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Thesis submitted in fulfillment requirement for PHD degree in diagnostic radiological technology

Grading of mycetoma using Magnetic Resonance Imaging

تـدرج الـمايستـوما باستـخـدام الـتـصوير بالـرنـين الـمغناطـيسـي

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بسم الله الرحمن الرحيم

" قل هل يستوي الذين يعلمون والذين لا يعلمون

انما يتذكر أولو الألباب"

صدق الله العظيم

سورة الزمر

الاية 9

Dedication

I hereby consecrate this work to the soul of my father.

To my mother, sisters and brothers for their help and support.

To my lovely and wonderful wife for her patient and continuous encourage.

To my children(*little angels*) Mohamed, Mozan and Aboubaker for dreaming proudly about their father holding PhD degree.

To the dearest people in my life for their cheers.

With love and hone

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ABSTRACT

The aims of the study is to investigate the role of Magnetic Resonance Imaging in classification and grading of mycetoma disease, the study was conducted at the center of Mycetoma Research -Khartoum University during the period 2018-2022.

The study deals with the patients of mycetoma disease transferred to Magnetic Resonance Imaging department in FADIAL hospital, ANTALIA diagnostic center and DAR AL-ELAJ hospital.

The study covered 150 patients including both genders 88.7 % male and 11.3 % female the sample is ranged between 10 years up to 62 years.

The MRI evaluated and the data were collected through a questionnaire contains the manifestation of the disease on Resonance Imaging by radiologists.

The data were analyzed by using SPSS program (Statistical Package for the Social Sciences) version 26 and excel program.

Categorical data were presented as frequencies, percentages and the result were displayed as tables and figures.

The result shows that males are more affected with disease than female with percentage of 88.7% the age is ranged between 21-31 years was more affected with percentage of 42%.

The spots were appeared in all images with prominent appearance 69.7% percentage.

Inlets sinuses appear is shown in 45% from the sample, otherwise bone destruction appearance is highly frequented in the data with percentage 75.7 %.

The ability to grading the disease with MSMB (Mycetoma Skin, Muscle and Bone System) had percentage of 100% that's mean the new grading system was done with all the samples.

The study conduct that Magnetic Resonance Imaging had great value in grading mycetoma disease but on the other hand it's not main role in classification between types that causing mycetoma disease.

ملخص البحث

الهدف من هذا البحث هو دراسة دور التصوير بالرنين المغناطيسي في التفريق بين العوامل المسببة لمرض المايستوما وتحيديد درجة التطور لذاك المرض.

اجريت الدراسة في مركز بحوث المايستوما التابع لجامعة الخرطوم في الفترة بين 2018-2022

هذه الدراسة اختصت بمرضى تم تشخيصهم بمرض المايستوما تم تحويلهم الي قسم الرنين المغناطيسي في كل من (مستشفى فضيل ,مركزانطاليا التشخيصي , مستشفى دار العلاج).

تمت الدراسة على 150 حالة تشمل كلا الجنسين بنسبة مئوية تقدر ب 88.7% رجال و 11.3% نساء.

وكانت العينة في المدى العمري بين 10-62 سنة.

تم تقييم الصور وجمع البيانات بواسطة استبيان يحوي مظاهر المرض في صورة الرنين المغنطيسي بواسطة اخصائي التشخيص بالاشعة وتم تحليل البيانات بواسطة استخدام برنامج الحزمة الاحصائية للعلوم الاجتماعية الاصدار 26.

تم عرض البيانات الصريحة في شكل ترددات ونسبة مئوية وتم عرض النتائج في جداول ورسوم بيانية.

اظهرت النتائج ان عدد المصابين من الرجال اكثر من المصابات من النساء بنسبة 88.7% , واكثر الاعمار تعرضا للاصابة هو متوسط الاعمار بين 21-31 سنة بنسبةاصابة بلغت 42%.

ظهر شكل النقاط داخل الدائرة في كل الصور مع هيمنة لظهوره بصورة واضحة 69.7% من العينة المدروسة.

مظهر الفتحات داخل الجيوب تكرر بظهور مقبول بنسبة تردد بلغت 45%.

مظهر تاكل وتهدم العظام كان مسيطرا علي العينة بنسبة تردد 75%.

تحديد مراحل المرض بواسطة (برنامج المايستوما , الجلد, العضلات ,العظام) تردد في 100% من العينة مما يعني ان استخدام البرنامج الجديد لتحديد مراحل تطور المرض تم استخدامه في كل العينات .

خلصت الدراسة الي ان التصوير بالرنين المغناطيسي له قيمة موثرة في تقييم تدرج مرض المايستوما داخل جسم الانسان.

لكن لايمكن الاخذ به بصورة قطعية لتقسيم مرض المايستوما اعتمادا علي العوامل المسببة له (بكتريا , فيروسات).

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List of abbreviations

(Alphabetical order)

abbreviation	**Mean**
Cm	Centimeter
CT	Computed Tomography
GE	General Electric Company
KGs	Kilo-grams
L	Liter
LCD	Liquid crystal display
MHZ	Mega-Hertz
MR	Magnetic Resonance
MRC	Mycetoma Research center
MRI	Magnetic Resonance Imaging
MSMBS	Mycetom Skin, Muscles and Bone System
NMR	Nuclear Magnetic Resonance
RF	Radio-frequency
SPP.	Several Species

SPSS	Statistical package for the social science
STIR	Short Tau Inversion Recovery
T	Tesla
T1	Longitudinal relaxation time image
T2	Transvers relaxation time image
U\S	Ultrasound imaging
U.S	Unit State of America
WHO	World Health Organization
‘’	Inch

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Chapter one

1.1 Introduction

This study deal to put under scoop two branches:

I – classification of mycetoma by Magnetic Resonance Imaging (MRI).

II – grading of mycetoma by Magnetic Resonance Imaging (MRI).

For that its will took in details mycetoma, MRI, role of MRI in classification and grading of mycetoma.

MRI based on physics phenomenon called nuclear magnetic resonance or NMR, in which magnetic field and radio waves activate atom to give off tiny radio signals.

Magnetic resonance imaging (MRI) since introduced in early 1980 has gained in popularity as diagnostic tool of disorder, many doctors believe that MRI is an accurate noninvasive method to diagnose and give sufficient information to conservative treatment (Hans. H. Schild, 1990).

Mycetoma was first record in 1812 by French missionary in India, Godfrey a surgeon in India 1864 reported on four patient lumpy swelling of foot tissue with bone destruction, Billingall in 1895 (without defining etiology) describe the microscopic details, Archbold in Sudan 1916 classified the etiology of mycetoma in to two forms:

Eumycetes which causing maduromycosis and Pseudomycetes which causing actinomycetoma (http://www.mycetoma.edu.sd)

1.2 Problem of study

The problem of study is state the role of Magnetic resonance imaging in classification and grading of mycetoma in Sudan.

1.3 Objectives:

1.3.1 Main objective:

Grading of mycetoma disease by using of Magnetic Resonance Imaging.

1.3.2 Specific objectives:

I- Grading of mycetoma disease using Magnetic Resonance Imaging.

1.4 Samplization:

1.4.1 Sample size:

150 medical record in the Hospital Information System (HIS) of patient that was diagnosed with soft tissue mycetoma and had undergone Magnetic Resonance Imaging, were reviewed by two diagnostic radiologist with an experience more than 3 years (all the cases were histologically proven by biopsy).

1.4.2 Sample duration:

2018 UP to 2022

1.4.3 Sample location:

Mycetoma Research Centre –university of Khartoum-Sudan

1.5 Thesis out line:

This thesis will concern with classification and grading of mycetoma using Magnetic resonance Imaging according to that purpose the thesis divided to the following chapters:

1.5.1 Chapter one:

Introduce to thesis and will present with general historical back-ground of MRI, mycetoma, problem of study, objectives, samplization and thesis out line.

1.5.2 Chapter two:

Historical back-ground of mycetoma, back-ground of mycetoma in Sudan, radiological method of diagnosing mycetoma, back-ground of Magnetic resonance imaging, concise MRI physics and previous work performed in this field.

1.5.3 Chapter three:

Describe the material and method that used to get the role of MRI in classification and grading of mycetoma.

1.5.4 Chapter four:

Present with mathematical analysis of data to reach the result study.

1.5.5 Chapter five:

Present with discussion, conclusion and recommendation attached with result of thesis and present suggestive to future work.

Chapter two

2.1 Mycetoma

2.1.1 Historical back-ground of mycetoma.

2.1.1.1 Background of mycetoma in the world

Mycetoma is a chronic granulomatous disease of the subcutaneous and deep tissues which lead to progressive destruction of tissue leads to loss of function of the affected site. The foot is commonly affected (Madura foot) but other parts of the body can also be involved including the hands, head, thigh, and wall of the chest. (Monica Chees Brough, 2006).

Madura foot is common in peoples who works in the field or not protect for their foot it has been particularly linked to minor penetrating wound caused by thorn.

Mycetoma is a chronic granulomatous disease, associated with a progressive, inflammatory reaction that clinically presents as tumor-like soft tissue swelling with sinus tract formation that drains purulent material containing grains. Mycetoma usually results of traumatic implantation of soil organisms on subcutaneous tissue; can be classified as eumycetoma or actinomycetoma depending on whether the infection is caused by filamentous fungi or aerobic filamentous actinomycetes, mycetoma represents a classical neglected disease that primarily affects the poorer populations and rural regions of Africa, Latin America, and Asia at latitudes defined as the "mycetoma belt" where higher mycetoma frequencies are observed, occur mostly in regions with higher humidity, while actinomycetoma caused by Actinomadura spp. and Streptomyces spp .(https://www.who.int/news-room.)

Most causative agents of mycetoma, including fungi and actinomycetes, have been isolated from soil, decaying organic matter, plants and thorns; and, the disease is usually associated with traumatic injury followed by inoculation of the microorganism.

There are main factors associated with data from different areas demonstrate that males are more affected (sex ratio 3–4:1), ranging in age between the third and fourth decades of life. (Ahmed Hassan Fahal, 2008)

First Mycetoma was recorded in 1812 by French missionaries in Ponchicherry in India, but it was noticed there since 1714, Gill (1842) of Madurai dispensary in

Madras Province, in Southern India, is frequently mistakenly quoted as the first to report on of mycetoma in the medical literature. He described this condition as “a foot covered with large fungoid excrescence discharging an offensive ichorous fluid".

In 1846 Godfrey, a garrison surgeon of Bellary in India, in an article in the Lancet, reported on four patients with lumpy swellings of the foot, in two of them there was bone destruction and, cysts filled with melanotic matter were recorded. He named this condition "morbus tuberculosis pedis". This observation was also reported by Colebrook (1848) who was Gill's successor in Madurai. He introduced for the first time the term Madura foot. (http://www.mycetoma.edu.sd).

In 1855 Billingall, without defining its aetiology, described the microscopic details of the disease, the bony changes and its destruction in mycetoma. Eyre from Madras reported in 1859 on 40 cases treated during 1844-1848, and amputation was the treatment of choice. Minas (1860) described the disease in the Hisaar District and reported on hand involvement and noted the prevalence of black grain mycetoma in his patients.

Van Dyke Carter in 1860, after the isolation of the fungus, stressed the fungal parasitic origin of the disease and coined the term mycetoma. He also described two varieties of mycetoma, the melanoid type with black granules and the ochroid one with white granules. He suggested that, the latter variety is produced by a different species of fungi. In 1874, he produced a monograph on mycetoma. (http://www.mycetoma.edu.sd)

In 1862 Bidie, described the disease and tried to map out areas of occurrence of mycetoma in India. He gave a brief account on the microscopic appearance of the grains. Further cases were reported by Eddowes (1867) who treated mycetoma patients by local excision and by the application of caustic potash or nitric acid. In 1881, Dymock reported for the first time on local recurrence after surgery in a case of yellow mycetoma. Bocarro from Bombay in 1893 presented his experience with 100 mycetoma cases and in 1894, he distinguished between, the black and the white varieties of mycetoma each of which had been caused by different organisms. Boyce and Surveyor studied in detail the morphology of the grains and their chemical reaction to different solvents and they were able to describe the host tissue reaction to the organism.

Although India is the birth place of mycetoma yet the interest in mycetoma research had shifted at the turn of the century to the African subcontinent. Gemy and Vincent

from Algeria reported the first African case of mycetoma and probably the patient contracted the infection when he was in Tunisia. They isolated an aerobic actinomycete, streptothrix madurae (Actinomadura madurae).

In 1906, Brumpt listed in his well-known monograph "Les mycetomes" the causal agents of mycetoma. Laveran in 1906 described the micrococcus pelletieri (Actinomadura pelletieri). Pinoy in 1913 was the first to study actinomycotic agents and classified mycetoma organisms into two main groups the actinomycetes and the filamentous (true fungi).

Archibold in the Sudan in 1916, classified the aetiological agents of mycetoma into two forms, eumycetes causing maduromycosis and pseudomycetes causing actinomycetoma. Chiefly through the works of Mackinnon of Uruguay and the scientists of the Pasteur Institute in Paris and Daker, the taxonomy of the causal fungi and actinomycetes had been considerably clarified. Thereafter information on mycetoma has rapidly accumulated and many studies had been published.

In the past, many terms were used to describe mycetoma. Amongst these were morbus tuberculosis pedis, Godfrey and Eyre's disease, Endemic degeneration of the bones of the foot, Fungus foot, Morbus pedis entophyticus, Madura foot and Mycetoma. The prevailing terms nowadays are Madura foot and mycetoma.

Figure 2.1 shows patient's foot that affected by euomycetoma (Madura foot)

The term Madura foot, though of ancient standing, is a misnomer; for generations it had created a geographical confusion by identifying the island of Madura in north east of Java in Indonesia rather than the town of Madurai in southern India where Colebrook used this term for the first time. The term mycetoma is far more perfect than Madura foot as it is neither confined to Madurai town nor to the foot. (http://www.mycetoma.edu.sd)

2.1.1.2 mycetoma in sudan

Sudan seems to be the homeland of mycetoma. The disease is known in the Sudan, before the advent of modern medicine, by its present common name of "Nebit" meaning growth. Treatment by cautery and/or amputation was practiced by native doctors since the time of the Mahdeya (1885-1899).

However, the first documented report of a case of mycetoma in the Sudan was published by Belfour in 1904. He noted that the disease was common amongst Northern Sudanese, that the foot was affected most and that the commonest type was the black grain variety. The first case from Southern Sudan was reported from Bor in Upper Nile by Wenyon in 1908.

