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**RESEARCH ARTICLE**

# Using advanced MRI to Visualize Specific Parts within the Amygdala

Munqith Mazin Mghamis[1*], Maher Finjan Taher[2], Lafta Fayez Kadhim[3]

[1,2]Department of Human Anatomy, University of Kufa, Kufa Iraq
[3]Department of Pharmacy, Al-Zahrawi University College, Karbala, Iraq

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***Corresponding Author:**

munqithm.almahmood@uokufa.edu.iq

**ABSTRACT**

The amygdala was imaged for a group of 12 samples from male and female individuals who did not suffer from any psychological or behavioral disorders using an advanced (Philips Achieva) 3.0 Tesla magnetic resonance imaging device at Al Zahraa Medical Center for resonance imaging. After scanning each sample for 15 minutes, the brain area was scanned. The amygdala was diagnosed accurately. The images showed dark, gray areas and light areas. Certain parts of the amygdala were identified, and it appeared that it was divided into seven regions, the clearest of these regions being the BLA, in addition to the amygdala nuclei, which were less clear than the BLA, which is a basal and cortical accessory. CAT As well as the transitional region specifically for the amygdala cortex, in addition to the anterior amygdala region, which appeared somewhat less clear, as well as (PL), which is the paralaminar nucleus, and also (OT), the optic nerve. The images were corrected for signal fluctuations specifically with a written code and then corrected for movement. The time series graphs were also done using spm8, then the image was divided between gray matter and white matter, as well as cerebrospinal fluid (CSF), and the images were displayed using the program (Sante DICOM Viewer Lite) on the personal computer. It was also found that the size of the amygdala in males is somewhat larger than in females. There were no significant differences in the size of the amygdala between the ages of 30 to 60 years. This study did not address psychological and behavioral disorders and their relationship to the size and activity of the amygdala, but was limited to identifying specific areas within the amygdala during the rest period.

## INTRODUCTION

In most mammals, the amygdala plays important roles in emotional processing such as fear, motivation, and attention, as well as learning and memory. The amygdala, specifically, is a group of nuclei and cell types that are well preserved in the brains of mammalian species, such as mice, monkeys, and humans. The amygdala consists primarily of the basolateral amygdala, which is called the BLA (basolateral, basal, and accessory nuclei). In addition to the central and medial nuclei and the cortex, they are all called the amygdala. Among these nuclei, the BLA is thought to be integral in processing and learning emotional memories (Klune et al., 2021). Functional magnetic resonance imaging (fMRI) is a well-established and widely used method for studying neural activation within the brain. There has been a growing understanding in the field of neuropsychology over the last decade that the amygdala has an important role in most mental health conditions. As is known, the functional connectivity (FC) of the amygdala with other parts of the brain is well documented in most studies; However, the role of the amygdala and its connections to behaviors are still not well understood, and this may be partly due to its very small size compared to the size of the brain. It is difficult to achieve sufficient spatial resolution to visualize amygdala activity using the 3T MRI systems widely used for this type of clinical research. Improving modern techniques and methods to improve data accuracy and reproducibility may lead to standardization and real progress in overall image quality in this field (Jam et al., 2014; Sheryl et al., 2022).

The amygdala, or amygdala complex, which includes the basal nucleus (BLA), contributes fundamentally to the brain's emotional, cognitive, and perceptual functions. However, defining structural plasticity of the amygdala in both normal and neurological contexts using imaging has been hampered by the difficulty of well defining the boundaries of the BLA. . This challenge is the result of poor contrast between the BLA and the surrounding gray matter, as well as other amygdala nuclei. Here, we describe a new approach to diffusion tensor imaging (DTI) to enhance their contrast, allowing correct identification of the BLA in the rodent brain from magnetic resonance (MR) images. This slide conversion approach has been used to accurately measure BLA volumes. (Andre et al., 2023).

Recently, many advanced imaging markers have appeared as important tools in visualizing the neuroanatomical and functional processes in the brain and the amygdala, specifically the advancement of magnetic resonance imaging to detect neuropathological features of negative neurological changes (PD) that affect the basic structure of the brain. Specifically, MRI can be used to detect the results of some diseases such as Parkinson's disease, distinguish Parkinson's disease from other Parkinson's syndromes, and monitor the progression of some diseases. There are currently quantitative methods by which biochemical changes in the brain, including iron deposits or reduction of local neuromelanin (NM) and microstructural integrity, can be estimated and these diagnoses can be derived through repeated imaging (Ghadery and Strafella 2018; Kanval et al., 2024).

In this study, we will perform advanced MRI imaging of the amygdala to identify specific parts within the amygdala for more than one sample. And the study of images and their relationship to the psychological state and emotional actions.

