, Ahmed Fahal, Wendy W. J. van de Sande. Mycetoma: Epidemiology, Treatment Challenges and Progress. *Mycetoma: epidemiology, treatment challenges and progress*. *Res Rep Trop Med*. 2015;6 31-36

109. Wendy WJ van de Sande, Marian ten Kate, Wim van Vianen, Ahmed Fahal, Irma Bakker-Woudenberg. Amphotericin B but not itraconazole is able to prevent grain formation in experimental *M. mycetomatis* mycetoma in mice. *Br J Dermatol.* 2015 Jul 6. doi: 10.1111/bjd.14025.
110. Kloezen W, van Helvert-van Poppel M, Fahal AH, van de Sande WWJ. A *Madurella mycetomatis* Grain Model in *Galleria mellonella* Larvae. *PLoS Negl Trop Dis* 2015; 9(7): e0003926. doi:10.1371/journal.pntd.0003926
111. Eshraga A. Ezaldeen, Raif Mohamed Ahmed, EL Sammani Wadella, Nadia EL Dawi, Ahmed Hassan Fahal. Actinomycetoma induced Cervical Spinal Cord Compression: A rare and serious complication. *JMM Case Reports.* 2015; DOI 10.1099/jmmcr. 0.000074.
112. Ahmed SA, van de Sande WW, Desnos-Ollivier M, Fahal AH, Mhmoud NA, de Hoog GS. Application of Isothermal Amplification Techniques for the Identification of *Madurella mycetomatis*, the Prevalent Agent of Human Mycetoma. *J Clin Microbiol.* 2015; 53(10):3280-5. doi: 10.1128/JCM.01544-15.
113. Verwer PEB, Notenboom CC, Eadie K, Fahal AH, Verbrugh HA, van de Sande WWJ. A polymorphism in the chitotriosidase gene associated with risk of mycetoma due to *Madurella mycetomatis* - a retrospective study. *PLoS Negl Trop Dis.* 2015 Sep 2;9(9):e0004061. doi: 10.1371/journal.pntd.0004061. eCollection 2015.
114. Najwa MA, Badr M Yousif, Ahmed Fahal, Wendy van de Sande. The nature of the *M. mycetomatis* mycetoma granuloma tissue pigments. *Khartoum Med J.* 2015; 8 (2): 1105 – 1110.
115. Ahmed Hassan Fahal. Aggressive actinomycetoma. *Khartoum Med J.* 2015; 8 (2): 1116.
116. Emmanuel E. Siddig, Aghapy E. Siddig, Ali Edreis, Ahmed Omer Almo-barak, Ahmed H Fahal. The Utility of Fine Needle Aspiration for cytology for the Diagnosis of Breast Lesions in low-resource Areas. *Khartoum Med J.* 2015; 8(3):1153-1157.

117. Emmanuel Edward Siddig, Najwa A. Mhmoud, Ahmed Hassan Fahal. Identification of *M. mycetomatis* fungus in pleural fluid and sputum of a patient with aggressive gluteal eumycetoma with pulmonary spread. *Khartoum Med J* 2015; 8(3): 1164-1167.
118. EE Zijlstra, WWJ van de Sande, AH Fahal. Mycetoma, Mycetoma: A Long Journey from Neglect. Editorial, *PLoS NTD*, DOI:10.1371/journal.pntd.0004244, January 21, 2016.
119. Zijlstra EE, van de Sande WW, Welsh O, Mahgoub ES, Goodfellow M, Fahal AH. Mycetoma. *Lancet Infect Dis.* 2016; 16(1):100-112. doi: 10.1016/S1473-3099(15)00359-X.
120. Scolding PS, Abbas MAQ, Omer RF, Fahal AH. *Madurella mycetomatis*-Induced Massive Shoulder Joint Destruction: A Management Challenge. *PLoS Negl Trop Dis* 2016; 10(8): e0004849. doi:10.1371/journal.pntd.0004849
121. Omer RF, Seif EL Din N, Abdel Rahim FA, Fahal AH. Hand Mycetoma: The Mycetoma Research Centre Experience and Literature Review. *PLoS Negl Trop Dis* 2016;10(8): e0004886. doi:10.1371/journal.pntd.0004886
122. Mohamed EISW, Seif El Din N, Fahal AH. Multiple Mycetoma Lung Secondaries from Knee Eumycetoma: An Unusual Complication. *PLoS Negl Trop Dis.* 2016 Jul 21; 10(7):e0004735. doi: 10.1371/journal.pntd.0004735. eCollection 2016.
123. Fahal AH, Finkelman MA, Zhang Y, Van de Sande WW. Detection of (1-3)- β -D-glucan in eumycetoma patients. *J Clin Microbiol.* 2016;54(10):2614-7. doi: 10.1128/JCM.01478-16
124. Nasr A, Abushouk A, Hamza A, Siddig E, Fahal AH. Th-1, Th-2 Cytokines Profile among *Madurella mycetomatis* Eumycetoma Patients. *PLoS Negl Trop Dis.* 2016 Jul 19; 10(7):e0004862. doi: 10.1371/journal.pntd.0004862. eCollection 2016.
125. Suleiman SH, Wadaella el S, Fahal AH. The Surgical Treatment of Mycetoma. *PLoS Negl Trop Dis.* 2016 Jun 23; 10(6):e0004690. doi: 10.1371/

126. Smit S, Derks MF, Bervoets S, Fahal A, van Leeuwen W, van Belkum A, van de Sande WW. Genome Sequence of *Madurella mycetomatis* mm55, Isolated from a Human Mycetoma Case in Sudan. *Genome Announc.* 2016 May 26;4(3). pii: e00418-16. doi: 10.1128/genomeA.00418-16
127. ELbadawi HS, Mahgoub E, Mahmoud N, Fahal AH. Use of immunoblotting in testing *Madurella mycetomatis* specific antigen. *Trans R Soc Trop Med Hyg.* 2016 May;110(5):312-6. doi: 10.1093/trstmh/trw023.
128. Emmanuel E, Siddig, Badr EL Din M, Yousif, Ali M, Edris, Ahmed H, Fahal. The Touch Imprint Cytology: A simple method for the diagnosis of mycetoma causative agents. *Khartoum Med J.* 2016; 9(1):1212-1216
129. Wadal A, Elhassan TA, Zein HA, Abdel-Rahman ME, Fahal AH. Predictors of Post-operative Mycetoma Recurrence Using Machine-Learning Algorithms: The Mycetoma Research Center Experience. *PLoS Negl Trop Dis.* 2016; 10(10): e0005007. doi:10.1371/journal.pntd.0005007
130. Mohamed NA, Fahal AH. Mycetoma Pulmonary Secondaries from a Gluteal Eumycetoma: An Unusual Presentation. *PLoS Negl Trop Dis.* 2016; 10(10): e0004945. doi:10.1371/journal.pntd.0004945.
131. Mitjà O, Marks M, Bertran L, Kollie K, Argaw D, Fahal AH, Fitzpatrick C, Claire Fuller L, Izquierdo BG, Hay R, Ishii N, Johnson C, Lazarus JV, Meka A, Murdoch M, Ohene SA, Smal PI, Andrew Steer A, Tabah EN, Tiendrebeogo A, Lance Waller L, Yotsu R, Walker SL, Asiedu K. Integrated Control and Management of Neglected Tropical Skin Diseases. *PLoS Negl Trop Dis* 2017, 11(1): e0005136. Doi
132. Fahal AH. Mycetoma: A global medical and socio-economic dilemma. *PLoS Negl Trop Dis* 2017; 11(4): e0005509. <https://doi.org/10.1371/journal.pntd.0005509>
133. Eadie K, Parel F, Helvert-van Poppel M, Fahal A, van de Sande W. Combining two antifungal agents does not enhance survival of *Galleria mellonella* larvae infected with *Madurella mycetomatis*. *Trop Med Int*