Extensive studies of two causal organisms were carried out by Dr. Albert Chalmers, Director of the Wellcome Tropical Research Laboratories, together with Captain R.G. Archibald, pathologist, and Dr. J.B. Christopher'son, Director of Khartoum and Omdurman Civil Hospitals. They carried out valuable systemic mycological and pathological studies of the causal organisms. Chalmers and Archibald gave quite an elaborative and specific definition of mycetoma. For the first time they introduced the terms Maduromycoses and Actinomycetoma proceeded afterwards to classify the mycetomas into Maduromycetoma the grains of which are composed of large segmented mycelia and Actinomycetoma with grains composed of fine non-segmented filaments. (http://www.mycetoma.edu.sd)

In 1931, Grantham-Hill, the senior surgeon, Khartoum Hospital reported a detailed clinical study of 184 patients with mycetoma, 64% of them had the black variety and 36% had the yellow type. Noting that the yellow type is actinomycotic and the black type is maduromycotic and he discussed the relative virulence of the two types. He thought that the actinomycotic mycetoma was more virulent, infiltrates gradually and once it penetrates the periosteum it disseminates rapidly in bone while the black maduromycotic mycetoma forms a localized usually subcutaneous tumor. He doubted the value of medical treatment by various drugs suggested up to that date. He thought that the best routine treatment was surgical, and that the key to success lies in early recognition and complete removal. In the case of black maduromycosis the pseudo-capsule can readily be identified by its bluish colour and dissection follows its outer surface. In the absence of sinuses an incision is made into the tumor to identify its nature. If it is found to be mycetoma, fresh instruments are taken and a defining incision made at a distance at about

one centimeter from the apparent margin of the growth. This caution in surgical removal reflects an excellent knowledge of the high rate of recurrence in the case of inadequate removal.

Grantham-Hill was aware that amputations will deter patients from attending to hospital and therefore encouraged early detection. He therefore, defended local removal as much as possible. In his series of 184 cases; 141 (77%) were treated by local removal and 43 (23%) by amputation. He gave support to the common belief that the "Nebit" usually follows a thorn prick by saying that in 30% of his patients with mycetoma of less than six months duration thorns were actually found embedded in the growth after removal at operation.

Peter Abbott, a surgeon at Wad Medani Civil Hospital was awarded the degree of M.D. (1954) from Cambridge University on his clinical and epidemiological Studies of Mycetoma. He also addressed the Royal Society of Tropical Medicine and Hygiene in London in December 1956 on mycetoma in Sudan. Abbott sent specimens from his cases abroad to Dr. Walker's Mycological Reference Laboratory in the London School of Hygiene and Tropical Medicine and to Professor Juan E. MacKinnon in Montevideo in Uruguay for mycological identification. (http://www.mycetoma.edu.sd)

Abbott carried out in vitro trials with antibiotics against Madurella mycetomi and Streptomyces somaliensis. He found that the growth of M. mycetomi was unaffected by chloramphenicol, oxytetracycline, carbomycin and polymyxin B. S. somaliensis was markedly sensitive to these antibiotics except Polymyxin B.

Regarding surgical treatment, Abbott reaffirmed the significance of either removal of the tumor in its border was ill defined, a margin of healthy tissue was removed as well to guard against recurrence. Abbott brought to light the fact that, mycetoma in the Sudan was a serious and common disease leading to the loss by amputation of many limbs. He reported on 1231 patients of mycetoma that were admitted to hospitals in Sudan or were seen in out-patient clinics in two and half years. His own study was based on 207 cases and therefore was referred to as the largest single study on mycetoma for many years.

From the specimens of Abbott, Professor MacKinnon settled the identity of black grain mycetoma in Sudan as M. mycetomi and showed that it is not different to merit the Glenospora khartoumensis coined early by Chalmers and Archibald in 1916 and that the yellow type is due to S. somaliensis.

Abbott noted that trophic and neurological changes were absent in mycetoma and on dissection of some of the mycetomata, glistening white tendons and nerves lay unaffected in the middle of damaged tissue.(http:// www.ncbi.nlm.nih.gov)

In 1964, Professor J.B. Lynch gave a Hunterian lecture on "Mycetoma in Sudan" to the Royal College of Surgeons of England. He reiterated the findings on the epidemiology of the diseases and gave a nice study of its pathology. He studied both the causal organisms and the tissue reaction. He estimated the incidence of mycetoma in the Sudan to vary from 300 to 400 new hospital cases annually, this figure does not take into account the considerable number of outpatients and those seen at peripheral dispensaries where qualified doctors might not even be present. However, recent estimates on the incidence of mycetoma have not been reported.

Mahgoub in 1964 published for the first time an article on the serological diagnosis of mycetoma. He also obtained a Ph.D. (1965) on Mycotic Infections in the Sudan, the major part of which was a mycological and serological study of mycetoma.

The late Mr. Ibrahim Moghraby in 1967, who worked for many years as a surgeon at Wad Medani Hospital, centre of endemic area for mycetoma, presented to the 6th Arab Medical Conference in Khartoum a study on "Mycetoma in the Gezeria, a public health problem".

Through the help of the World Health Organization, the Ministry of Overseas Development of the United Kingdom which was initiated by the late Professor Julian Taylor the Professor of Surgery, University of Khartoum and the Ministry of Health of the Sudan and University of Khartoum a mycetoma clinic and mycetoma ward were

established at the Khartoum North Civil Hospital. The objectives of this project were to conduct clinical trials for treatment of mycetoma and take full care of the patients.

However, the availability of patients and technical capabilities of the team in charge made it possible to carry out further research on serological diagnosis.

Mahgoub, Gumma and EL Hassan studied the immunological status of patients who were found to be partially deficient in cell mediated immunity. El Hassan and Mahgoub in 1972 confirmed beyond doubt the spread of mycetoma through the lymphatics.

Mahgoub 1978 managed to produce mycetoma grains in the "Nu-Nu" nude mice which are deficient in cell mediated immunity. The major results of research conducted in this project were trials at perfection of making a reliable serological test by preparation of specific antigens and introduction of medical treatment instead of ablating surgery.

Mahgoub in 1976 published methods for in vitro testing of mycetoma organisms and reported on the medical management of 144 patients with actinomycotic mycetoma caused by Streptomyces somaliensis, Actinomadura madurae and Actinomadura pelletieri. Of these patients 63% were cured by one or the other of a combination of antibiotic or chemotherapeutic agents namely streptomycin, together with dapsone, or with co-tri-moxazole, or with sulphadoxine pyrimethamine or with rifampicin. This publication found a wide circulation to the extent that it was globally accepted as the treatment of actinomycetoma.

Mahgoub addressed the Royal Society of Tropical Medicine and Hygiene on Mycetoma in Sudan in 1977, where the emphasis was made on the success of medical treatment and sero-diagnosis. In 1980 Mahgoub delivered the "Ian Murray Memorial Lecture" to the general congress of the British Society for Mycopathology highlighting success in the diagnosis, treatment and follow up of mycetoma patients. (Mahgoub E. S., 1973)

The problem of treating mycetoma due to M. mycetomatis remained unsolved for quite a time, and once more success of treatment with Ketoconazole was reported from Sudan in

a series of 13 patients five were cured and four greatly improved by daily intake of Ketoconazole. (Mahgoub & Gumma 1984).

2.1.2 Transmission route of disease:

The organisms are usually present in the soil in the form of grains. After they are moistened by rain, they form conidia or other forms able to infect the host. This infecting agent is then implanted into the host tissue through a breach in the skin produced by trauma caused by sharp objects such as thorn pricks, stone or splinters. However, in many patients there is no history of trauma at the site of infection. In areas where mycetoma is frequent the habit of going barefooted is common and thorns are plentiful. As a result, natural infection is expected to be more frequent than it actually is, if this theory of route of infection is true.

The disease is not contagious from person to other or from animal to human. (Emanuel Rubin et al, 1999).

2.1.3 Incubation Period

The incubation period in mycetoma is unknown due to the difficulty in establishing the time of initial infection, however, in experimental animals the formation of the granuloma was noted after a period of 3 weeks from the inoculation of the organism (Monica Chees Brough, 2006).

2.1.4 Classification of mycetoma:

The mycetoma swelling is nodular and contains sinuses. Mucopus containing small grains, or granules (colonies), is discharged through sinuses which open on the surface of the skin. When the mycetoma is caused by a fungus, the swelling is called a euomycetoma, and when caused by an actinomycete it is called an actinomycetoma. (Monica Chees Brough , 2006).

Table 2-1 below describe species of euomycetoma organism, common spread area of organism and the manifestation of the sinuses and discharge.

SPECIES	DISTRIBUTION	GRANULE
Madurella mycetomatis	Tropical Africa Dark India, S. America,Madagascar, Indonesia	red to black,hard,1-5 mm
Madurella grisea	Mainly South and Central America Caribbean	Black, hard, 1–2 mm
Exophiala jeanselmei	Tropics	Black, soft ,below 0.5 mm
Leptosphaeria senegalensis	Tropics and subtropics	Hard, Black, elongate, 0.5–2 mm
Pseudallescheria boydii	Africa	White, soft,up to 1mm
Aspergillus nidulans	Sudan and elsewhere	White-yellow, soft,1-2 mm

Table 2-1: fungi causing mycetoma

Actino-mycosis is highest incident of mycetoma is probably in Sudan it was thought that 300-400 cases developed every year there may be more because many cases are probably not reported.

Table 2-2 below describe species of actinomycetoma organism, common spread area of organism and the manifestation of the sinuses and discharge.

SPECIES	DISTRIBUTION	GRANULE
Actinomadura madurae	India, Ethiopia, Somalia, Argentina , Brazil, Middle East	White-yellow or pink, soft ,about 2 mm
Actinomadura pelletieri	Sudan, Senegal, Nigeria, India, South America	Red, firm, about 0.5 mm
Streptomyces somaliensis	Somalia, Ethiopia, Sudan, Egypt, West Africa, Brazil	White-yellow ,hard, 1–2 mm
Nocardia brasiliensis	Brazil, Venezuela, Mexico	White-yellow, soft up to 0.5 mm

Table 2-2: actinomycetes causing mycetoma

2.1.5 Radiological examination of mycetoma:

A series of radiological changes are seen in mycetoma. This is due to the fact that all mycetoma agents are osteophilic and due to the effect of the granuloma on both the affected bone and its blood supply. These changes are clearly seen with N. brasiliensis and with A. pelletieri which are the most destructive and osteolytic mycetoma agents. The changes are average with S. somaliensis and A. madurae and are minimal and late with M. mycetomatis.

Radiology, as a means for the diagnosis of mycetoma, is not helpful in the early stages of the disease but in late stages it demonstrates the presence and the extent of the soft tissue and bone involvement. It may be of a prognostic value and for follow up of patients during treatment.

2.1.5.1 Ultrasonic Imaging of Mycetoma

The mycetoma grains, its capsule and the accompanying inflammatory granuloma have characteristic ultrasonic appearances. Ultrasound imaging can differentiate between eumycetoma and actinomycetoma and between mycetoma and other non-mycetoma lesions.

In eumycetoma lesions, the grains produce numerous sharp bright hyper-reflective echoes, which are consistent with the black grains. The grain cement substance is most probably the origin of these sharp echoes. Also there are multiple thick walled cavities with absent acoustic enhancement. The absence of the acoustic enhancement is due to the thick walled cavity.

In actinomycetoma lesion the findings are similar but the grains are less distinct. This may be due to their smaller size and consistency, individual embedding of the grains or the absence of the cement substances in some of them. (Fahal A. H. et al ,1997)

The ultrasonic diagnosis of mycetoma is more precise and accurate in lesions with no sinuses. Grains identification within the lesion in the presence of active sinuses is difficult. This is due to technical difficulty i.e. lack of direct contact of the transducer

with the lesion and/ or to the presence the fibrous tissue along the sinus tract and at it's opening which may disturb the ultrasonic beam. The size and extent of the lesion can be determined ultrasonically and this is important in planning surgical incisions and procedures.

U\S proved to be simple, rapid, sensitive and non-invasive method to document the presence of mycetoma and its classification into eumycetoma and actinomycetoma. The technique provides information that is difficult to obtain on clinical and radiological examinations alone. It can be used in the routine diagnosis of mycetoma and epidemiological surveys. However it is also important to appreciate that, it is difficult to distinguish between the different types of actinomycetoma. (Fahal A. H. et al, 1997)

2.1.5.2 Angiography in Mycetoma:

In most patients with mycetoma, angiographic examination showed normal big arteries. In patients with eumycetoma the terminal branches feeding the inflammatory granuloma are dilated and tortuous. Within the lesion, there is marked blush and pathological circulation when compared to the adjacent normal tissue. This pathological circulation is similar to that seen within solid tumour which is characterized by change in vessels caliber, increased tortuosity and abnormal vascular space or lakes. However this circulation is brisk and excessive in the mycetoma while in solid tumour it is mostly hypovascular. These changes are more marked at the site of bone destruction.

Early venous filling and increased veins are seen in patients with dense pathological circulation as in eumycetoma but it is not commonly noted in actinomycetoma patients. No arterio-venous shunts are demonstrated in mycetoma patients. This pathological circulation correlates well with the neo-vessel formation seen histologically. The difference in the angiographic appearance of the two types of mycetoma can be attributed to the presence of a capsule and dense fibrosis in eumycetoma compared to that seen in actinomycetoma (P. E. S. Palmer et al, 2001).

2.1.5.3 Magnetic Resonance Imaging

In the majority of patients, the MRI examination revealed an ill-defined lesion of abnormal signal intensity extending from the subcutaneous tissue planes infiltrating the underlying muscle and bone. The lesion had predominant bright signal intensity at T2WI, fat suppressed images of granulomatous tissue and is low-intense signal at T1WIs. In addition, multiple discrete spherical hyper-intense lesions at T2WIs were noted, which were separated by low signal intensity fibrous network. Some of these lesions showed central low signal intensity foci of forming the central dot in circle sign (Target sign) which indicating mycetoma grains (httpps; /radiopaedia or g).

The figure 2.2 below demonstrate well defined hyper-intense lesion with hypo-intense rims (dot in circle appearance) in medial aspect of distal foot (arrows).

Dot-in-circle appearance which is common mark view in MRI that associated the mycetoma disease.