- Health. 2017 Mar 25. doi: 10.1111/tmi.12871.
134. Ahmed AA, van de Sande W, Fahal AH. Mycetoma laboratory diagnosis: Review article. *PLoS Negl Trop Dis*. 2017; 11(8): e0005638. <https://doi.org/10.1371/journal.pntd.0005638>
 135. Siddig EE, Fahal AH. Histopathological Approach for the Diagnosis of Mycetoma Causative Agents: A Mini Review. *J Cytol Histol*. 2017; 8: 466. doi: 10.4172/2157-7099.1000466.
 136. Saad ESA, Fahal AH. Broncho-pleuro-cutaneous fistula and pneumothorax: Rare challenging complications of chest wall eumycetoma. *PLoS Negl Trop Dis* 2017; 11(9): e0005737. <https://doi.org/10.1371/journal.pntd.0005737>
 137. Ahmed HM Ibrahim, Ali Mohamed Osman, Ahmed H Fahal, Alnada A M Ibrahim. The use of a documentary drama film to improve the knowledge, attitude and practice of an endemic village population towards mycetoma at Sennar State, Sudan. *Khartoum Med J*. 2017; 10(2):1385 – 1391
 138. Queiroz-Telles F, Fahal AH, Falci DR, Caceres DH, Chiller T, Pasqualotto AC. Neglected endemic mycoses. *Lancet Infect Dis*. 2017; 17(11):e367-e377. doi: 10.1016/S1473-3099(17)30306-7. Epub 2017 Jul 31.
 139. Kloezen W, Parel F, Brüggemann R, Asouit K, Helvert-van Poppel M, Fahal A, Mouton J, van de Sande W. Amphotericin B and terbinafine but not the azoles prolong survival in *Galleria mellonella* larvae infected with *Madurella mycetomatis*. *Med Mycol*. 2018; 1;56(4):469-478. doi: 10.1093/mmy/myx064.
 140. van de Sande W, Fahal A, Ahmed SA, Serrano JA, Bonifaz A, Zijlstra E. Closing the mycetoma knowledge gap. *Med Mycol*. 2018 Apr 1; 56(suppl_1):153-164. doi: 10.1093/mmy/myx061.PMID:28992217
 141. Bakhiet SM, Fahal AH, Musa AM, Mohamed ELSW, Omer RF, Ahmed ES, El Nour M, Mustafa ERM, Sheikh A Rahman ME, Suliman SH, El Mamoun MAG, El Amin HM. A holistic approach to the mycetoma

- management. *PLoS Negl Trop Dis*. 2018; 12(5):e0006391. <https://doi.org/10.1371/journal.pntd.0006391>
142. Abdallah MOE, Algizouli UK, Suliman MA, Abdulrahman RA, Koko M, Fessahaye G, Shakir JH, Fahal AH, Elhassan AM, Ibrahim ME Mohamed. HSEBV-Associated Breast Cancer Whole Methylome Analysis Reveals Viral and Developmental Enriched Pathways. *Front. Oncol*. 2018; 8:316. doi: 10.3389/fonc.2018.00316
 143. Lim W, Eadie K, Horst-Kreft D, Ahmed SA, Fahal AH, van de Sande WWJ. VNTR confirms *Madurella mycetomatis* heterogeneity and is a promising typing tool for *Madurella mycetomatis*. *Med Mycol*. 2018 Jul 31. doi: 10.1093/mmy/myy055.
 144. Bakhiet SM, Edwar Siddig EE, Abdallah OB, Mohamed SW, Fahal AH. Fine Needle Aspiration Cytology Utility in the Identification of Mycetoma Causative Agents: The Mycetoma Research Center Experience. *Khartoum Med J*. 2018; 11(0): 1499 – 1506.
 145. Nyuykonge B, Lim W, Fahal AH, van de Sande WWJ. Mycetoma. *Dutch Journal of Infectious Diseases*. 2018; 13(6): 143-150.
 146. Fahal AH, Suliman SH, Hay R. Mycetoma – The Spectrum of Clinical Presentation. *Trop. Med. Infect. Dis*. 2018, 3, 97; doi:10.3390/tropicalmed 3030097
 147. Abbas M, Scolding PS, Yosif AA, EL Rahman RF, EL-Amin MO, Elbashir MK, Groce N, Fahal AH. The disabling consequences of Mycetoma. *PLoS Negl Trop Dis*. 2018; 12(12): e0007019. <https://doi.org/10.1371/journal.pntd.0007019>
 148. Bakhiet SM, Mohamed SW, Najwa A Mhmoud, Siddig EE, Ibrahim DM, Ahmed ES, Fahal AH. *Madurella mycetomatis* causing Multiple mycetoma lesions: A rare presentation. *Khartoum Med J*. 2018; 11(0): 1499 – 1506.
 149. Suleiman SH, Yosif AA, Bakhiet SM, Fahal AH. Massive progressive scroto-perineal eumycetoma and its therapeutic challenges. *Khartoum Med J*. 2019; 12(2): 1622 - 1627

150. Mhmoud NA, Santona A, Fiamma M, Siddig EE, Deligios M, Bakhiet SM, et al. *Chaetomium atrobrunneum* causing human eumycetoma: The first report. *PLoS Negl Trop Dis*. 2019; 13(5): e0007276. <https://doi.org/10.1371/journal.pntd.0007276>
151. Siddig EE, Mohammed Edris AM, Bakhiet SM, van de Sande WWJ, Fahal AH. Interleukin-17 and matrix metalloprotease-9 expression in the mycetoma granuloma. *PLoS Negl Trop Dis*. 2019; 13(7): e0007351. <https://doi.org/10.1371/journal.pntd.0007351>
152. Abushouk A, Nasr A, Masuadi E, Allam G, Siddig EE, Fahal AH. The Role of Interleukin-1 cytokine family (IL-1 β , IL-37) and interleukin-12 cytokine family (IL-12, IL-35) in eumycetoma infection pathogenesis. *PLoS Negl Trop Dis*. 2019; 13(4): e0007098. <https://doi.org/10.1371/journal.pntd.0007098>
153. Siddig EE, Mhmoud NA, Bakhiet SM, Abdallah OB, Mekki SO, El Dawi NI, Van de Sande W, Fahal AH. The Accuracy of Histopathological and Cytopathological Techniques in the Identification of the Mycetoma Causative Agents. *PLoS Negl Trop Dis*. 2019 Aug 29;13(8): e0007056. doi: 10.1371/journal.pntd.0007056. [Epub ahead of print]
154. Nyuykonge B, Croughs P, Fahal AH, Verbon A, van de Sande WWJ. Pyomelanin Secretion in *Madurella mycetomatis* Interferes with Spectrophotometrically End-point Reading using the Sensititre® YeastOne Alamar Blue Assay but not with Visual End-point Reading. *Antimicrob Agents Chemother*. 2019 Oct 14. pii: AAC.01532-19. doi: 10.1128/AAC.01532-19.
155. Hay R, Denning DW, Bonifaz A, Queiroz-Telles F, Beer K, Bustamante B, Chakrabarti A, Chavez-Lopez MG, Chiller T, Cornet M, Estrada R, Estrada-Chavez G, Fahal A, Gomez BL, Li R, Mahabeer Y, Mosam A, Soavina Ramarozatovo L, Rakoto Andrianarivelo M, Rapelanoro Rabenja F, van de Sande W, Zijlstra EE. The Diagnosis of Fungal Neglected Tropical Diseases (Fungal NTDs) and the Role of Investigation and Laboratory Tests: An Expert Consensus Report. *Trop Med Infect Dis*. 2019 Sep 24;4(4). pii: E122. doi: 10.3390/tropicalmed4040122.

156. Amir Arastehfar, Wilson Lim, Farnaz Daneshnia, Wendy WJ van de Sande, Ahmed H Fahal, Marie Desnos-Ollivier, Gerrit S de Hoog, Teun Boekhout, Sarah A Ahmed. *Madurella* Real-Time PCR, a Novel Approach for Eumycetoma Diagnosis *PLoS Negl Trop Dis*. 2020 Jan 15[Online ahead of print] PMID: 31940343 DOI: 10.1371/journal.pntd.0007845
157. Rita O Oladele, Iorhen E Akase, Ahmed H Fahal, Nelesh P Govender, Martin Hoenigl, Jean Pierre Gangneux, Tom M Chiller, David W Denning, Oliver A Cornely, Arunaloke Chakrabarti. Bridging the Knowledge Gap on Mycoses in Africa: Setting Up a Pan-African Mycology Working Group. *Mycoses*. 2020 Mar;63(3):244-249. doi: 10.1111/myc.13044. Epub 2019 Dec 30.
158. Hussein HS, Bakhiet SM, Fahal AH. The late presentation of mycetoma patients: the challenges. *Khartoum Med J*. 2018; 13(01): 1681 – 1687.
159. Wilson Lim, Kimberly Eadie, Mickey Konings, Bart Rijnders, Ahmed H. Fahal, Jason D. Oliver, Mike Birch, Annelies Verbon, Wendy van de Sande. The eumycetoma causative agent *Madurella mycetomatis* is highly susceptible towards olorofim. *J Antimicrob Chemother* 2020; 75: 936–941 doi:10.1093/jac/dkz529.
160. Khidir ES, Ahmed A, Fahal AH, Ibrahim AA. Draft Genome Sequences of Three Clinical Isolates of *Madurella mycetomatis*, the Major Cause of Black-Grain Mycetoma. *Microbiol Resour Announc*. 2020 Apr 16;9(16). pii: e01533-19. doi: 10.1128/MRA.01533-19.
161. Sheehan G, Konings M, Lim W, Fahal A, Kavanagh K, van de Sande WWJ. Proteomic analysis of the processes leading to *Madurella mycetomatis* grain formation in *Galleria mellonella* larvae. *PLoS Negl Trop Dis*. 2020 Apr 8;14(4):e0008190. doi: 10.1371/journal.pntd.0008190. eCollection 2020 Apr.
162. Ali RS, Newport MJ, Bakhiet SM, Ibrahim ME, Fahal AH. Host genetic susceptibility to mycetoma. *PLoS Negl Trop Dis*. 2020; 14(4): e0008053. <https://doi.org/10.1371/journal.pntd.0008053>.

163. Kwizera R, Bongomin F, Meya DB, Denning DW, Fahal AH, Lukande R. Mycetoma in Uganda: A neglected tropical disease. *PLoS Negl Trop Dis.* 2020; 14(4): e0008240. <https://doi.org/10.1371/journal.pntd.0008240>
164. Elkheir LYM, Haroun R, Mohamed MA, Fahal AH. *Madurella mycetomatis* causing eumycetoma medical treatment: The challenges and prospects. *PLoS Negl Trop Dis.* 2020; 14(8): e0008307. <https://doi.org/10.1371/journal.pntd.0008307>
165. Kunna E, Yamamoto T, Fahal A. The use of traditional medicines among mycetoma patients. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):297-306.
166. Zaman S, Nahara P, MacGregor H, Barker T, Bayiseng J, Callow C, Fairhead J, Fahal AH, Hounsoumea N, Roemer-Mahler A, Mugumec P, Tadelef G, Davey G. Severely stigmatised skin neglected tropical diseases: a protocol for social science engagement. *Trans R Soc Trop Med Hyg* 2020; 114: 1013–1020 doi:10.1093/trstmh/traa141
167. Fahal AH. The Khartoum call for action, Khartoum, Sudan – 2019. *Trans R Soc Trop Med Hyg.* 2021;115:295–296. doi:10.1093/trstmh/traa043. Advance Access publication 5 March 2021.
168. Bertrand Nyuykonge, Kimberly Eadie, Willemien H A Zandijk, Sarah A Ahmed, Marie Desnos-Ollivier, Ahmed H Fahal, Sybren de Hoog, Annelies Verbon, Wendy W J van de Sande, Corné H W Klaassen. A Short-Tandem-Repeat Assay (Mmy STR) for Studying Genetic Variation in *Madurella mycetomatis*. *J Clin Microbiol* 2021 Feb 18;59(3): e02331-20. doi: 10.1128/JCM.02331-20. Print 2021 Feb 18.
169. Konings M, Kimberly E, Lim W, Fahal A, Mouton J, Tesse N, van de Sande W. The synthetic synergistic cinnamon oil CIN-102 is active against *Madurella mycetomatis*, the most common causative agent of mycetoma. *PLoS Negl Trop Dis.* 2021 Jun 9;15(6):e0009488. doi: 10.1371/journal.pntd.0009488. eCollection 2021 Jun.
170. Lim W, Siddig E, Eadie K, Nyuykonge B, Ahmed S, Fahal AH, Verbon A,

- Smit S, van de Sande WJJ. The development of a novel diagnostic PCR for *Madurella mycetomatis* using a comparative genome approach. *PLoS Negl Trop Dis*. 2020 Dec 16;14(12):e0008897. doi: 10.1371/journal.pntd.0008897. eCollection 2020 Dec.
171. Siddig EE, Ahmed A, Ali Y, Bakhiet SM, Mohamed NS, Ahmed ES, Fahal AH. *Eumycetoma* Medical Treatment: Past, Current Practice, Latest Advances and Perspectives. *Microbiol. Res*. 2021, 12, 899–906. <https://doi.org/10.3390/microbiolres12040066>
 172. Nyuykonge B, van Amelsvoort L, Eadie K, Fahal AH, Verbon A, van de Sande W. Comparison of Disc Diffusion, Etest, and a Modified CLSI Broth Microdilution Method for In Vitro Susceptibility Testing of Itraconazole, Posaconazole, and Voriconazole against *Madurella mycetomatis*. *Antimicrob Agents Chemother*. 2021 Aug 17;65(9):e0043321.
 173. Hassan R, Simpson H, Cano J, Bakhiet S, Ganawa E, Argaw D, Newport MJ, Deribe K, Fahal AH. Modelling the spatial distribution of mycetoma in Sudan. *Trans R Soc Trop Med Hyg*. 2021 Oct 1;115(10):1144–1152.
 174. Oladele RO, Ly F, Sow D, Akinkugbe AO, Ocansey BK, Fahal AH, van de Sande WWJ. Mycetoma in West Africa. *Trans R Soc Trop Med Hyg*. 2021 Apr 14;115(4):328–336.
 175. Azrag RS, Bakhiet SM, Mhmoud NA, Almalik AM, Mohamed AH, Fahal AH. A possible role for ticks in the transmission of *Madurella mycetomatis* in a mycetoma-endemic village in Sudan. *Trans R Soc Trop Med Hyg*. 2021 Apr 14;115(4):364–374.
 176. Yosif AA, Bakhiet SM, Abdalla TH, Mhmoud NA, Siddig EE, Fahal AH. Invasive, aggressive mastoid bone eumycetoma: a treatment challenge. *Trans R Soc Trop Med Hyg*. 2021 Apr 14;115(4):431–435.
 177. Ganawa ETS, Bushara MA, Musa AEA, Bakhiet SM, Fahal AH. Mycetoma spatial geographical distribution in the Eastern Sennar locality, Sennar State, Sudan. *Trans R Soc Trop Med Hyg*. 2021 Apr 14;115(4):375–382.
 178. Kébé M, Ba O, Mohamed Abderahmane MA, Mohamed Baba ND, Ball M, Fahal A. A study of 87 mycetoma patients seen at three health facili-