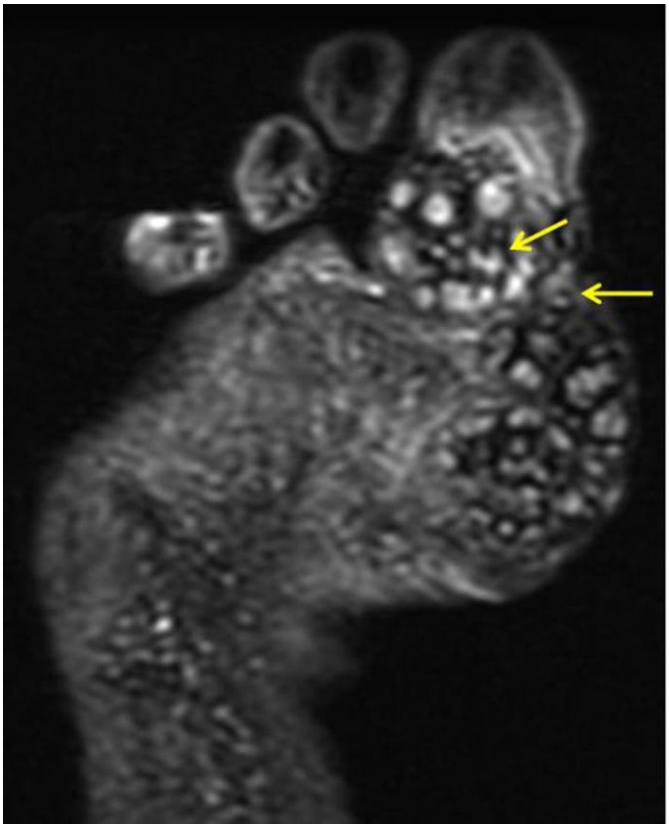


Figure 2-2 dot-in-circle appearance in Sagittal T2-weighted MRI image.

The mycetoma grains appeared did not enhance on post contrast study. Skin sinuses and sinus tracts were seen in most patients and they may or may not contain the low signal mycetoma grains.

Muscle infiltration was in the form of muscle oedema at fat suppressed images or muscle infiltration with soft tissue abscesses. Two types of abscesses were seen and these were micro-abscesses less than one cm or macro-abscess more than one cm in diameter. The bone infiltration included extensive destructing bone cavitation contains low signal mycetoma grains or just early bone marrow edema at fat suppressed images (P. E. S. Palmer et al, 2001).

In the table 2-3 below give some different between euomycetoma and actinomycetoma in some MRI appearance.

Manifestation	euomycetoma	actinomycetom
General course of disease	Less invasive	Highly invasive
Soft tissue change	a-long history years b-slow spread c-significant localized mass	a-shorter history b-fast spread
periosteum	Mild to moderate periosteal reaction	Marked to exuberant periosteal reaction
bone	Marked plastic moulding fewer and larger holes sesamoid involvement rare joint rarely involved	Moth-eaten appearance Multiple smaller hole Sesamoid involvement common Joint frequently involved+subarticular osteoprosis

Table 2-3 some different between euomycetoma and actinomycetoma in some MRI appearance.

2.1.6 Grading of mycetoma:

There are many way that describe the progress of mycetoma disease according to Magnatic resonance imaging appearance.

This appearance is soft tissue granuloma shows as a dense shadow or as scattered multiple granulomas. Calcification may be seen in some patients, involvement of the cortex, the cortex may be compressed from the outside by the granuloma leading to scalloping and this is usually followed by a variable amount of periosteal reaction, which is thick and compact. The sinus tracts appear speculated with loss of the cortical margin definition. Periosteal new bone spicules are laid down at right angle to the cortex to create a sun-ray appearance, involvement of the whole bone there may be multiple punched out cavities through the normal density of the bone. These cavities are large in size, few in number with well-defined margins, the cavities are usually filled with solid masses of grains which provides bone support, and this According to this grading system mycetoma lesion was classified as

Old grading system mild, moderate or severe.

MSMBS system (Mycetoma skin, Muscle, Bone grading system (American journal of roentgen Volume 180 issue 3) which is used in this study.

In the table 2-4 below give demonstrated the modern MSMBS that used this days for grading of mycetoma disease.

Table 2-4 demonstrated the modern MSMBS.

score	MRI Finding
Skin and subcutaneous tissue	
0	No skin or subcutaneous involvement
1	Obliteration of skin and fascial planes
2	Abscess formation
3	Formation of sinus tract without grains
4	Formation of sinus tract with grains
	Total
Muscle	
0	No muscles involvement
1	Muscle odema
2	Formation of micro abscess
3	Formation of macro abscess
	Total
Bone	
0	No bone involvement
1	Bone oedema
2	Bone cavitation
3	Bone destruction
	total

2.2 Magnetic resonance imaging.

2.2.1 Introduction to MRI

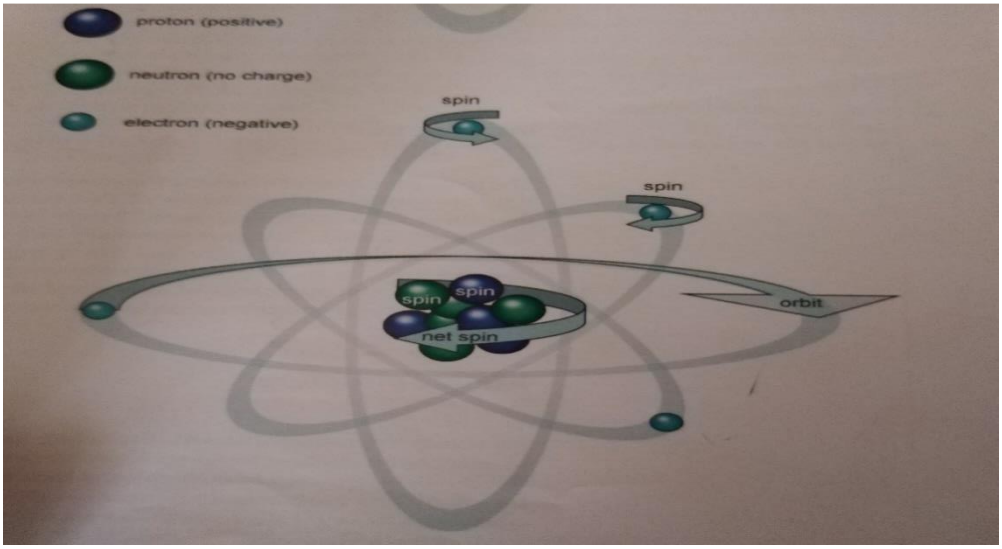
Imaging becoming an increasingly important tool in both research and clinical care, arrange of imaging technologies now provide unprecedented sensitivity to diagnosed disease.

One of this tools is Magnetic resonance imaging which is rapidly gross with high contrast sensitive to soft tissue differences and inherent safety to the patient from using ionizing radiation (Jerrold, et al, 2002).

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body in both health and disease. MRI scanners use strong magnetic fields, radio waves, and field gradients to generate images of the inside of the body.

Atoms consist of three fundamental particles, proton which poses positive charge; neutron which have no charge and electron which have negative charge the proton and neutron are located in uncles or core of an atom, where was electron located in shells orbital surrounding the nucleus. (CHien Daisy &Robert R. Edelman 1991).

The figure 2-3 is demonstrated the atom's particles, approximately comparing size of them and the particles' movements inside the atom.



The figure 2-3 shows the atoms parts movements.

Magnetic resonance (MR) is based upon the interaction between an applied magnetic field and a nucleus that possesses spin, nuclear spin or more precisely nuclear spin angular momentum and its value depend on its precise atomic composition, electron

spinning on their own axis and electron motion orbit which lies around the nucleus (Catherin west, et al 2005).

MRI phenomenon plays an important roles in many application in industry and medicine this phenomenon used in medicine for diagnostic purpose since this work concern with MRI there for it is important to know physical principle of MRI include definition of magnetic moment, resonance longitudinal – transvers relaxation time (T1-T2), radio-frequency and the role of radio-frequency in the imaging technique. (Thomas Brequest , 2001).

MRI, which identifies atoms by how they behave in a magnetic field, has become an extremely useful non-invasive method for imagining internal bodily structures and diagnosing disease.

2.2.2 Historical back ground of MRI

MRI is based on a physics phenomenon called nuclear magnetic resonance or NMR, in which magnetic fields and radio waves cause atoms to give off tiny radio signals.

The life-saving medical technique has its foundations in the work of physicist Isidor Isaac Rabi, who during the 1930s developed a method of measuring magnetic properties of atomic nuclei.

Throughout the 1930s, Rabi improved the molecular beam method and used it to gather increasingly accurate values for the nuclear spin of atoms, including hydrogen.

During the year of 1946 Felix Bloch and Edward Purcell independently discovered the magnetic resonance phenomena during this year, and were later awarded the Nobel Prize in 1952, (luca Saba, 2016).

The work culminated in the magnetic resonance method which is the basis for magnetic resonance imaging Peter Mansfield of Nottingham, England, further developed the utilization of gradients in the magnetic field. He showed how the signals could be mathematically analyzed, which made it possible to develop a useful imaging technique.

Peter Mansfield also showed how extremely fast imaging could be achievable. This became technically possible within medicine a decade later.

Up until the 1970s MRI was being used for chemical and physical analysis in 1970, Raymond Damadian, a medical doctor and research scientist, discovered the basis for using magnetic resonance imaging as a tool for medical diagnosis.

He found that different kinds of animal tissue emit response signals that vary in length, and that cancerous tissue emits response signals that last much longer than non-cancerous tissue.

Less than two years later he filed his idea for using magnetic resonance imaging as a tool for medical diagnosis with the U.S Patent Office, entitled "Apparatus and Method for Detecting Cancer in Tissue." A patent was granted in 1974, it was the world's first patent issued in the field of MRI. By 1977, Dr. Damadian completed construction of the first whole-body MRI scanner, which he dubbed the "Indomitable."

Since there within Medicine use of magnetic resonance imaging has developed rapidly. The first MRI equipment in health were available at the beginning of the 1980s. In 2002, approximately 22 000 MRI cameras were in use worldwide, and more than 60 million MRI examinations were performed. (luca saba, 2016)

2.2.3 Basic principle of MRI:

MRI is founded on the principle of nuclear magnetic resonance (NMR).

The principle of NMR are based on the fact that nuclei of certain element have magnetic moment. This means that if a sample of atoms of one of these element were placed in magnetic field, its nuclei would tend to line up with the filed.

The nuclei don’t actually line up exactly in the direction of the magnetic field however, the laws of quantum mechanics dictate that they align at an angle to the direction of the field.

Each type of nucleus has a quality to know as angular momentum associated with it. The idea with intrinsic angular momentum of the nucleus is fundamental magnetic resonance imaging. It can be likened to an example of spinning top. When atop is spun at an angle to the vertical, it will process about the vertical axis. That is the top will rotate about its own axis, and the axis of the tops rotation will revolved about the vertical axis. (Catherine Wstbrock, 2008).

This precession is due to the angular momentum of the top, which is in turn due to spinning of the top, in the same; a nucleus that aligned at an angle to the direction of magnetic field will process about the axis of the field.

The analogy is so exact that the nuclei are common referred to as spins that are manipulated to generate images.

In quantum mechanics a number called the spin of nucleus represents the angular momentum, depending on the value of the spin number of particular, there will be several different orientation in which the nuclei may line up in a magnetic field.

Each orientation is representing by different angel from direction of the magnetic field about which the nuclei may line up in a magnetic field. Each orientation is representing by a different angle from the direction of the magnetic field about which the nucleus will process.

MRI takes advantage of the fact that the nucleus of Hydrogen atom (a single proton) has magnetic momentum, the spin of proton is such that the proton has exactly two possible way to line up with applied magnetic field, because of its abundance in the body; Hydrogen is wonderful candidate for use in magnetic resonance imaging.

The frequent which the nucleus processes is function of both the strength of magnetic field and the particular nucleus this frequency, called the Larmor frequency, and the equal to product of the strength of the magnetic field and constant called the gyro-magnetic ratio.

The gyro-magnetic ratio is unique for each nucleus that has magnetic moment (Catherine Wstbrock, 2008).

Every element on periodic table except argon and cerium has at least one naturally occurring isotopes that possesses spin, thus in principle every element can be examined using MR and the basic idea of resonance absorption and relaxation are common to all of the element. (Donald T. Grhan et al, 2011).

The Larmer frequency is important, because it's the frequency at which the nucleus will absorb energy that will cause it to change its alignment.

In proton imagining this energy is in radio frequency(RF) range, meaning that the frequency typically varies from(1 to 100)MHz, if an RF pulse at Larmer frequency B0 applied to proton will change its alignment so that rather than being aligned with the main magnetic field , it will be aligned opposite the field.

Over a period of the time the proton will flip back to align with field, it will emit energy whose frequency is also exactly the larmor frequency, this emmition of the energy that made NMR such a useful means to located on the image proton (Catherine Wstbrock,2008).

The term resonance refer to that property of procession nucleus in which it absorbs energy only at the larmor frequency, if the frequency is of even by small amount, the nucleus will not absorb any energy ,nor will it change state (Catherine Wstbrock,2008).

2.2.4 MRI instrumentation:

The MRI system consist of the magnet, the coils and the computer.

2.2.4.1 The magnet:

The heart of all MR system is the magnet. There are three type of the magnets in common use for MRI ; all have in common that they can generate large uniform magnetic field, the different in the cost to produce the magnet, the strength can be produced, energy requirement to support the magnet and the direction of the main magnetic field (Catherine Wstbrock,2008) .

This three type of magnet are super conducting magnet, resistive magnet and permanent magnet.

2.2.4.2 Coils:

Which is assembly that produced and utilized and improve the phenomena of resonance and there are many type of coils; gradient coils which control the strength of magnetic field, radio-frequency coils which is produce a band of radio frequency corresponding to larmor equation to produce exchange of energy with atoms, shim coils which improve the homogeneous of magnetic field, volume coils, surface coils, phase array coils and circufertial coils.

2.2.4.3 The computer:

MRI computer system vary with manufacturing most however consist of a mini computer with expansion a capability, an array processor for Fourier transformation, an image processor that takes data from array processor to form an image, hard disk driver for storage of raw data and pulse sequence parameters and a power distribution mechanism to distribute and filter the alternating current (Catherine Wstbrock, 2008).

2.3 Previous study

(M. E. Elshamy et al, 2012) studied new MRI grading system for diagnosing and management –grading- of mycetoma, with sample consist of forty –two patient with confirmed mycetoma patients and had MRI, they found that all patient images had criteria of dot-in-circle, MSMBS can grade disease severity and help to management them, they recommended further studies to determine the role of grading system to management patient's progress.

(Jesus D. Guerra et al 2018) deal with establish the diagnosing of mycetoma in foot imaging and identify the principle radiological signs with sample of six mycetoma patients, they

found manifestation of dot-in-circle in all patients but difficult to distinguish between the type of organism.

(Ternan Laohawiriyakamol et al 2014) they deal with eight patients affected with mycetoma (two groups euomycetoma and actinomycetoma) and studied the dot-in-circle sign which appear in their image they found that MRI were not significantly different in both patient`s groups (euomycetoma and actinomycetoma).

(Wendy W. J. van de Sande et al 2014) studied mycetoma patients (euomucetoma - actinomycetoma) with multiple diagnostic tools to determine the extent of infection and identify the causative agent they found that diagnostic tools identification the extent of the disease- grading- , they also emphasize the fact that there is no ideal diagnostic tool available to identify the causative agent and they recommended future research focused diagnostic tools.

(Fahal Ahmed et al 2015) reported forty nine patients with head and neck mycetoma followed up at the Mycetoma Research Center done for them MRI and CT –Computed Tomography-the researchers recommended that MRI and CT most accurate diagnostic tools to determine the disease extent .

A three cases study reported with Madura foot and magnetic Resonance Imaging with protocol of T1, T2 weighted and STIR image was done to them, the dot-in-circle appears in all patients, in MRI easy to assess the extent of disease to soft tissue but the distinction between the two forms of mycetoma is not possible MRI.

(Rowa Fathelrahman Omer et al 2016) reported 533patient with hand mycetoma management over period of 24 years at Mycetoma Research Center, University of Khartoum.one of the specific objectives of this study to determine the MRI role of grading disease ,they found that MRI accurately determine the disease extension.

Chapter three

3.1 Material and methodology

This study were analytical study, the data were collected prospectively through the data sheet.

3.1.1 Material

3.1.1 Samplization

Sample size consist of 150 medical record in the Hospital Information System (HIS) of patient that was diagnosed with soft tissue mycetoma in MRC (Mycetoma Research Center) and had undergone Magnetic Resonance Imaging, their MRI images were reviewed by two radiologist with an experience more than 3 years (all the cases were histologically proven by biopsy).

This study duration extend since 2018 UP to 2022.

The sample placed was in three diagnostic centers that the patients refer to them for Magnetic Resonance imaging after confirming the disease by biopsy; these center are:

I ANTALIA DIGNOSTIC CENTER

II Dar AL-ELAJ HOSPITAL

III FADIAL HOSPITAL

3.1.2 Equipments

In this section we clarify the Magnetic Resonance Imaging machine and the computer that produced the images in details (company, year of manufacturing, magnet strength…. etc.).This information was collected from the biomedical engineer who's responsible of machine.

3.1.2.1 Specification of ANTALIA DIGNOSTIC CENTER MRI machine:

The manufacturing company of the magnet is General Electric Company, and the year of establishing is September2010.

3.1.2.1.1 The magnet:

The magnet type is close, the magnet made of super-conductive material, the magnetic field strength created by the magnet is 1.5 T (Tesla). The cooling system by helium gas.

3.1.2.1.2 The coils

There are many types of coils are impeded inside the gantry or capable as accessories coils the benefits of that coils are produced, utilized and improve the phenomena of resonance and there are many type of coils; radio-frequency coils which is produce a band of radio frequency corresponding to larmor equation to produce exchange of energy with atoms, shim coils which improve the homogeneous of magnetic field, volume coils, surface coils, phase array coils.

Gradient coils which control of magnetic field strength and graded variation in the static magnetic field.

The gradient coils that used in the machine are three sets of flat coil with in the magnet housing.

There are two sets of RF the first set is transmitted the pulse in to the body of the patient and the other set is receiving the signal that coming out from the patient`s body.

3.1.2.1.3 The patient table:

The table of the machine is fixed on the floor in front of the gantry, on the top of the table was a wood with carbon fiber support that slide in to opening of gantry carrying the patient to start exam, and it was 90 cm In width and 200 cm in length, the maximum weight that permit for this table is 121 KGs this table was created in India under consideration of GE -General Electric Company-.

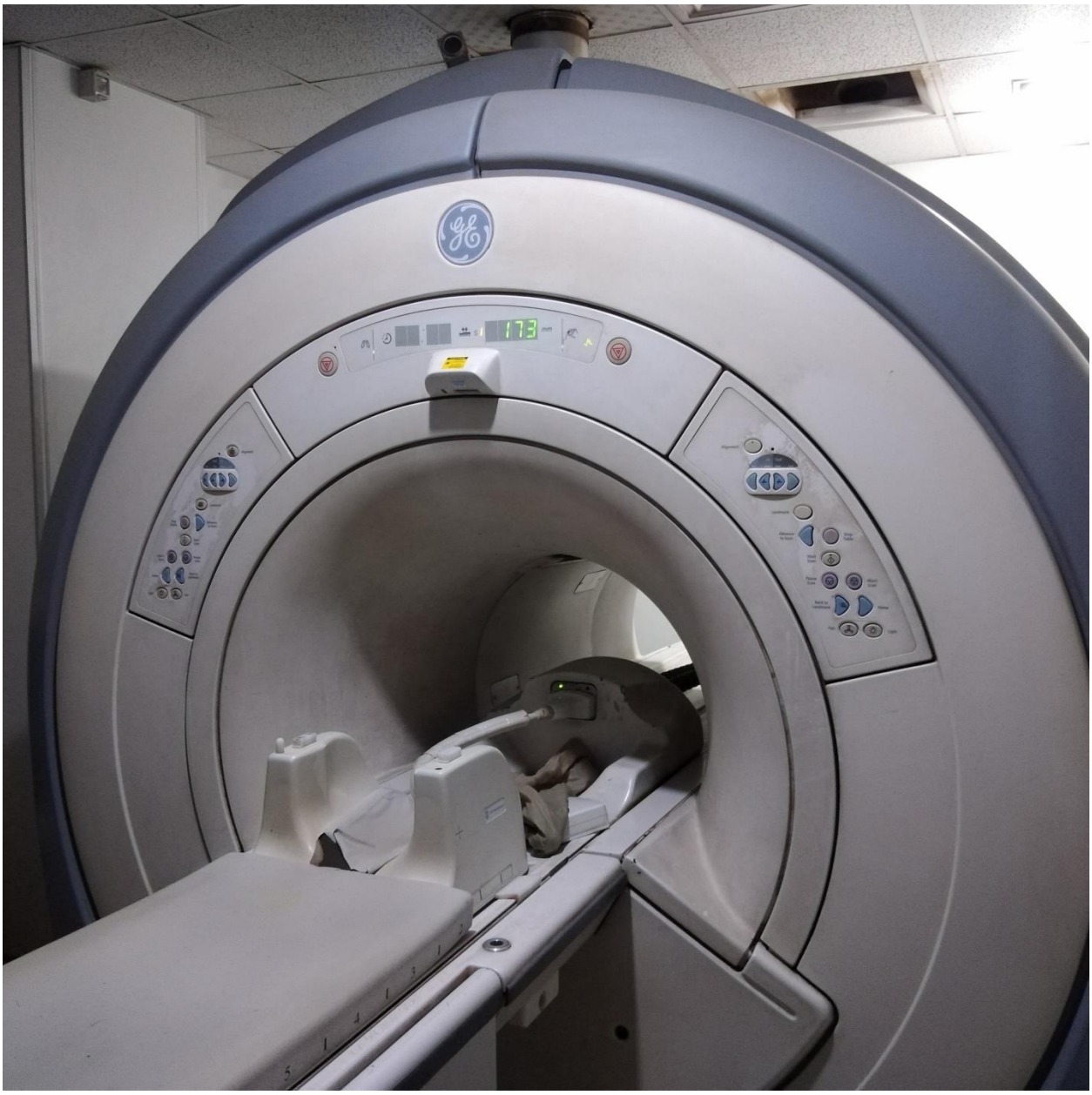


Figure (3.1) shows a picture of MRI machine, 1.5 Tesla (General Electric) of ANTALIA MEDICAL CENTER.

3.1.2.1.4 The operating console:

The operating console is assembly through which the operator scanning, reconstruction, viewing, filming and data storage.

It consist of three part the first part is computer which is highly performance that's conduct magnum data base and operation console together, it's created by General Electric company and its processor was array processor.

Second part is input devices which have main role for inter information and create order to the magnum it consist of key-board and here was King-stone and mouse was made by Logitech Company.

The third part of operating console is out-put device which include of screen.

The characteristic of screen in this department was 20`` -inch-, flat, colored, LCD multi-sync screen established by NEC Company.

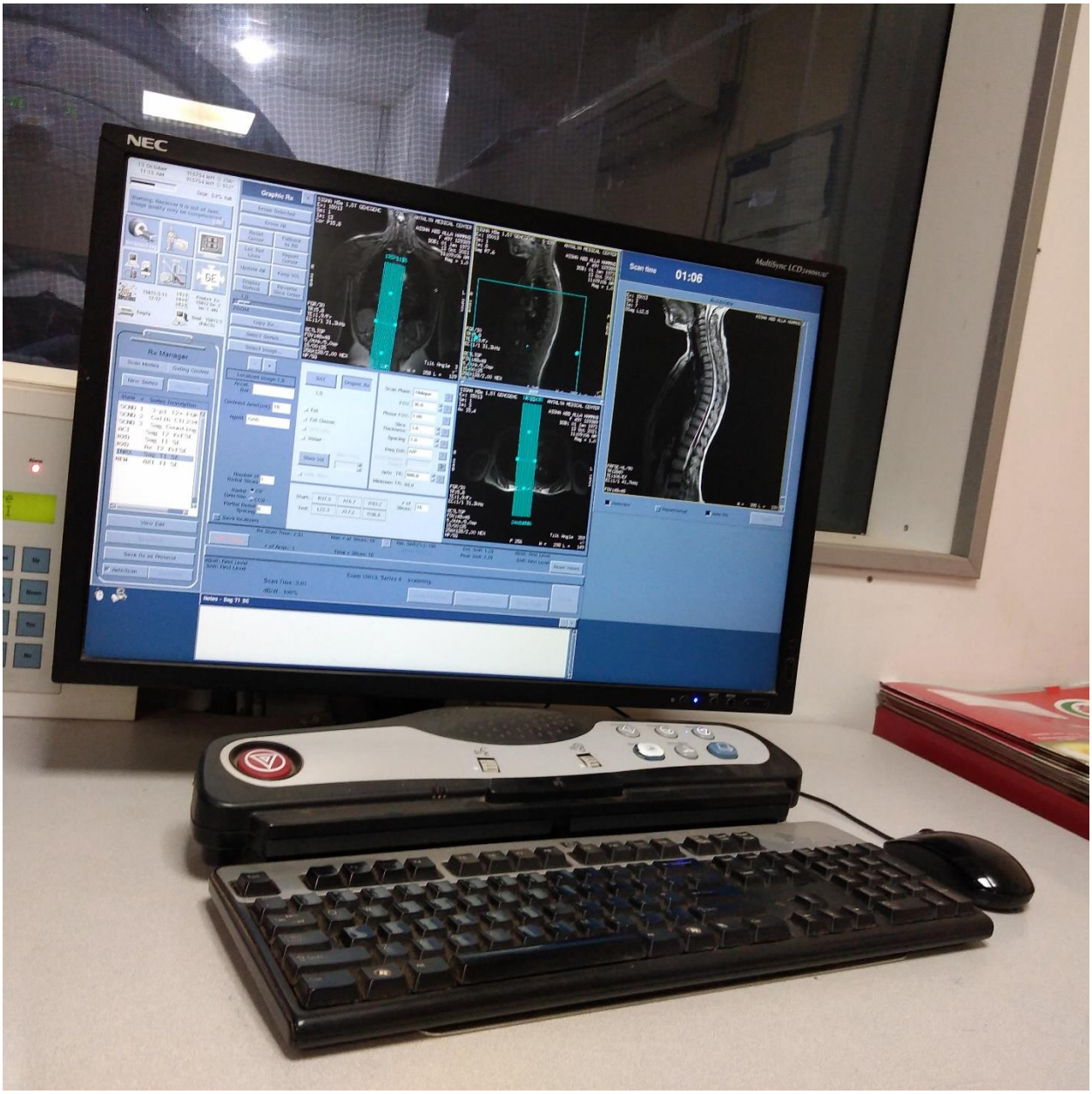


Figure 3.2 shows operating console of MRI machine (GE 1.5 Tesla) in INTALIA MEDICAL CENTER

3.1.2.2 Specification of DAR AL-ELAJ HOSPITAL:

The manufacturing company of the magnet was Philips Company model -Intera and a chive- and the year of establishing is May 2007

3.1.2.2.1 The magnet:

The magnet type is closed, the magnet made of superconductive material, the magnetic field strength created by the magnet is 1.5 Tesla and the cooling system by helium with minimum capacity not less than 39.00L (liter).

3.1.2.2.2 The coils

There are many types of coils are impeded inside the gantry or capable as accessories coils the benefits of that coils are produced, utilized and improve the phenomena of resonance and there are many type of coils; radio-frequency coils which is produce a band of radio frequency corresponding to larmor equation to produce exchange of energy with atoms, shim coils which improve the homogeneous of magnetic field, volume coils, surface coils, phase array coils, Gradient coils which control of magnetic field strength and graded variation in the static magnetic field.

The gradient coils that used in the machine are two sets of flat coil with in the magnet housing.

There are two sets of RF the first set is transmitted the pulse in to the body of the patient and the other set is receiving the signal that coming out from the patient`s body.

3.1.2.2.3 The patient table:

The table of the machine is fixed on the floor in front of the gantry, on the top of the table was a cradle that slide in to opening of gantry carrying the patient to start exam, and it was 90 cm In width and 220 cm in length. The maximum weight that permit for this table is 100 KGs

3.1.2.2.4 The operating console:

The operating console is assembly through wish the operator scanning, reconstruction, viewing, filming and data storage.

It consist of computer which is highly performance that's conduct magnum data base and operation console together, it's created by Philips and it is processor is array processor

Second part is input devices which have main role for inter information and create order to the magnum it consist of screen and key-board and here our key-board was brand of Corsair and mouse was Logitech Company.

3.1.2.3 Specification of FEDIAL HOSPITAL machine:

The manufacturing company of the magnet is Siemens Company, and the year of establishing is 2008

3.1.2.3.1 The magnet:

The magnet type is closed, the magnet made of superconductive material the magnetic field strength created by the magnet is1.5 tesla and the cooling system is combined between water and helium.

3.1.2.3.2 The coils

There are many types of coils are impeded inside the gantry or capable as accessories coils the benefits of that coils are produced, utilized and improve the phenomena of resonance and there are many type of coils; radio-frequency coils which is produce a band of radio frequency corresponding to larmor equation to produce exchange of energy with atoms, shim coils which improve the homogeneous of magnetic field, volume coils, surface coils and phase array coils.