- ties in Nouakchott, Mauritania. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):315-319.
179. Fahal AH. Mycetoma: the journey from neglect to recognition as a neglected tropical disease. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):292-294.
180. Bahar ME, Bakheet OELH, Fahal AH. Mycetoma imaging: the best practice. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):387-396.
181. Mohamed ESW, Bakhiet SM, El Nour M, Suliman SH, El Amin HM, Fahal AH. Surgery in mycetoma-endemic villages: a unique experience. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):320-323.
182. Mhmoud NA, Siddig EE, Nyuykonge B, Bakhiet SM, van de Sande WWJ, Fahal AH. Mycetoma caused by *Microascus gracilis*: a novel agent of human eumycetoma in Sudan. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):426-430.
183. Omer RF, Ahmed ES, Ali BM, Alhaj HE, Bakhiet SM, Mohamed ESW, Strub-Wourgaft N, Fahal AH. The challenges of recruitment in clinical trials in developing countries: the Mycetoma Research Centre experience. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):397-405.
184. Ezaldeen EA, Ahmed ES, Fahal AH. Massive complicated secondary inguinal mycetoma: a case series. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):420-425.
185. Siddig EE, van de Sande WWJ, Fahal AH. Actinomycetoma laboratory-based diagnosis: a mini-review. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):355-363.
186. Santana A, Mhmoud NA, Siddig EE, Deligios M, Fiamma M, Bakhiet SM, Barac A, Paglietti B, Rubino S, Fahal AH. Metagenomics of black grains: new highlights in the understanding of eumycetoma. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):307-314.
187. Zaid DM, Bakheet OE, Ahmed ES, Abdalati F, Mhmoud NA, Mohamed ESW, Bakhiet SM, Siddig EE, Fahal AH. Multiple extensive Maduraella

- mycetomatis eumycetoma lesions: a case report and review of the literature. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):411-414.
188. Bakheet OE, Hassan MA, Fahal AH. Extensive perineal Actinomadura pelletieri actinomycetoma-induced urethral stricture: a rare complication. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):415-419.
189. Siddig EE, Nyuykonge B, Ahmed MT, Hassan R, Saad ESA, Mhmoud NA, Bakhiet SM, van de Sande WWJ, Fahal AH. Human actinomycetoma caused by Actinomadura mexicana in Sudan: the first report. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):406-410.
190. Traxler RM, Beer KD, Blaney DD, van de Sande WWJ, Fahal AH, Asiedu KB, Bower WA, Chiller T. Development of the Global Mycetoma Working Group. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):437-440.
191. Hay RJ, Asiedu KB, Fahal AH. Mycetoma - a long journey out of the shadows. *Trans R Soc Trop Med Hyg.* 2021 Apr 14;115(4):281-282.
192. Siddig EE, Verbon A, Bakhiet S, Fahal AH, van de Sande WWJ. The developed molecular biological identification tools for mycetoma causative agents: An update. *Acta Trop.* 2022 Jan; 225:106205. doi: 10.1016/j.actatropica.2021.106205. Epub 2021 Oct 21. PMID: 34687643
193. Fahal LA, Ahmed ES, Bakhiet SM, Siddig EE, Fahal AH. The Mycetoma Research Centre experience during the COVID-19 pandemic: obstacles and beyond. *Trans R Soc Trop Med Hyg.* 2022 Jan 19;116(1):1-3. doi: 10.1093/trstmh/trab111. PMID: 34313305
194. Hashizume H, Taga S, Sakata MK, Taha MHM, Siddig EE, Minamoto T, Fahal AH, Kaneko S. Detection of multiple mycetoma pathogens using fungal metabarcoding analysis of soil DNA in an endemic area of Sudan. *PLoS Negl Trop Dis.* 2022 Mar 11; 16(3):e0010274. doi: 10.1371/journal.pntd.0010274. eCollection 2022 Mar. PMID: 35275915
195. Nyuykonge B, Lim W, van Amelsvoort L, Bonifaz A, Fahal A, Badali H, Abbastabar M, Verbon A, van de Sande W. Eumycetoma Causative Agents are Inhibited in vitro by Luliconazole, Itraconazole and Ravuconazole. *Mycoses.* 2022 Apr 10. doi: 10.1111/myc.13442. Online

ahead of print. PMID: 35398930

196. Lim W, Konings M, Parel F, Eadie K, Strepis N, Fahal A, Verbon A, van de Sande WWJ. Inhibiting DHN- and DOPA-melanin biosynthesis pathway increased the therapeutic value of itraconazole in *Madurella mycetomatis* infected *Galleria mellonella*. *Med Mycol*. 2022 Feb 2;60(2):myac003. doi: 10.1093/mmy/myac003. PMID: 35064672
197. Lim W, Nyuykonge B, Eadie K, Konings M, Smeets J, Fahal A, Bonifaz A, Todd M, Perry B, Samby K, Burrows J, Verbon A, van de Sande W. Screening the pandemic response box identified benzimidazole carbamates, Olorofim and ravuconazole as promising drug candidates for the treatment of eumycetoma. *PLoS Negl Trop Dis*. 2022 Feb 4;16(2):e0010159. doi: 10.1371/journal.pntd.0010159. eCollection 2022 Feb. PMID: 35120131.
198. Fahal AH, Otieno LA, Ahmed ES, Kashif T, Khalid M, Mahmoud AH, Ododo L, Kyalo T, Bakhiet SM. Visual ethnographic documentation: a novel tool for mycetoma awareness and advocacy. *Trans R Soc Trop Med Hyg*. 2022 May 30: trac048. doi: 10.1093/trstmh/trac048. Online ahead of print. PMID: 35640654
199. Rawaa Adlan Elhady Ahmed, Alkhair Abd Almahmoud Idris, Nadia Ibrahim Eldawi, Ahmed Hassan Fahal. Role of special stains in the identification of fungi in eumycetoma among Sudanese patients in Soba University Hospital. *Microbes Infectious Dis*. 2022; 3(1): 185-191. DOI: 10.21608/mid. 2021.96355.1193
200. Siddig EE, El Had Bakhait O, El Nour Hussein Bahar M, Siddig Ahmed E, Bakhiet SM, Motasim Ali M, Babekir Abdallah O, Ahmed Hassan R, Verbon A, van de Sande WWJ, Fahal AH. Ultrasound-guided fine-needle aspiration cytology significantly improved mycetoma diagnosis. *J Eur Acad Dermatol Venereol*. 2022 Jun 24. doi: 10.1111/jdv.18363. Online ahead of print. PMID: 35748131
201. Musa EA, Abdoon IH, Bakhiet SM, Osman B, Abdalla SA, Fahal AH. Mycetoma management and clinical outcomes: the Mycetoma Research Center experience. *Trans R Soc Trop Med Hyg*. 2022 Jul 28: trac069. doi:

- 10.1093/trstmh/trac069. Online ahead of print. PMID: 35903002
202. Watson AK, Kepplinger B, Bakhiet SM, Mhmoud NA, Chapman J, Allenby NE, Mickiewicz K, Goodfellow M, Fahal AH, Errington J. Systematic whole-genome sequencing reveals an unexpected diversity among actinomycetoma pathogens and provides insights into their antibacterial susceptibilities. *PLoS Negl Trop Dis*. 2022 Jul 25;16(7):e0010128. doi: 10.1371/journal.pntd.0010128. Online ahead of print. PMID: 35877680
203. Hassan R, Deribe K, Fahal AH, Newport M, Bakhiet S. Clinical epidemiological characteristics of mycetoma in Eastern Sennar locality, Sennar State, Sudan. *PLoS Negl Trop Dis*. 2021 Dec 13;15(12):e0009847. doi: 10.1371/journal.pntd.0009847. eCollection 2021 Dec. PMID: 34898611
204. Emanwell Siddig, Antonella Santona, Najwa A Mhmoud , Massimo Deligios Maura Fiamma, Bianca Paglietti, Sahar Mubarak Bakhiet, Salvatore Rubino, Ahmed Hassan Fahal. Metagenomic detection of eumycetoma causative agents from households of patients residing in two Sudanese endemic villages in White Nile State. *PLoS NTD* Accepted.
205. Nyuykonge B, Siddig EE, Konings M, Bakhiet S, Verbon A, Klaassen CHW, Fahal AH, van de Sande WWJ. *Madurella mycetomatis* grains within a eumycetoma lesion are clonal. *Med Mycol*. 2022 Jul 29;60(7):myac051. doi: 10.1093/mmy/myac051. PMID: 35833294
206. Hassan R, Deribe K, Simpson H, Bremner S, Elhadi O, Alnour M, Fahal AH, Newport M, Bakhiet S. Individual Risk Factors of Mycetoma Occurrence in Eastern Sennar Locality, Sennar State, Sudan: A Case-Control Study. *Trop Med Infect Dis*. 2022 Aug 10;7(8):174. doi: 10.3390/tropicalmed7080174. PMID: 36006266
207. Nyuykonge B, Siddig EE, Mhmoud NA, Nyaoke BA, Zijlstra EE, Verbon A, Bakhiet S, Fahal AH, van de Sande WWJ. Epidemiological cut-off values for itraconazole and ravuconazole for *Madurella mycetomatis*, the most common causative agent of mycetoma. *Mycoses*. 2022 Jul 30. doi: 10.1111/myc.13509. Online ahead of print. PMID: 36005544

208. Siddig EE, Ahmed A, Hassan OB, Bakhiet SM, Verbon A, Fahal AH, van de Sande WWJ. Using a *Madurella mycetomatis*-specific PCR on grains obtained via non-invasive fine-needle aspirated material is more accurate than cytology. *Mycoses*. 2023 Jun;66(6):477-482. doi: 10.1111/myc.13572. Epub 2023 Feb 19. PMID: 36740735.
209. Siddig EE, Nyuykonge B, Mhmoud NA, Abdallah OB, Bahar MEN, Ahmed ES, Nyaoke B, Zijlstra EE, Verbon A, Bakhiet SM, Fahal AH, van de Sande WWJ. Comparing the performance of the common used eumycetoma diagnostic tests. *Mycoses*. 2023 May;66(5):420-429. doi: 10.1111/myc.13561. Epub 2023 Jan 17. PMID: 36583225
210. Fahal AH, Ahmed KO, Saeed AA, Elkhawad AO, Bakhiet SM. Why are mycetoma patients are still neglected. *PLoS Negl Trop Dis*. 2022 Dec 29;16(12):e0010945. doi: 10.1371/journal.pntd.0010945. eCollection 2022 Dec. PMID: 36580447
211. Adam SAY, Ahmed ES, Mohammed Adam SI, Abdallah OB, Siddig EE, Fahal AH. Eumycetoma with pulmonary dissemination: an unusual complication: Case series and literature review. *PLoS Negl Trop Dis*. 2022 Nov 10;16(11):e0010867. doi: 10.1371/journal.pntd.0010867. eCollection 2022 Nov. PMID: 36355778
212. Fongwen N, Asiedu KB, Bakhiet S, Bonifaz A, Cruz I, Argaw D, Estrada-Chavez G, Fahal AH, Litvintseva A, Marks M, Salinas-Carmona MC, Sow D, van de Sande WWJ. Diagnostics to support mycetoma management-Development of two target product profiles. *Trop Med Int Health*. 2022 Dec;27(12):1059-1064. doi: 10.1111/tmi.13828. Epub 2022 Nov 14. PMID: 3632962
213. Litvintseva AP, Bakhiet S, Gade L, Wagner DD, Bagal UR, Batra D, Norris E, Rishishwar L, Beer KD, Siddig EE, Mhmoud NA, Chow NA, Fahal A. Genomics and metagenomics of *Madurella mycetomatis*, a causative agent of black grain mycetoma in Sudan. *PLoS Negl Trop Dis*. 2022 Nov 2;16(11):e0010787. doi: 10.1371/journal.pntd.0010787. eCollection 2022 Nov. PMID: 36322569
214. Hounsorne N, Hassan R, Bakhiet SM, Deribe K, Bremner S, Fahal AH,

- Newport MJ. Role of socioeconomic factors in developing mycetoma: Results from a household survey in Sennar State, Sudan. *PLoS Negl Trop Dis*. 2022 Oct 17;16(10):e0010817. doi: 10.1371/journal.pntd.0010817. eCollection 2022 Oct. PMID: 36251732
215. Hassan R, Cano J, Fronterre C, Bakhiet S, Fahal A, Deribe K, Newport M. Estimating the burden of mycetoma in Sudan for the period 1991–2018 using a model-based geostatistical approach. *PLoS Negl Trop Dis*. 2022 Oct 14;16(10):e0010795. doi: 10.1371/journal.pntd.0010795. eCollection 2022 Oct. PMID: 36240229
216. Nyuykonge B, Siddig E, Mhmoud NA, Bakhiet S, Zijlstra E, Verbon A, Fahal AH, van de Sande WWJ. Wako β -D-glucan assay can be used to measure serum β -D-glucan in Sudanese patients to aid with the diagnosis of eumycetoma caused by *Madurella mycetomatis*. *J Eur Acad Dermatol Venereol*. 2023 Apr;37(4):783–786. doi: 10.1111/jdv.18642. Epub 2022 Oct 17. PMID: 36201367
217. Siddig EE, El Had Bakhait O, El Nour Bahar M, Siddig Ahmed E, Bakhiet SM, Motasim Ali M, Babekir Abdallah O, Ahmed Hassan R, Verbon A, van de Sande WWJ, Fahal AH. Ultrasound-guided Fine Needle Aspiration Cytology significantly improved mycetoma diagnosis. *J Eur Acad Dermatol Venereol*. 2022 Jun 24.
218. Siddig EE, Nyuykonge B, Bakheit OEH, Hassan OB, Ahmed ES, Osman AA, Bakhiet SM, van de Sande WW, Fahal AH. *Staphylococcus aureus* causing primary foot botryomycosis mimicking actinomycetoma: a case report from Sudan. *Int J Infect Dis*. 2022 Nov;124:224–226. doi: 10.1016/j.ijid.2022.10.010. Epub 2022 Oct 12. PMID: 36241164.
219. Fahal AH. The International Research Collaboration: A room for improvement. *Khartoum Med J*. 2022; 15(3): 1987.
220. Ali HO, Fahal AH. Why is mycetoma still a public health dilemma and a unique neglected tropical disease? *Khartoum Med J*. 2022; 15(3): 1990–1999.
221. Ahmed KO, Osman IA, Abdalnabi AM, Bakhiet SM, Elkhawad A, Fahal