Gradient coils which control of magnetic field strength and graded variation in the static magnetic field.

The gradient coils that used in the machine are three sets of flat coil with in the magnet housing.

There are two sets of RF the first set is transmitted the pulse in to the body of the patient and the other set is receiving the signal that coming out from the patient`s body.

3.1.2.3.3 The patient table:

The table of the machine is fixed on the floor in front of the gantry, on the top of the table was a cradle that slide in to opening of gantry carrying the patient to start exam, and it was 90 cm in width and 250 cm in length. The maximum weight that permit for this table is 150 KGs

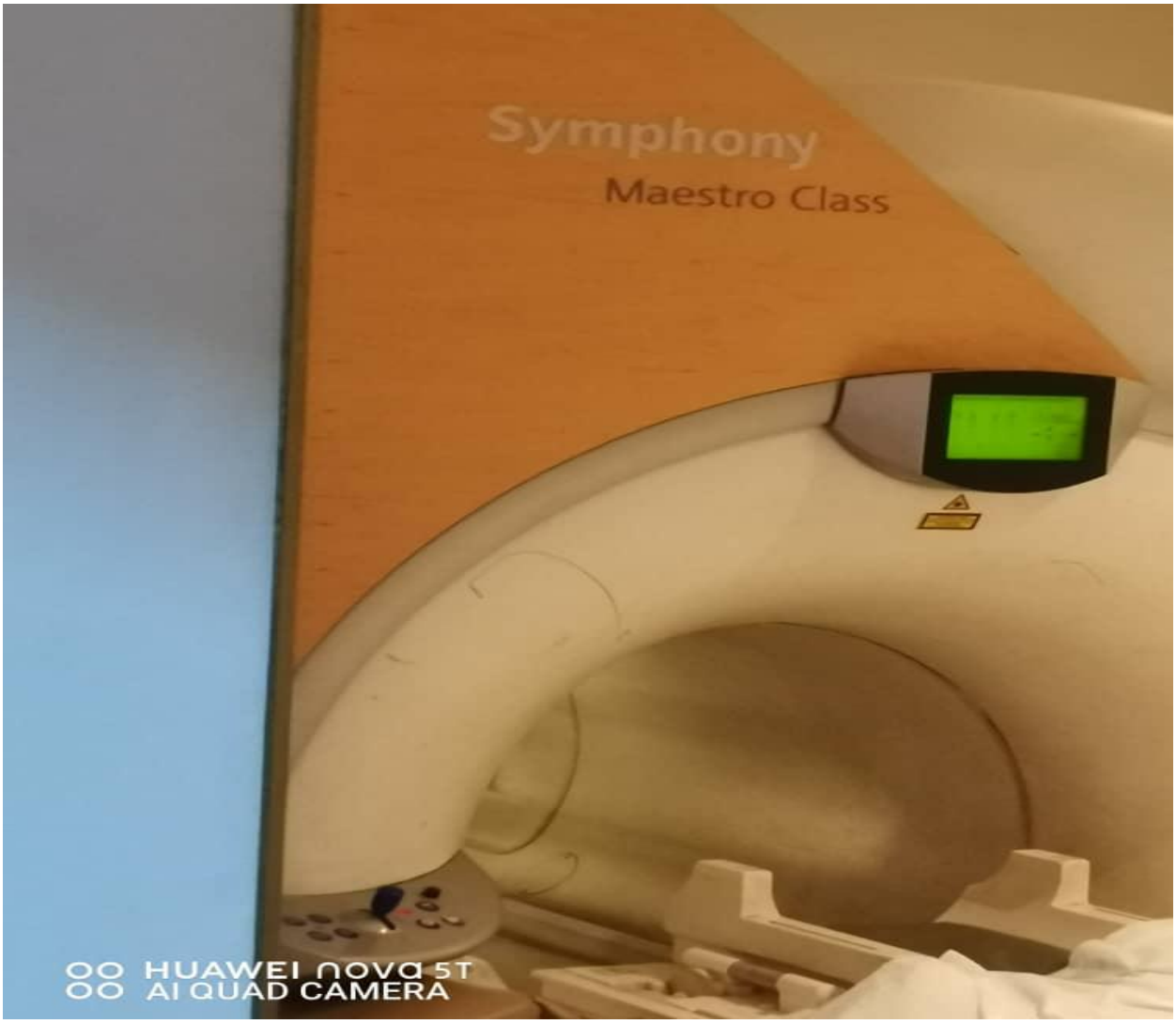


Figure (3.3) shows a picture of MRI machine, 1.5 Tesla (Siemens) of FEDIAL HOSPITAL

3.1.2.3.4 The operating console:

The operating console is assembly through wish the operator scanning, reconstruction, viewing, filming and data storage.

It consist of three part the first part is computer which is highly performance that's conduct magnum data base and operation console together, it's created by Antel Company and it processor is array processor.

Second part is input devices which have main role for inter information and create order to the magnum it consist of key-board and mouse.

The third part of operating console is out-put device which include of screen and printer, the characteristic of screen in this department is flat, color, 18 inch, LCD manufactured by Fujitsu Company.

Figure 3.4 shows operating console of MRI machine (Simenes 1.5 Tesla) in FADIAL HOSPITAL

3.1.2 Methodology:

The data were collected prospectively through the data sheet (questionnaire type) , which combine with MRI images and reviewed by two radiologist with an experience more than 3 years then they fill the data sheet, after that this sheet collect by researcher and analyzed to reach for final results.

The figure 3.5 below shows the data sheet that used in the research (questionnaire type) that consist question survey the title query –classification and grading of mycetoma- such as sinuses shape, size, number, capsule.

Also grains -in-side sinuses- shape and size furthermore extension of infectious inside the body.

It also containing the appearance of invasion of disease with skin, soft tissue and bone.

Sudan University of science and technology

Faculty of graduate study

Synopses; Classification and grading of mycetoma using Magnetic Resonance Imaging (MRI).

Collecting data sheet

Patient ID: ……..

Type of exam requested: ……..

MRI protocol used: ……..

* Dot in circle appearance? ( ) appear ( ) not appear ( ) doubt

* Holes sinuses appearance? ( ) appear ( ) not appear ( ) doubt

* The size of the sinuses? ( ) small < 1 cm ( ) medium 1-2 cm ( ) large > 2 cm

* The number of the sinuses? ( ) few ( ) average ( ) multiple

* Grains shapes appearance? ( ) circle ( ) oval ( ) irregular

* Is it diagnosable as euomycetoma? ( ) yes ( ) no ( ) doubt

* Is it diagnosable as actinomycetoma? ( ) yes ( ) no ( ) doubt

* Subcutaneous reaction appearance? ( ) yes ( ) no ( ) doubt

* Sinuses tract appearance? ( ) yes ( ) no ( ) doubt

* Soft tissue reaction -soft tissue oedema- appearance? ( ) yes ( ) no ( ) doubt

* Formation abscess appearance? ( ) yes ( ) no ( ) doubt

* Periosteal reaction –bone oedema – appearance? ( ) yes ( ) no ( ) doubt

* Cortical invasion appearance? ( ) yes ( ) no ( ) doubt

* Bone cavitation appearance? ( ) yes ( ) no ( ) doubt

* Bone destruction appearance? ( ) yes ( ) no ( ) doubt

* Could you followed the Mycetoma Skin Muscle Bone System –MSMBS-? ( ) yes ( ) no ( ) doubt

* Other comment ……..
……..……

Signature……

Figure 3.5 the sample of data sheet through which the data was collected.

Chapter four

4.1 Results

This study is performed over period 2018- 2022 with data collected by direct questionnaires that received from radiologists the data have been presented in the form of number and percentage to get the frequency distribution by using statistical analysis program SPSS (Statistical Package for the Social Sciences) version 26 and by Microsoft Excel program.

age group	Frequency	Percent %
10-20 years	27	18.0
21-31 years	63	42.0
32-42years	36	24.0
54-64 years	24	16.0
Total	150	100.0

Table (4.1) Frequency distribution of age group

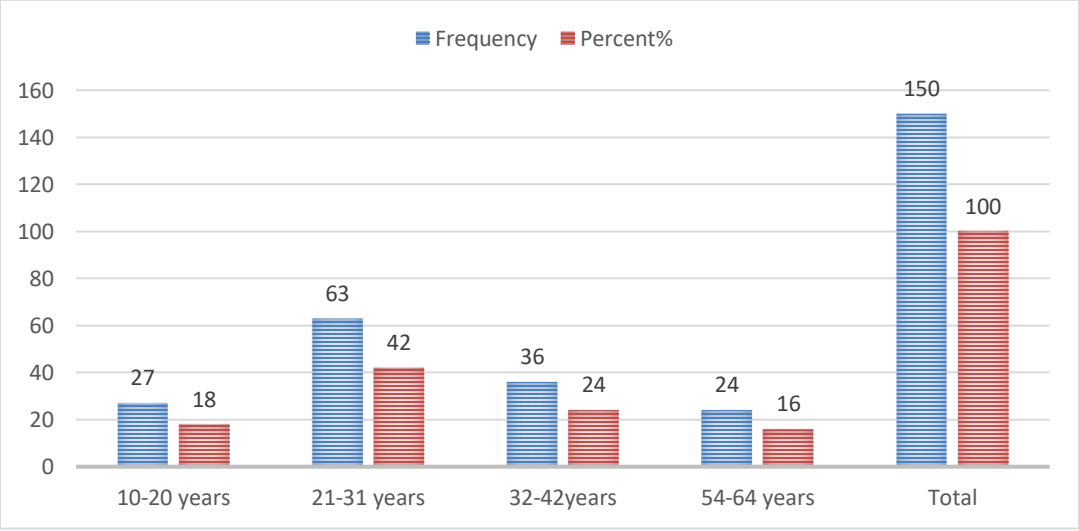


Figure (4.1) Frequency distribution of age groups.

gender	Frequency	Percent %
Male	133	88.7
Female	17	11.3
Total	150	100.0

Table (4.2) Frequency distribution of gender

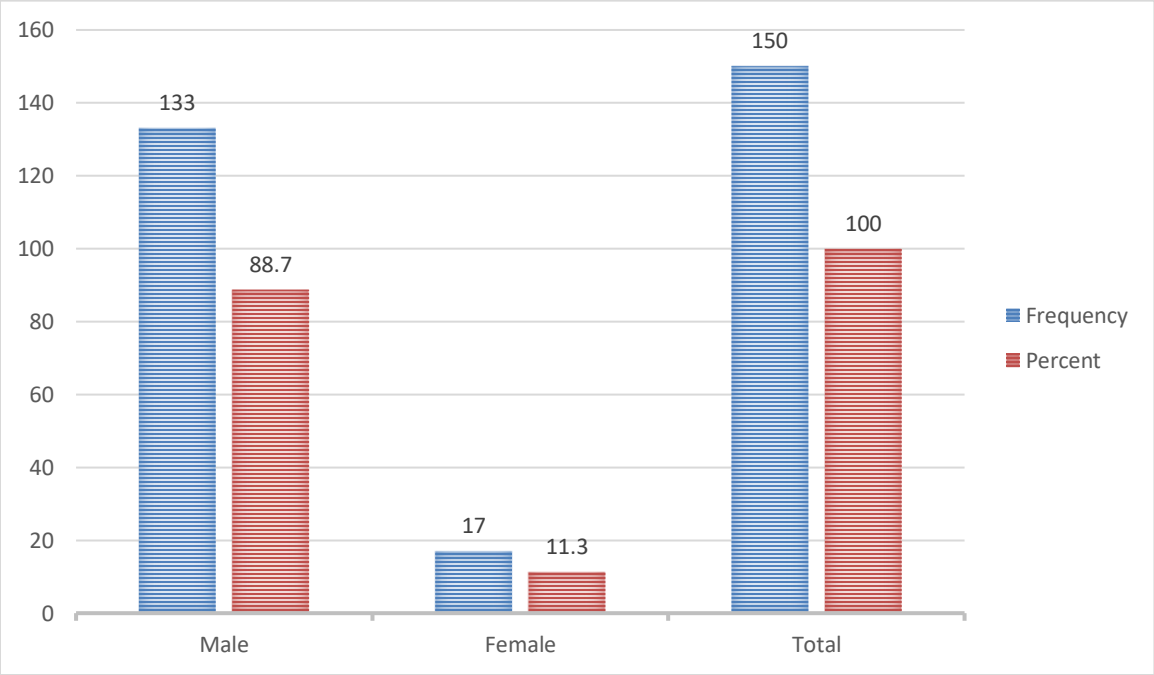


Figure (4.2) Frequency distribution of gender

Dot in circle appearance	Frequency	Percent %
good appear	209	69.7
acceptable appear	90	30.0
poor appear	1	0.3
Total	300	100.0

Table (4.3) Frequency distribution of Dot in circle appearance

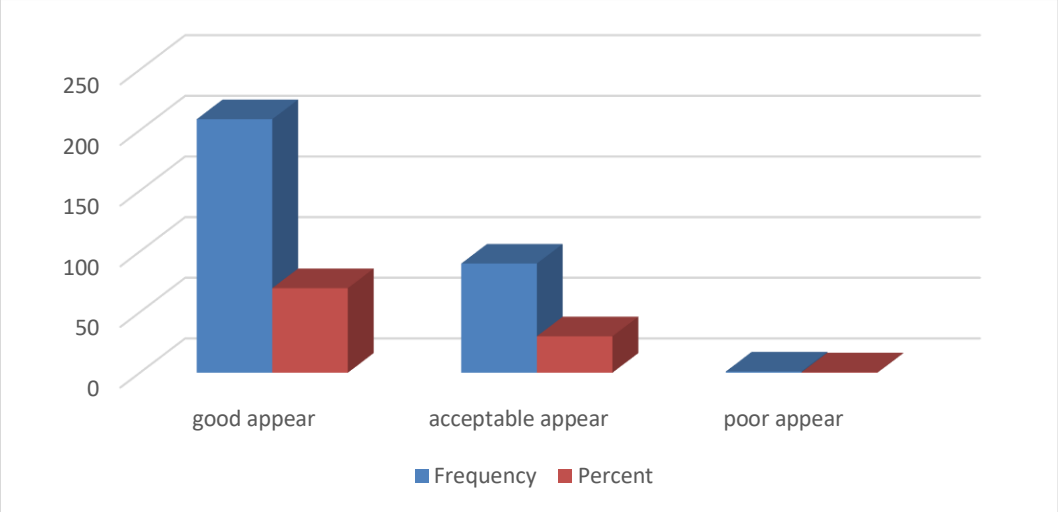


Figure (4.3) Frequency distribution of Dot in circle appearance

Holes sinuses appearance	Frequency	Percent %
good appear	92	30.7
acceptable appear	135	45.0
poor appear	73	24.3
Total	300	100.0

Table (4.4) Frequency distribution of Holes sinuses appearance

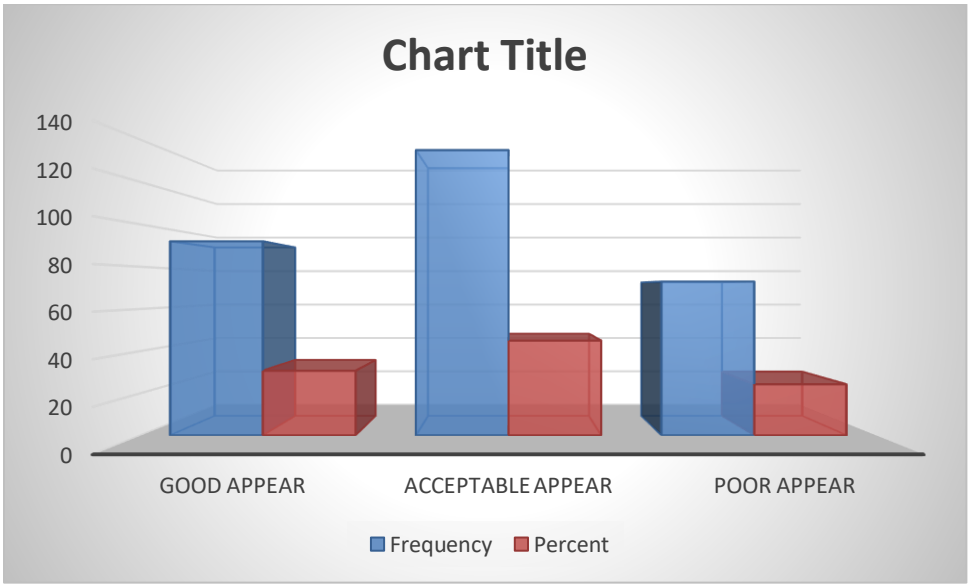


Figure (4.4) Frequency distribution of Holes sinuses appearance

The size of sinuses	Frequency	Percent %
small<1cm	30	10.0
medium1-2cm	127	42.3
large>2cm	143	47.7
Total	300	100.0

Table (4.5) Frequency distribution of the size of sinuses

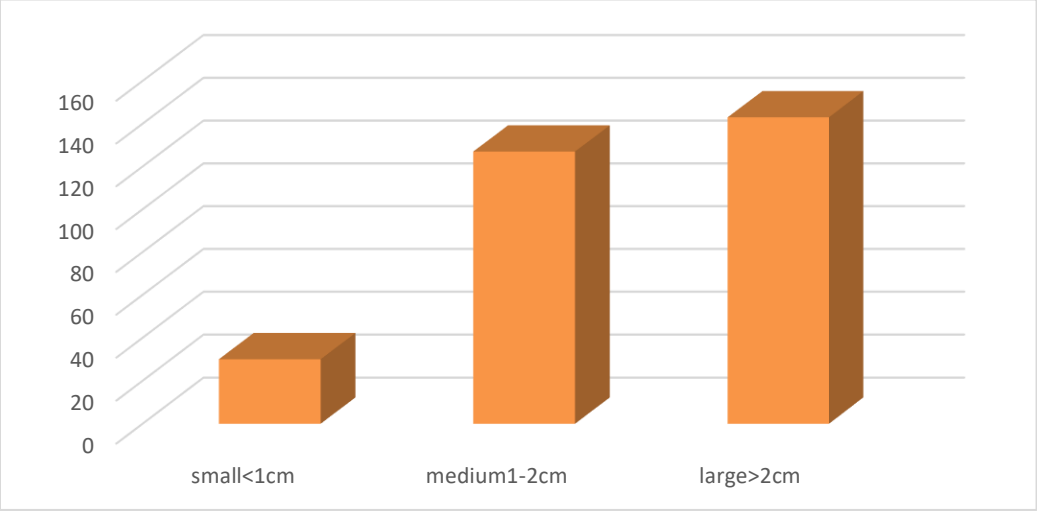


Figure (4.5) Frequency distribution of the size of sinuses

The number of sinuses	Frequency	Percent %
few	18	6.0
average	119	39.7
multiple	163	54.3
Total	300	100.0

Table (4.6) Frequency distribution of the number of sinuses

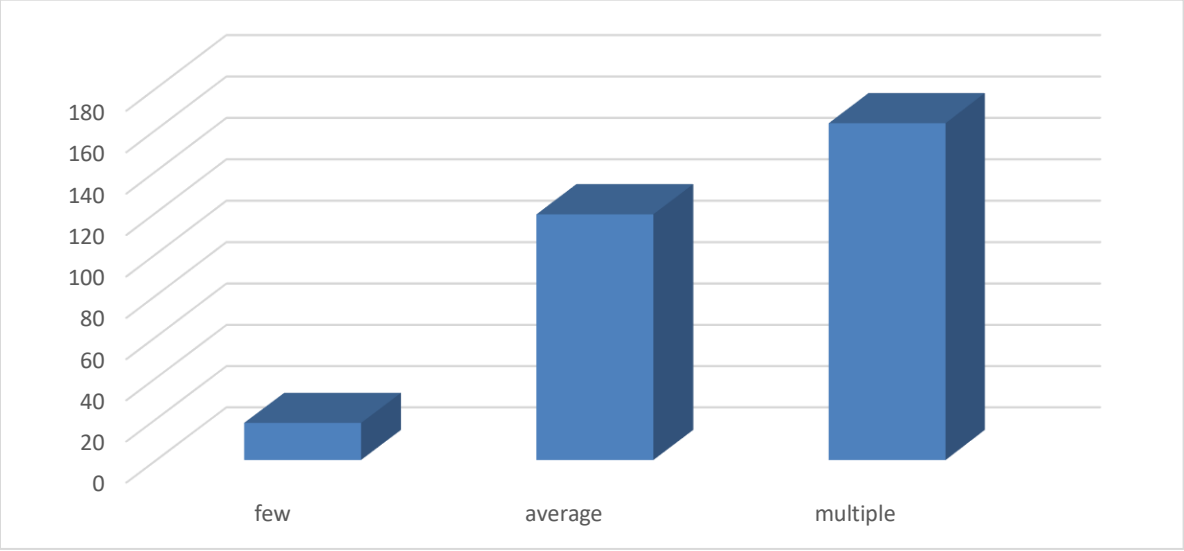


Figure (4.6) Frequency distribution of the number of sinuses

Grain shapes appearance	Frequency	Percent %
circle	12	4.0
oval	169	56.3
irregular	119	39.7
Total	300	100.0

Table (4.7) Frequency distribution of Grain shapes appearance

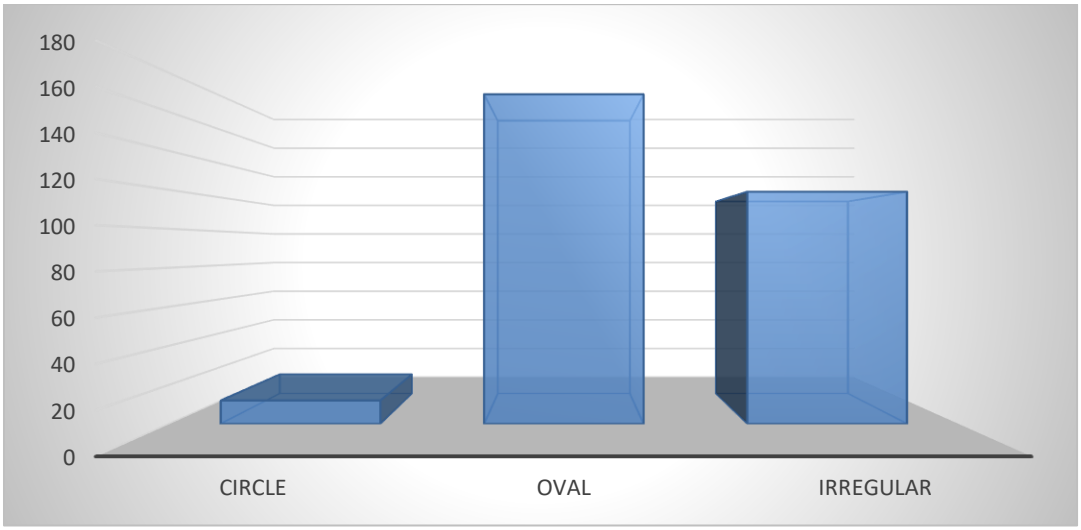


Figure (4.7) Frequency distribution of Grain shapes appearance

diagnosable of euomysetoma	Frequency	Percent %
yes	4	1.3
no	247	82.3
doubt	49	16.3
Total	300	100.0

Table (4.8) Frequency distribution of diagnosable of euomysetoma

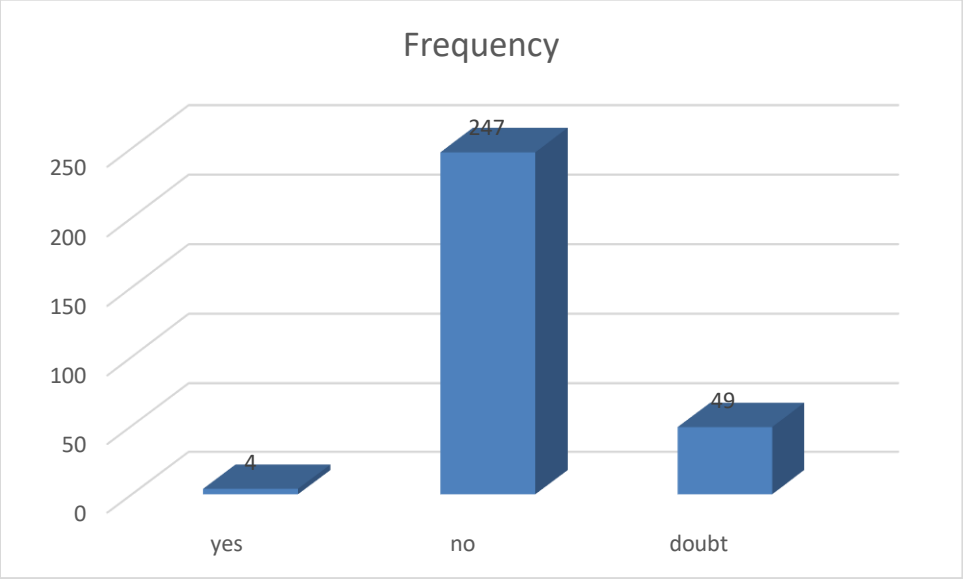


Figure (4.8) Frequency distribution of diagnosable of euomysetoma

diagnosable of actinomycetoma	Frequency	Percent %
yes	76	25.3
no	198	66.0
doubt	26	8.7
Total	300	100.0

Table (4.9) Frequency distribution of diagnosable of actinomycetoma

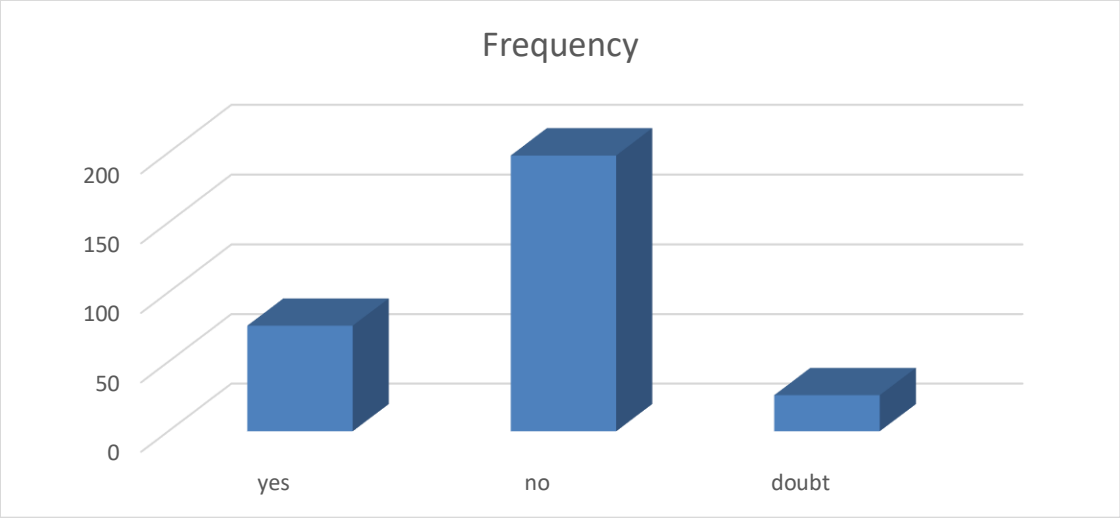


Figure (4.9) Frequency distribution of diagnosable of actinomycetoma

Subcutaneus reaction appearance	Frequency	Percent %
good appear	123	41.0
acceptable appear	174	58.0
poor appear	2	0.7
not appear	1	0.3
Total	300	100.0

Table (4.10) Frequency distribution of Subcutaneus reaction

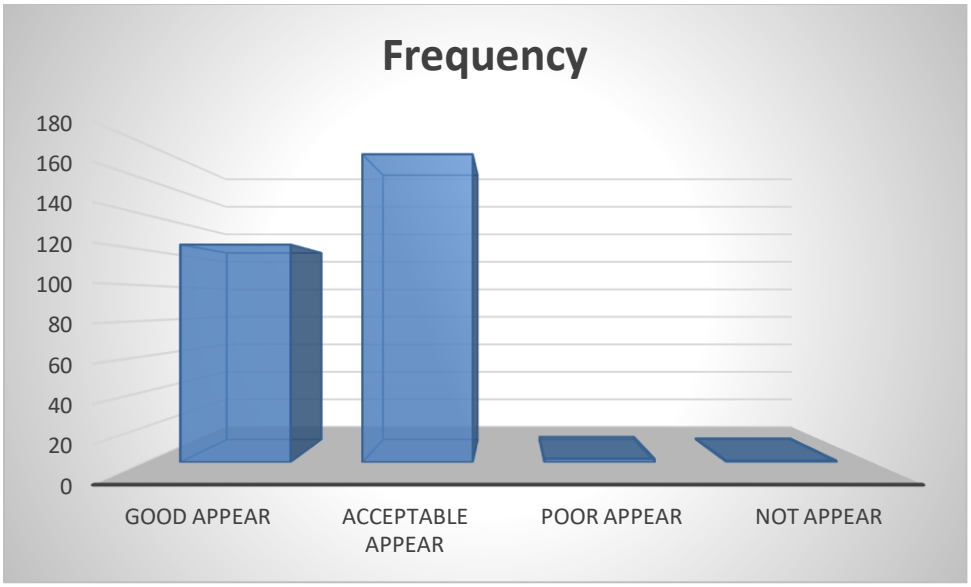


Figure (4.10) Frequency distribution of Subcutaneous reaction

Sinuses tract appearance	Frequency	Percent%
good appear	193	64.3
acceptable appear	104	34.7
poor appear	2	0.7
not appear	1	0.3
Total	300	100.0