- AH. Are pharmacists neglecting the neglected mycetoma in the most endemic area in Sudan? An opportunity for improvement. *Khartoum Med J.* 2022; 15(3): 2000-2008.
222. Siddig EE, Ahmed A, Hassan OB, Bakhiet SM, Verbon A, Fahal AH, van de Sande WWJ. Using a *Madurella mycetomatis* specific PCR on grains obtained via non-invasive Fine Needle Aspirated material is more accurate than cytology. *Mycoses.* 2023 Feb 5. doi: 10.1111/myc.13572. Epub ahead of print. PMID: 36740735.
223. Siddig EE, Ahmed A, Eltigani HF, Bakhiet SM, van de Sande WWJ, Fahal AH. The First Case of *Fusarium falciforme* Eumycetoma in Sudan and an Extensive Literature Review about Treatment Worldwide. *J Fungi (Basel).* 2023 Jul 6;9(7):730. doi: 10.3390/jof9070730. PMID: 37504719
224. Eltigani HF, Elsheikh SM, Ahmed KO, Bakhiet SM, Fahal AH. Mycetoma National Campaign Report. *Khartoum Med J.* 2022; 15; (3); 2018 - 202
225. Yoshioka I, Mori Y, Fahal AH, Siddig EE, Kaneko S, Yaguchi T. Specific and sensitive loop-mediated isothermal amplification (LAMP) method for *Madurella* strains, eumycetoma filamentous fungi causative agent. *PLoS Negl Trop Dis.* 2023 Sep 18;17(9):e0011644. doi: 10.1371/journal.pntd.0011644. PMID: 37721946; PMCID: PMC10538720.
226. Nyuykonge B, Siddig EE, Nyaoke BA, Zijlstra EE, Verbon A, Bakhiet SM, Fahal AH, van de Sande WWJ. Using (1,3)- β -D-glucan concentrations in serum to monitor the response of azole therapy in patients with eumycetoma caused by *Madurella mycetomatis*. *Mycoses.* 2023 Oct 23. doi: 10.1111/myc.13664. Epub ahead of print. PMID: 37872649.
227. Konings M, Eadie K, Strepis N, Nyuykonge B, Fahal AH, Verbon A, van de Sande WWJ. The combination of manogepix and itraconazole is synergistic and inhibits the growth of *Madurella mycetomatis* in vitro but not in vivo. *Med Mycol.* 2023 Nov 13: myad118. doi: 10.1093/mmy/myad118. Epub ahead of print. PMID: 37960934.
228. Fahal AH, Bakhiet SM. Mycetoma and the environment. *PLoS Negl Trop Dis.* 2023, 17(11): e0011736. <https://doi.org/10.1371/journal.pntd.0011736>.

pntd.0011736.

229. Badri R, Fahal AH (2023) The impact of the Sudan armed conflict on Mycetoma control. *PLoS Negl Trop Dis* 17(12): e0011783. <https://doi.org/10.1371/journal.pntd.0011783>
230. Hashizume H, Taga S, Sakata MK, Hussein M, Siddig EE, Minamoto T, Fahal AH, Kaneko S. Environmental detection of eumycetoma pathogens using multiplex real-time PCR for soil DNA in Sennar State, Sudan. *Trop Med Health*. 2023 Dec 19;51(1):71. doi: 10.1186/s41182-023-00563-3. PMID: 38115141.
231. Konings M, Gerrits van den Ende B, Raats MWJ, Fahal AH, van de Sande WWJ, Hagen F. Complete Genome Sequence of the Itraconazole Decreased Susceptible *Madurella fahalii* Type-Strain CBS 129176. *Mycopathologia*. 2024 Jan 17;189(1):6. doi: 10.1007/s11046-023-00807-0. PMID: 38231295; PMCID: PMC10794591.
232. Gabani MH, Ahmed AA, Hassan AA, Abdalla MA, Mustafa SA, Alobaid TA, Khatir AA, Mohammed RM, Awad NI, Abdellateef TA, Hassan A, Ahmed ES, Ali MZ, Fahal AH. The nutritional status of mycetoma-affected patients seen at the Mycetoma Research Center, Sudan. *PLoS Negl Trop Dis*. 2024 Jan 2;18(1):e0011726. doi: 10.1371/journal.pntd.0011726. Epub ahead of print. PMID: 38166142.
233. Ali HO, Elkheir LYM, Fahal AH. The use of artificial intelligence to improve mycetoma management. *PLoS Negl Trop Dis*. 2024 Feb 8;18(2):e0011914. doi: 10.1371/journal.pntd.0011914. PMID: 38329930; PMCID: PMC10852264.
234. Fahal A, Smith DJ, Nyaoke B, Asiedu K, Falves F, Warusavithanas S, Argaw D, Hay R. Towards enhanced control of mycetoma: a roadmap to achieve the UN's sustainable development goals by 2030. *Trans R Soc Trop Med Hyg*. 2024 Mar 26:trae016. doi: 10.1093/trstmh/trae016. Epub ahead of print. PMID: 38530874.
235. Saeed AA, Mahdi MA, Elalawy IAMA, Alawad SS, Gibree OA, Fahal AH. Integrating Artificial Intelligence in Snakebite Management:

- An Innovative Approach. *Migrat. Lett.* [Internet]. 2024Mar.6 [cited 2024Mar.30];21(5):893-901. Available from: <https://migrationletters.com/index.php/ml/article/view/9285>
236. Fahal AH, Abdelmunim AMS, El Mardi TES. Reviewing the Health Ramifications and Recovery Avenues for Sudan's April 2023 Armed Conflict. *SJMS*. 2023; 19(1): DOI 10.18502/13
237. van de Sande WWJ, Fahal AH. An updated list of eumycetoma causative agents and their differences in grain formation and treatment response. *Clin Microbiol Rev*. 2024 May 1: e0003423. doi: 10.1128/cmr.00034-23. Epub ahead of print. PMID: 38690871.
238. Alhaj AAM, Ahmed ES, Hassan A, Fahal AH. Epidemiological observations and management challenges in extrapedal mycetoma: A three-decade review of 420 cases. *PLoS Negl Trop Dis*. 2024 May 10;18(5):e0011841. doi: 10.1371/journal.pntd.0011841. Epub ahead of print. PMID: 38728359.
239. Omar Ali H, Abraham R, Desoubieux G, Fahal AH, Tauber C. Evaluation of a computational model for mycetoma-causative agents identification. *Trans R Soc Trop Med Hyg*. 2024 Apr 6;118(4):253-263. doi: 10.1093/trstmh/trad057. PMID: 38088215.
240. Ma J, Eadie K, Schippers M, Fahal A, Laleu B, Verbon A, van de Sande WWJ. Novel Compound MMV1804559 from the Global Health Priority Box Exhibits In Vitro and In Vivo Activity against *Madurella mycetomatis*. *Int. J. Mol. Sci*. 2024, 25, 6227. <https://doi.org/10.3390/ijms25116227>
241. Ma J, Eadie K, Fahal A, Verbon A, van de Sande WWJ. The performance and costs of XTT, resazurin, MTS and luciferin as viability dyes in in vitro susceptibility testing of *Madurella mycetomatis*. *Trans R Soc Trop Med Hyg*. 2024 May 9: tra030. doi: 10.1093/trstmh/trae030. Epub ahead of print. PMID: 38721683.
242. du Pré S, Konings M, Schoorl DJA, Fahal AH, Arentshorst M, Ram AFJ, van de Sande WWJ. Protoplast-mediated transformation of *Madurella*

- la mycetomatis using hygromycin resistance as a selection marker. *PLoS Negl Trop Dis*. 2024 Apr 5;18(4):e0012092. doi: 10.1371/journal.pntd.0012092. PMID: 38578808; PMCID: PMC11108199.
243. Fahal AH, Ahmed ES, Bakhiet SM, Bakhiet OE, Fahal LA, Mohamed AA, Mohamedelamin ESW, Bahar MEN, Attalla HY, Siddig EE, Mhmoud NA, Musa AM, van de Sande WWJ, Scherrer B, Oyieko P, Egondi TW, Onyango KO, Hata K, Chu WY, Dorlo TPC, Brüggemann RJ, Nyaoke BA, Strub-Wourgaft N, Zijlstra EE. Two dose levels of once-weekly fos-ravuconazole versus daily itraconazole in combination with surgery in patients with eumycetoma in Sudan: a randomised, double-blind, phase 2, proof-of-concept superiority trial. *Lancet Infect Dis*. 2024 Nov;24(11):1254-1265. doi: 10.1016/S1473-3099(24)00404-3. Epub 2024 Aug 1. PMID: 39098321.
244. Elkheir LYM, Delaye PO, Penichon M, Eadie K, Mohamed MA, Besson P, Chesnay AG, Desoubeaux G, Roger S, van de Sande WWJ, Fahal AH, Enguehard Gueiffier C. Emerging Therapeutics: The imidazo[1,2-b] pyridazine scaffold as a novel drug candidate for eumycetoma, a neglected tropical disease. *Eur J Med Chem*. <https://doi.org/10.1016/j.ejmech.2024.116720>.
245. Fahal AH, Ahmed IS, Saaed AA, Smith DJ, Alves F, Nyaoke B, Asiedu K, Hay R. Hope amidst neglect: Mycetoma Research Center, University of Khartoum. A holistic management approach to achieve the United Nations' Sustainable Development Goals. *PLoS Negl Trop Dis*. 2024 Sep 5;18(9):e0012420. doi: 10.1371/journal.pntd.0012420. PMID: 39235990; PMCID: PMC11376558.
246. Fahal AH, Ahmed ES, Mahmoud AH, Saaed AA. The Mycetoma Research Center, University of Khartoum, Sudan's experience in community engagement initiatives spans 3 decades. *PLoS Negl Trop Dis*. 2024 Aug 22;18(8):e0012304. doi: 10.1371/journal.pntd.0012304. PMID: 39172748; PMCID: PMC11340884.
247. El-Amin SO, El-Amin RO, El-Sadig SM, Fahal AH, Musa A. Painful mycetoma: a study to understand the risk factors in patients visiting the Mycetoma Research Centre (MRC) in Khartoum, Sudan. *Trans R Soc*

- Trop Med Hyg. 2024 Nov 29: trae093. doi: 10.1093/trstmh/trae093. Epub ahead of print. PMID: 39611590.
248. Mohamed AF, Saeed AA, Mohamoud MA, Jama AA, Fahal AH. Mycetoma in Somalia. The Mycetoma in Somalia: An updated literature Review. *Ann Med Surg. Annals of Medicine and Surgery* (>):10.1097/MS9.0000000000002851, December 19, 2024. | DOI: 10.1097/MS9.0000000000002851
249. Chandler DJ, Davey G, Hay RJ, Fahal A; Mycetoma Activity and Severity clinical Scale (MASS) expert panel. Development of the Mycetoma Activity and Severity clinical Scale (MASS): an international Delphi study. *Lancet Infect Dis.* 2025 Feb 26:S1473-3099(24)00808-9. doi: 10.1016/S1473-3099(24)00808-9. Epub ahead of print. PMID: 40023182.
250. Fahal AH, Smith DJ, Saeed AA, Nyaoke B, Alves F, Asiedu K, Hay R. Global health initiatives and mycetoma management: the unmet promise. *Trans R Soc Trop Med Hyg.* 2025 Feb 4:traf001. doi: 10.1093/trstmh/traf001. Epub ahead of print. PMID: 39901853.
251. Hussein SME, Saeed AA, Fahal AH. Mycetoma management: Therapeutic challenges and the role of pharmacovigilance. *PLoS Negl Trop Dis.* 2025 Feb 20;19(2):e0012827. doi: 10.1371/journal.pntd.0012827. PMID: 39977423.
252. Yoshioka I, Fahal AH, Kaneko S, Cao W, Yaguchi T. Itraconazole resistance in *Madurella fahalii* linked to a distinct homolog of the gene encoding cytochrome P450 14- α sterol demethylase (CYP51). *PLoS Negl Trop Dis.* 2025 Mar 27;19(3):e0012623. doi: 10.1371/journal.pntd.0012623. PMID: 40146733; PMCID: PMC11964275.
253. Ouangré A, Yerbanga IW, Savadogo I, Ouédraogo H, Bado ND, Nagalo A, Traoré F, Dem AK, Bouda SAK, Koulybari DFD, Sawadogo A, Nakana-bo Diallo S, Gangneux JP, Fahal AH, Bamba S. Burden of mycetoma in Burkina Faso: case series and systematic review. *Trans R Soc Trop Med Hyg.* 2025 Feb 28: traf015. doi: 10.1093/trstmh/traf015. Epub ahead of print. PMID: 40036719.

254. Fahal AH, Ahmed ES, Saeed AA, Fahal LA, Hussein SME, Nakano K, Hata K, Alves F, Nyaoke BA. A balancing act: Navigating the advantages and challenges of pioneering mycetoma treatment in Sudan- A landmark trial by the Mycetoma Research Center. *PLoS Negl Trop Dis*. 2025 Apr 21;19(4):e0013000. doi: 10.1371/journal.pntd.0013000. PMID: 40257994; PMCID: PMC12011228.
255. Konings M, Siddig E, Eadie K, Minlekib CP, Faye M, Sow D, Fahal A, Verbon A, van de Sande W. The development of a multiplex recombinase polymerase amplification reaction to detect the most common causative agents of eumycetoma. *Eur J Clin Microbiol Infect Dis*. 2025 Apr 30. doi: 10.1007/s10096-025-05134-4. Epub ahead of print. PMID: 40304898.
256. Ma J, Eadie K, Konings M, Fahal A, Verbon A, van de Sande WWJ. Ibrexafungerp prolongs survival and reduces the eumycetoma grain size in *Galleria mellonella* infection models of two different causative agents of eumycetoma. *J Antimicrob Chemother*. 2025 Apr 30:dkaf133. doi: 10.1093/jac/dkaf133. Epub ahead of print. PMID: 40304084.
257. Abdulazeem Abbass O, Hassan AAA, Hamed RHA, Saeed AA, Fahal AH. Orbital actinomadura madurae actinomycetoma: Case report and literature review. *PLoS Negl Trop Dis*. 2025 Apr 29;19(4):e0013035. doi: 10.1371/journal.pntd.0013035. PMID: 40299927; PMCID: PMC12040158.
258. Alyson M. Cavanaugh, Amanda Ribeiro dos Santos, Dayvison Francis Saraiva Freitas, James Venturini, Ahmed Fahal, Conceição de Maria Pedrozo e Silva de Azevedo, Jeremy A.W. Gold. Quality of Life, Disability, and Fungal Neglected Tropical Diseases. *Current Fungal Infection Reports* (2025) 19:4. <https://doi.org/10.1007/s12281-025-00503-0> REVIEW.
259. Abugessaisa I, Konings M, Manabe RI, Murphy CM, Kawashima T, Hasegawa A, Takahashi C, Tagami M, Okazaki Y, Eadie K, Lim W, Doyle S, Verbon A, Fahal AH, Kasukawa T, van de Sande WWJ. Iron regulatory pathways differentially expressed during *Madurella mycetomatis*