Table (4.11) Frequency distribution of Sinuses tract appearance

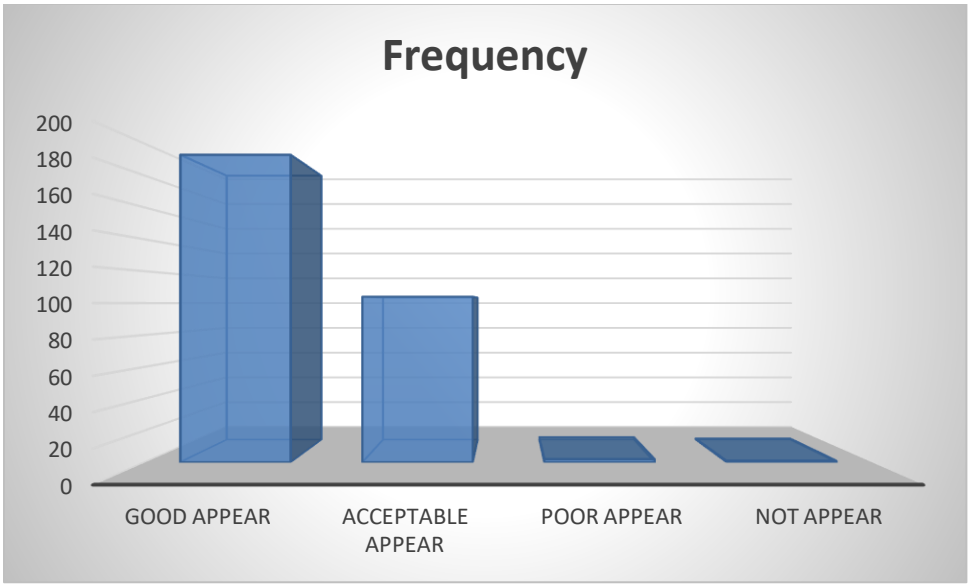


Figure (4.11) Frequency distribution of Sinuses tract appearance

Soft tissue reaction soft tissue oedema appearance	Frequency	Percent %
good appear	253	84.3
acceptable appear	43	14.3
poor appear	4	1.3
Total	300	100.0

Table (4.12) Frequency distribution of Soft tissue reaction soft tissue oedema appearance

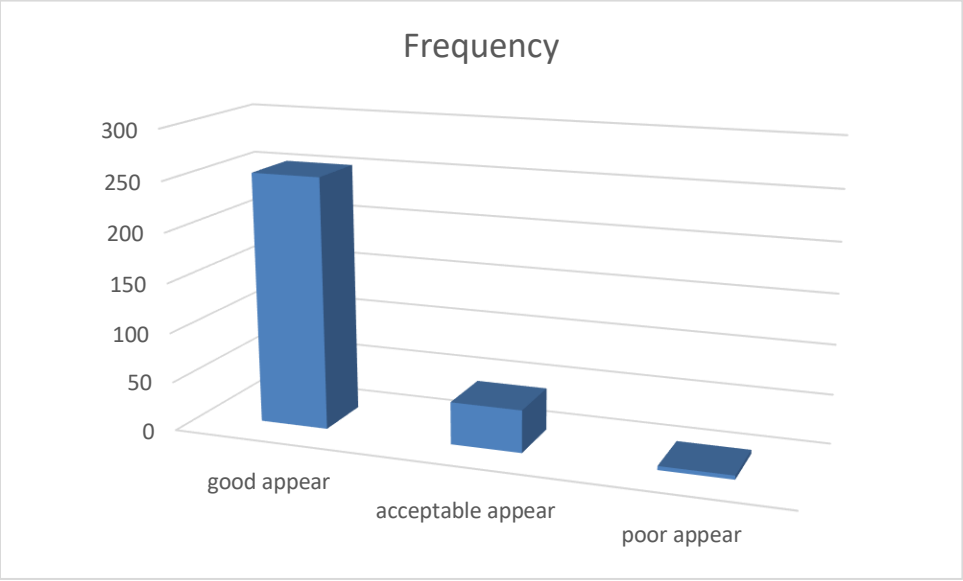


Figure (4.12) Frequency distribution of Soft tissue reaction soft tissue oedema appearance

Formation abscess appearance	Frequency	Percent %
good appear	250	83.3
acceptable appear	47	15.7
poor appear	3	1.0
Total	300	100.0

Table (4.13) Frequency distribution of Formation abscess appearance

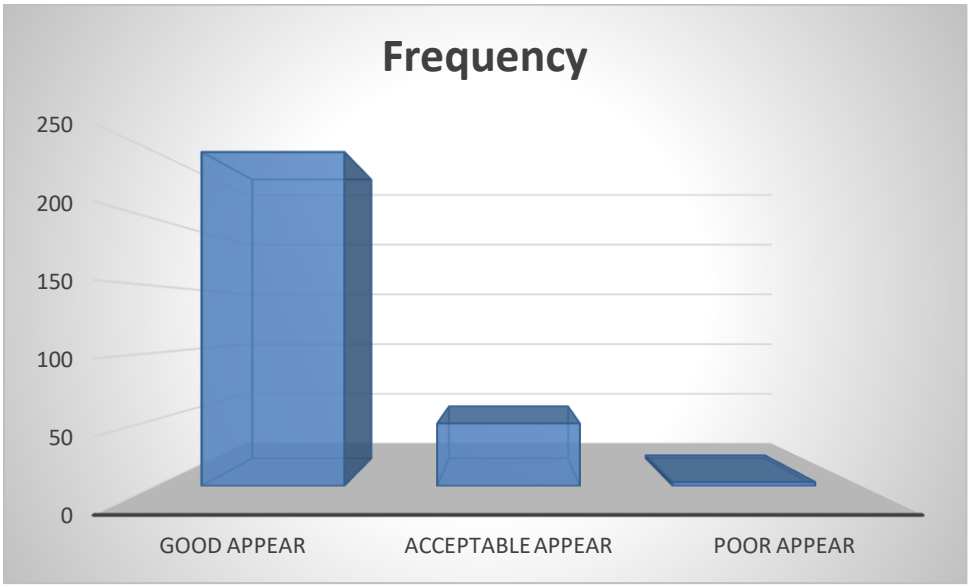


Figure (4.13) Frequency distribution of Formation abscess appearance

Periosteal reaction bone oedema appearance	Frequency	Percent %
good appear	242	80.7
acceptable appear	51	17.0
poor appear	5	1.7
not appear	2	0.7
Total	300	100.0

Table (4.14) Frequency distribution of periosteal reaction bone oedema appearance

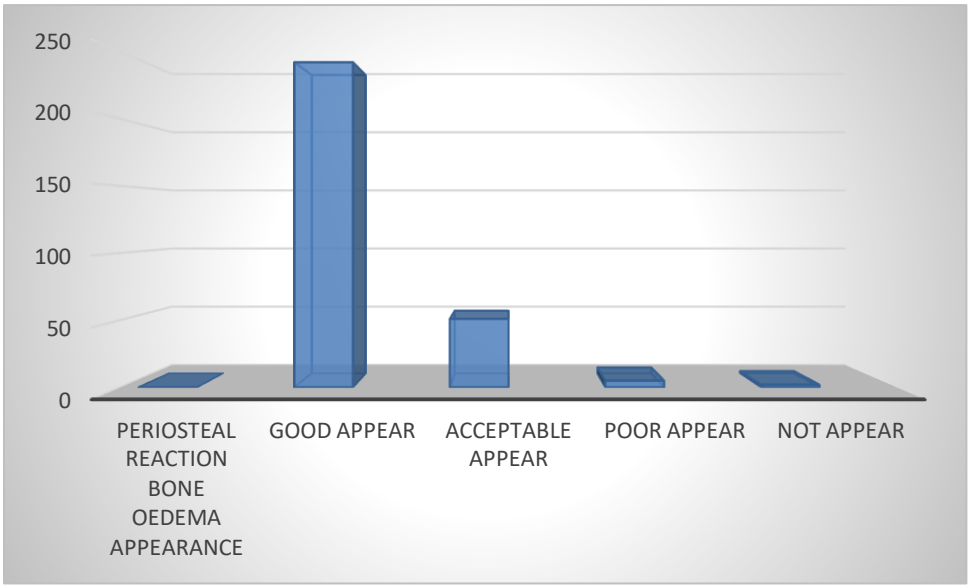


Figure (4.14) Frequency distribution of periosteal reaction bone oedema appearance

Cortical invasion appearance	Frequency	Percent %
good appear	170	56.7
acceptable appear	117	39.0
poor appear	9	3.0
not appear	4	1.3
Total	300	100.0

Table (4.15) Frequency distribution of cortical invasion appearance

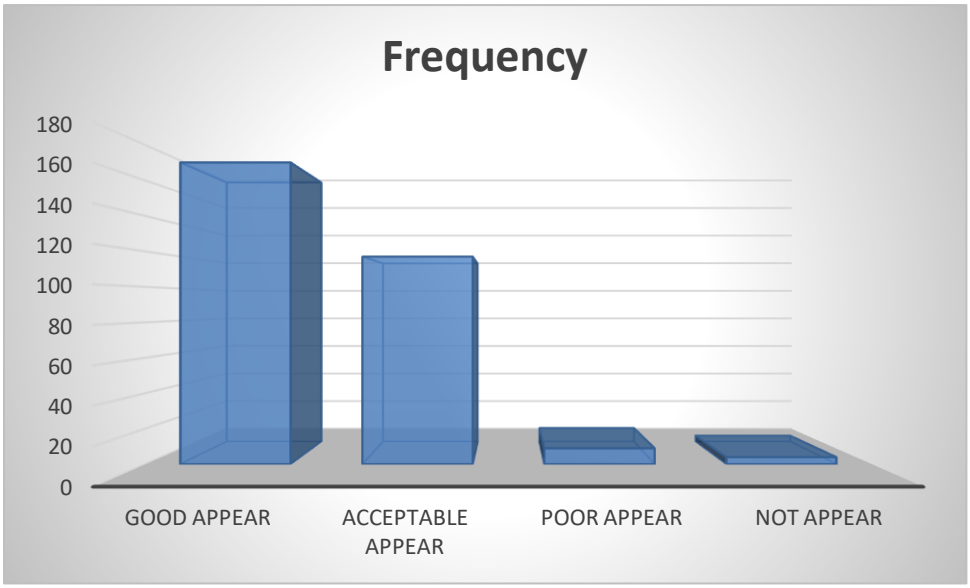


Figure (4.15) Frequency distribution of cortical invasion appearance

Bone cavitation appearance	Frequency	Percent %
good appear	151	50.3
acceptable appear	137	45.7
poor appear	8	2.7
not appear	4	1.3
Total	300	100.0

Table (4.16) Frequency distribution of Bone cavitation appearance

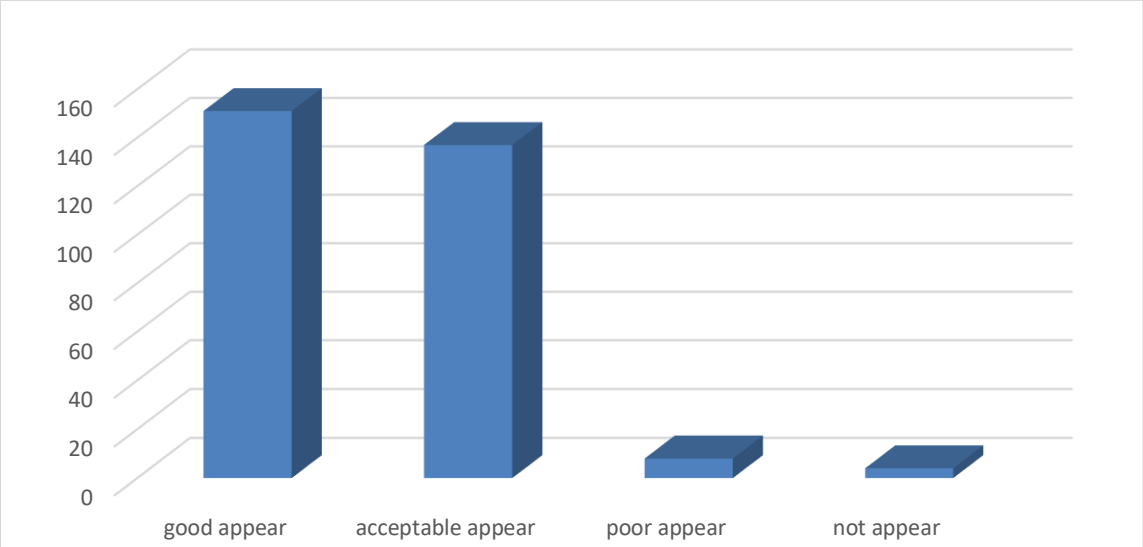


Figure (4.16) Frequency distribution of Bone cavitation appearance

Bone destruction appearance	Frequency	Percent %
good appear	227	75.7
acceptable appear	68	22.7
poor appear	3	1.0
not appear	2	0.7
Total	300	100.0