- grain development in *Galleria mellonella*. *Nat Commun*. 2025 Jun 25;16(1):5324. doi: 10.1038/s41467-025-60875-2. PMID: 40562743; PMCID: PMC12198395.
260. Chu WY, Fahal AH, Ahmed ES, Bakhiet SM, Bakhiet OE, Fahal LA, Mohamed AA, Mohamedelamin ESW, Bahar MEN, Attalla HY, Siddig EE, Mhmoud NA, Musa AM, Oyieko P, Egondi T, Brüggemann RJ, Hata K, Strub-Wourgaft N, Alves F, Nyaoke BA, Zijlstra EE, Dorlo TPC. Pharmacokinetics and Pharmacodynamics of Fosravuconazole, Itraconazole and Hydroxyitraconazole in Sudanese Patients With Eumycetoma. *J Infect Dis*. 2025 May 28;jiaf279. doi: 10.1093/infdis/jiaf279. Online ahead of print. PMID: 40433693
 261. Salah ME, Fearon Scales ML, Habib K, Alhamwi F, Abdelwahab S, Ahmed Y, Khalid MM, Smith DJ, Fahal A. Global sociodemographic, clinical, and epidemiological profiling of patients with mycetoma: A systematic review. *PLoS Negl Trop Dis*. 2025 Aug 14;19(8):e0013217. doi: 10.1371/journal.pntd.0013217. Epub ahead of print. PMID: 40811735.
 262. Mohammed Hussein, Elshimaa Ali, Yassin Kamal, Ali Elhouni, Yousif El-tayeb, Ali Awadella Saaed, Ahmed Hassan Fahal. The Utility of Artificial Intelligence in the Management of Dengue Fever- *Trans R S Trop Med Hyg*- traf103, <https://doi.org/10.1093/trstmh/traf103>
 263. Hassan Fahal A, Ahmed AO, El Hassan L, Saeed AA. The contribution of mycetoma grains to suboptimal disease management. *Nat Commun*. 2025 Nov 7;16(1):9855. doi: 10.1038/s41467-025-64908-8. PMID: 41203632; PMCID: PMC12594801.
 264. Erber, Astrid and Dahal, Prabin and Bonifaz, Alexandro and Brack, Matthew and Brodersen, Joanna and Harriss, Eli and Jeleff, Maren and Maguire, Brittany J. and Nyaoke, Borna and Regensburger, Sandra and Srambickal, Amala and Strub Wourgaft, Nathalie and Tirado-Sanchez, Andrés and Weichselberger, Tobias and Fahal, Ahmed H. and Zijlstra, Eduard E. and Guérin, Philippe J., A Systematic Review of the Clinical Study Landscape for Eumycetoma, 1990-2024. Available at SSRN: <https://ssrn.com/abstract=5368722> or <http://dx.doi.org>.

org/10.2139/ssrn.5368722

265. Smith DJ, E Silva de Azevedo CMP, Fahal A, Lipner SR, Grijzen ML, Hay R. Approach to Diagnosing and Managing Implantation Mycoses. *Cutis*. 2025 Sep;116(3):88-104. doi: 10.12788/cutis.1266. PMID: 41183475.
- 266.
267. Saeed AA, Hussein SME, Al Zamel AM, Eisa LB, Daud AOA, Seedahmed HSM, Ahmed FOI, Al-Jabali TAKT, Kheir E, Fahal AH. Medical and health students' insights into mycetoma: A survey-based study on knowledge and clinical practices. *PLoS Negl Trop Dis*. 2025 Oct 9;19(10):e0013583. doi: 10.1371/journal.pntd.0013583. PMID: 41066411; PMCID: PMC12510600.
268. Yoshioka I, Fahal AH, Sow D, Kaneko S, Mori Y, Ban S, Yaguchi T. Simultaneous Detection of Four *Madurella* Species Using Loop-Mediated Isothermal Amplification (LAMP) for *Eumycetoma* Diagnosis. *Mycopathologia*. 2025 Oct 29;190(6):105. doi: 10.1007/s11046-025-01019-4. PMID: 41152542; PMCID: PMC12568910.
269. Saeed AA, Osman MSS, Fahal AH. Molecular docking approaches in mycetoma: Toward improved patient management. *PLoS Negl Trop Dis*. 2026 Feb 11;20(2):e0013963. doi: 10.1371/journal.pntd.0013963. PMID: 41671243
270. Mosi L, Acharya B, Asiedu K, Bamisaiye A, Benbow ME, De Souza D, Elson L, Fahal A, Hay R, Nyangacha R, Quaye C, Shitu Sa'id A, Smith DJ, Jordan H. Integrated action for skin NTDs: Deconstructing transmission, addressing knowledge gaps, and championing one health strategies. *Nat Commun*. 2026 Feb 3. doi: 10.1038/s41467-026-69065-0. Epub ahead of print. PMID: 41629311.
271. Ahmed R, Saeed AA, Fahal AH, Dube A. Advances in the treatment of mycetoma: the emerging role of nanomedicine. *Nanomedicine*. 2026;1-11. DOI: 10.1080/17435889.2026.2645392. <https://doi.org/10.1080/17435889.2026.2645392>.
272. Badri R, Fahal AH. Left Gluteal and Perianal *Eumycetoma* Lesion

- Extending Into the Left Greater Sciatic Foramen, Pelvic Cavity to the External Anal Sphincter," Clinical Case Reports. 2026; 14(3): e72316, <https://doi.org/10.1002/ccr3.72316>.
273. Dallas J. Smith, Doudou Sow, Wendemagegn Embiale, María Francisca Colom, John Lochuke Ekai, Borna Nyaoke, Ahmed Fahal. The Neglected Burden of Eumycetoma in Africa. The Lancet Regional Health - Africa. 2026, Pages 100032.
274. Yousif MH, Alsammani A, Abdalla MH, Bashier EBM, Mohammed MAY, Saeed AA, Fahal AH. Interpretable machine-learning prognosis of mycetoma from routine clinical data. Trans R Soc Trop Med Hyg. 2026 May 28;trag061. doi: 10.1093/trstmh/trag061. Epub ahead of print. PMID: 42206479.
275. Fahal AH, Mycetoma in Mora-Montes HM, Leila M. Lopes-Bezerra L (Editors) Current Progress in Medical Mycology, Springer Nature 2017, pp 355-380. DOI 10.1007/978-3-319-64113-3
276. Ottawa 2010, Assessment & Technology, Consensus Statement. Zubar Amin, David A. Cook, Rachel Ellaway, Ahmad Fahal, Roger Kneebone, Moira Maley, Doris Ostergaard, Gominda Ponamperuma, Andy Wearn, Jack Boulet, Amitai Ziv, 2011
277. van de Sande WWJ, Fahal AH, de Hoog GS, Van Belkum A, Madurella. In: Liu D, editor. Molecular detection of human fungal pathogens. Boca Raton: CRC Press, Taylor & Francis Group. 2011, pp. 117–128.
278. Fahal, AH. Mycetoma in Richard, Guerrant, Walker, Peter, Tropical Infectious Diseases: Principles, Pathogens and Practice. Third edition, Elsevier Publisher, 2011, chapter 83, pp. 565-568
279. Fahal AH. Mycetoma in Williams, Bulstrode, O'Connell, Bailey and Love's Short Practice of Surgery 26E: 26th Edition, Oxford University Press, 2013, pp 64-68.
280. van Belkum A, Fahal, AH, van de Sande WW. Mycetoma by madurella mycetomatis: A completely neglected medico-social dilemma. In Hot Topics in Infection and Immunity in Children IX. Springer Science &

Business Media New York 2012

281. Fahal AH, Mycetoma: Clinico-pathological Monograph, University of Khartoum Press. 2006.
282. Fahal AH, Actinomycetoma in Africa: in Serrano JA, Sandoval AH, Beaman BL. Actinomicetoma, Merida, Venezuela, 2006.
283. Hassan MA, Fahal AH. Mycetoma: in Tropical Surgery, Kamil R, Lumbly J, Westminster Publication LTD, 2004.
284. Fahal AH, Evidence-Based Guidelines for the Management of Mycetoma Patients, 2001.
285. Scolding P, Fahal A, Yotsu RR. Drug therapy for Mycetoma. Cochrane Database Syst Rev 2018: <https://doi.org/10.1002/14651858.CD013082>



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