Table (4.17) Frequency distribution of Bone destruction appearance

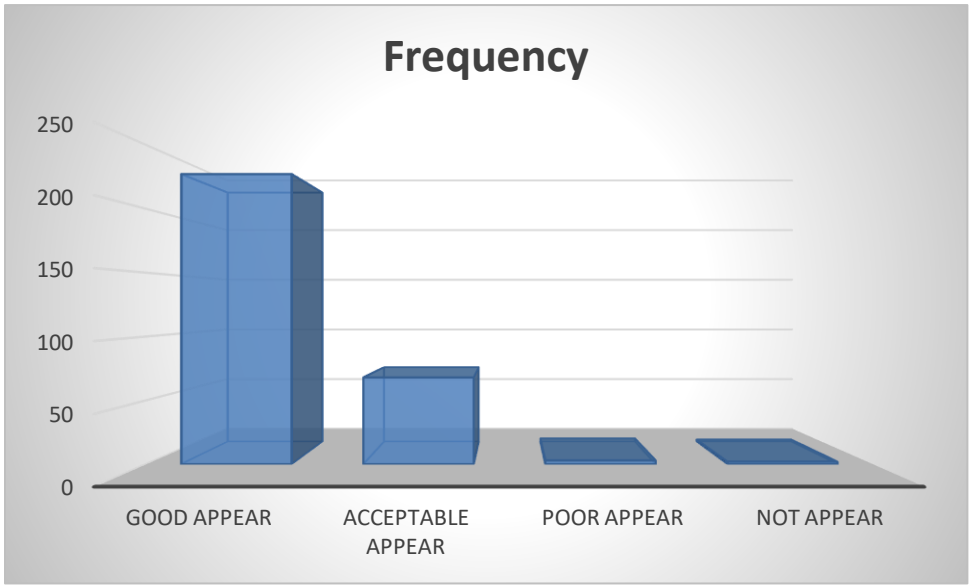


Figure (4.17) Frequency distribution of Bone destruction appearance

Could you followed the mycetoma skin muscle bone system MSMBS	Frequency	Percent
yes	300	100.0

Table (4.18) Frequency distribution of could you followed the mycetoma skin muscle bone system MSMBS

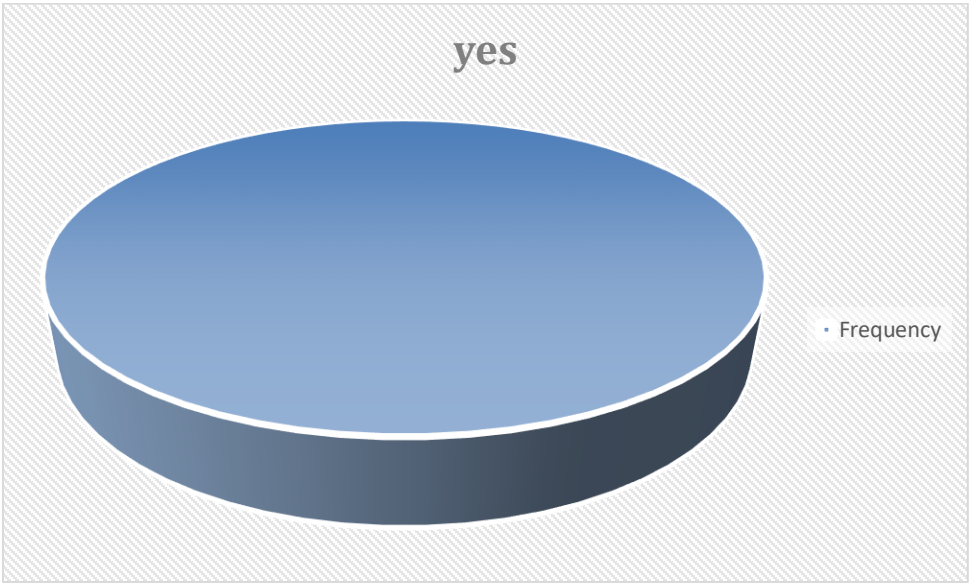


Figure (4.18) Frequency distribution of could you followed the mycetoma skin muscle bone system MSMBS

MSMBS staging	Frequency	Percent %
Stage one	0	0
Stage two	14	9.3
Stage three	136	90.7
Total	150	100.0

Table (4.19) staging mycetoma by using MSMBS (Mycetoma Skin, Muscle, Bone system)

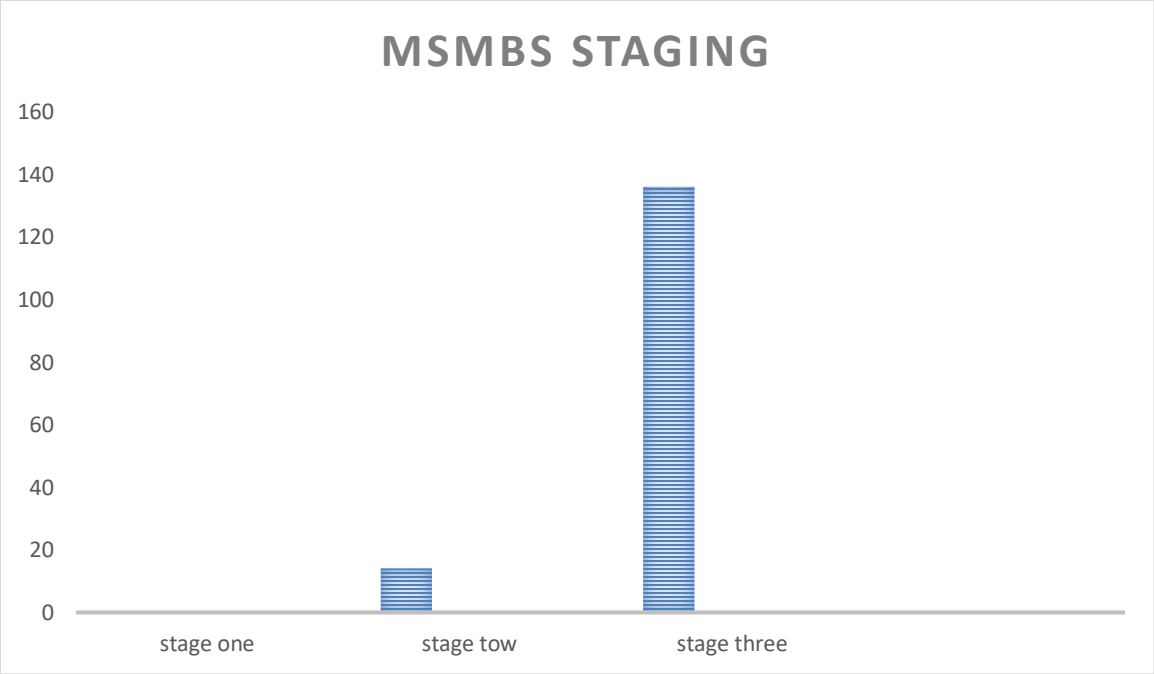


Figure (4.19) staging mycetoma by using MSMBS (Mycetoma Skin, Muscle, Bone system)

Chapter five

Discussion, conclusion and recommendations

5.1 Discussion

This study has been carried in mycetoma research center with general aim to explore the role of magnetic resonance imaging in classification and grading of mycetoma for that 150 MRI images were enrolled in this study.

The issue as shown in table 4-1 and figure 4-1 shows age distribution of the patients ranged from 10-62 years the highest frequency of age was 63 patients (42%) in age group (21-31) years, while the lowest one was 42 patients (16%) in group (54-64) years. Which is near to WHO (world health organization) receded that published in January2022 records which mentioned the prominent affect age between 15-30 years.

As shown in table 4-2 and figure 4.2 we noticed that the percentage of repetition between both genders, that the frequency of male higher than female. Male gender was 133 with percentage (88.7%) and female gender 17 (11.3%).

With ratio of 1: 7.8 this ratio is higher than mentioned by (Fahal et. al 2018) which mention the ratio 1: 3.7.

The dot in circle appearance was appear in all samples as shown in table 4.3 and figure 4.3 with high percentage of good appearance which represented 209 or 69.7% cases and lowest frequency was presented 1 or 0.3 % case this observed in poor appearance cases.

Regarding holes in sinuses appearance in the study performed it was shown that the highest frequency is acceptable appear 135 case or 45% and the lowest frequency is poor appear 73 case which act as 24.3% and the good appearance is 92 cases which is 30% as we noticed from table 4.4 and figure 4.4.

Table 4.5 and figure 4.5 demonstrated that the size of sinuses appearance reparation as the following records which the highest frequency is large size of sinuses >2cm or 143 case which representing of 47.7% and the medium sinuses 1-2 cm appear in 127 case

with percentage of 42.3% and the small sinuses which is less than 1cm shows the smallest repetition 30 case which percentage 10.0 % from sample.

The sinuses is divided to three level rendering to their numbers as shown in table 4.6 and figure 4.6 , the higher frequency was multiple size which is 163 case or 54.3% and the sinuses in average rang size shown in119 sample with percentage of 39.7 % and the lowest frequency was few which appear in 18 cases with percentage of 6.0%.

The shapes of grain inside sinus is alienated to (circle- oval- irregular) and the oval shape represented highest frequency 196 cases or 56.3 % followed by irregular shape 119 cases or 39.7% and the lowest shape that is circle shape 12 cases or act as 4% from the sample size.as displayed in table 4.7 and figure 4.7 .

The diagnosable of euo-mycetoma according the manifestation of the image appearance is located under (yes sure – doubt about it – no can`t) and its repetition showed in table 4.8 and figure 4.8 there are 247 samples or 82.3 %, and 49 samples or 16.3% doubt about it and four case or 1.3% sure to identify as euo-mycetoma.

The diagnosable of actino-mycetoma according the manifestation of the image appearance is located under (yes sure – doubt about it – no can`t) and its repetition showed in table 4.9 and figure 4.9 there are 198 samples or 66 %, and 76 samples or approximately 25.3% sure to identify as actino-mycetom, lastly 26 samples or 8.7 % doubt about it .

Table 4.10 and figure 4.10 shows the frequency of subcutaneus reaction with mycetoma the acceptable appear repeated in174 samplesor 58% and followed by good appear are 123 samples or 41 % and poor appearance repeat in two case or 0.7% and not appearance 1case or 0.3 % consecutively.

In the study performed, as in table 4.11 and figure 4.11 it was shown that sinuses tract appearance good appearance 193 samples or 64.3% and followed by acceptable appearance are 104 samples or 34.7% and poor appearance I two samples or 0.7% and not appearance repeated in one case or 0.3% cases consecutively.

Regarding the soft reaction of the body with disease and reparation of the sign in the MRI images the table 4.12 and figure 4.12 concern with it and shows Soft tissue oedema appearance are good appearance in 253 case or 84.3 % and followed by acceptable appearance are in 43 case or 14.3% and poor appearance repeat in 4 case or 1.3 % cases consecutively.

Table 4.13 and figure 4.13 shows the formation abscess appearance are good appearance in 250 cases or 83.3 % and followed by acceptable appearance are 47 cases or 15.7% and poor appearance 3 or 1. % case.

In the study performed, it was shown that the periosteal reaction -bone oedema-were good appear 242 cases or 80.7 % and acceptable appear are repeated in 51 cases or 17% ,poor appearance 5 cases or 1.7% and not appearance in two cases or 0.7 % cases, as shown in table 4.14 and figure 4.14.

The cortical bone invasion by disease appearance in MRI images is descriptive in table 4.15 and table 4.15 which shows good appearance repeat in 170 cases or 56.7 % and followed by acceptable appear with in 117 cases or 39% ,the poor appearance shown in 9 cases or 3 % and not appearance in 4 cases or 1.3 % from the sample size.

The study found that the bone cavitation appearance in MRI images repetition is focused by table 4.16 and 4.16 which demonstrated that frequency of good appearance in 151 cases or 50.3 % and followed by acceptable appear are in 137 cases or 45.7% ,the poor appearance in 9 cases or 1.3% and not appearance were in 4 cases or 1.3 % .

The last stage of mycetoma disease progression was bone destruction and its repetition demonstrated in the table 4.17 and figure 4.17 which verified that

Good appearance of bone destruction was in 227 case or 75.7 % and acceptable appear of bone destruction were in 68 cases or 22.7%, the poor appearance of bone destruction were in 3 case or1% and not appear in two cases or 0.7% from the samples.

The new grading system MSMBS (Mycetoma, skin, muscle and bone system)

Could be followed by radiologist on all the samples as shown in table 4-18 and figure 4-18 and they satisfy from it.

As shown in table 4-19 and figure 4.19 by applying the MSMBS (Mycetoma skin, Muscle, Bone grading system) to the samples and according the manifestation of first stage and giving score for the following signs (subcutaneous involvement, obliteration of skin, abscess formation, formation of sinus tract without grains, formation of sinus tract with grains) we noticed that all the samples is beyond the score of first stage of mycetoma.

By applying the MSMBS (Mycetoma skin, Muscle, Bone grading system) to the samples and according the manifestation of second stage and giving score for the following signs (muscle odema, formation of micro abscess, formation of macro abscess) we noticed that there was 14 samples on the range of second stage and the rest was beyond the score of second stage of mycetoma.

By applying the MSMBS (Mycetoma skin, Muscle, Bone grading system) to the samples and according the manifestation of second stage and giving score for the following signs (bone oedema, bone cavitation, bone destruction) we noticed that there was 136 samples on the range of third stage.

5.2 Conclusion

This study deal with classification and grading of mycetoma to find the role Magnetic Resonance Imaging in management of mycetoma disease.

After analysis and interpretation of the data collected the main finding of this study was summarized as:

* Magnetic Resonance Imaging is consider as excellent non-invasive method to determine the stages of progress mycetoma disease inside the patient`s body.

* In the study performed the dot -in -circle appearance repeat in all the samples that lead us to consider this manifestation as inherent sign for mycetoma.

* The highest gender affected by mysetoma was male because the greater risk of exposure to micro-organisms in the soil during activity mostly farmer,and social concepts.

* The highest ages affected by disease was laying in the range between 21-31 years.

* The Magnetic Resonance Imaging was not considered as defiantly method to demonstrate the etiology (euo-mycetoma, actino-mycetoma) of the disese.

* Most cases arrival to mycetoma research center in late stages after reach the level of bone destruction.

Limitation of the research is listed below

The researcher was note free from work load.

There were collecting images sometimes during the thesis time.

Un –cooperation of some worker in Mycetoma research center.

Shortage of facilities available for the research writing and shortage of financially resources.

Global pandemic of coronavirus (COVID -19).

Unstable situations in Sudan lead the thesis took long time to finish.

5.3 Recommendations

By the end of this thesis the researcher approach the following recommendations to improve the role of usage of MRI in diagnosing mycetoma in Sudan

Establishment of periodic work-shops, lectures and seminar in which the method in developing the field.

Invited the radiological colleges and K.M.C co-operating together to establish intensive course for radiological imaging role in mycetoma and impacted in their curriculum.

Comprehensive studies should be carried out to resolve the issue of whether it possible to classification of mycetoma using MRI.

The researcher recommended future comprehensive studies between radiological tools in diagnosing and grading of mycetoma.

Future comparative studies between MRI protocols and its role in diagnosing and management of mycetoma.

Future studies with specific protocol purpose to reach the optimum measurement of MRI slice thickness.

Trained MRI staff of factors and protocols for management and treat of mycetoma.

Finally the researcher hope that these recommendation are considered and this study is useful for all person who working or responsible in the field of radiology.

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