**Research aims**

1- Advanced magnetic resonance imaging of the amygdala.
2- Identifying specific parts within the amygdala through magnetic resonance imaging
3- Trying to identify the subnuclei in the amygdala

## LITERATURE REVIE

### What is the amygdala?

The amygdala is located inside the right and left temples of the brain, near the center of the brain. The size of the amygdala does not exceed a few cubic centimeters, and although the two halves of the amygdala work together, one side functionally dominates the other, and the amygdala forms part From the limbic system, the amygdala is located directly opposite the hippocampus, and information is transferred between the amygdala to the hippocampus, which in turn transmits it to other parts of the brain such as the cerebral cortex, the hypothalamus, which secretes hormones, and the thalamus, which By transmitting sensory and motor signals to the cerebral cortex, the amygdala is a complex structure of cells located in the middle of the brain, next to the hippocampus (which is associated with memory formation). It is part of the cerebellar system and plays a key role in processing feelings and emotional reactions. (Olivia, 2023).

**Components of the amygdala**

The amygdala consists of a lateral nucleus, a basal nucleus, a central nucleus, intercalated cells, and a medial nucleus, (Kronel et al., 2015). In a study (Andre et al., 2023), the results were validated by direct comparison of both traditional techniques based on histological and cellular identification (Parvalbumin) to determine BLA in the same brain samples used in MRI. Research has confirmed BLA connectivity targets using specifically DTI-based imaging. The new approach allows accurate and reliable identification of BLA. Since this nucleus is responsible for and changes through developmental, degenerative and adaptive processes. Most studies have confirmed the association of negative affect and persistent activity in the amygdala, which is a brain region known for processing subjective emotional experiences. The fMRI experiments involved showing participants images of positive or negative facial expressions, mixed with these images of neutral facial expressions. It has been found that neural activity continues in the amygdala in response to negative images for a longer period than to positive images or positive expressions. Studies have confirmed the existence of a relationship between continuous activation of the left amygdala in response to negative images and more frequent negative emotions, and it has basically been shown that those people who have continuous activity in left amygdala after negative stimuli were more likely to have a negative emotional outlook in general. (Sethi et al., 2018).

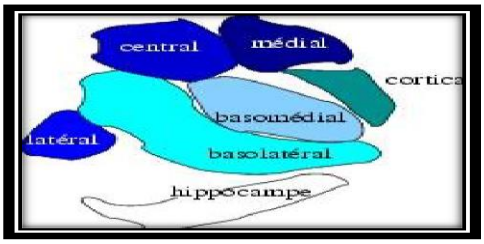


**Figure (1) Anatomy of the amygdala, (Sethi et al., 2018).**

Using this knowledge, researchers can create a picture of both brain structure and function. Using special computer programs. One of the most amazing things is that an MRI camera can take pictures of your brain while it is active without even touching you, but there are some challenges facing people who participate in research studies using MRI.

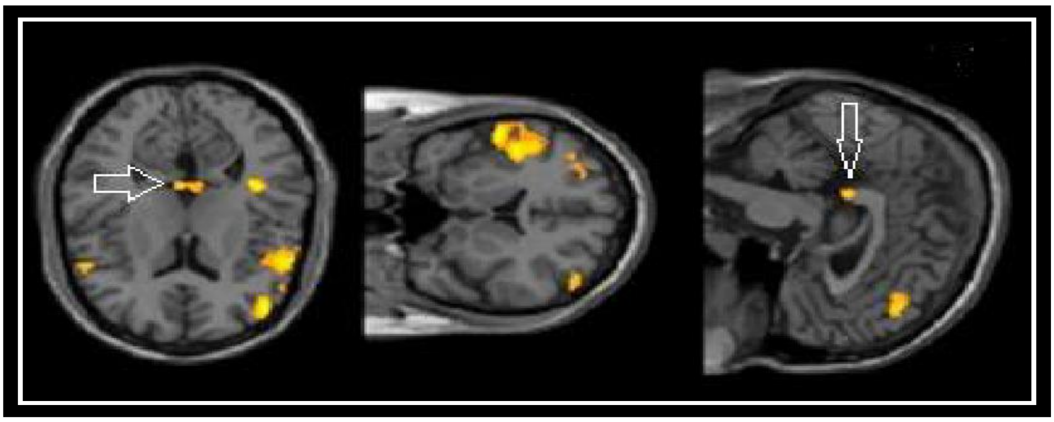

**Figure (2) Different views of a child's brain as captured by an MRI camera. The areas**

**colored in yellow are important for processing and regulating emotions (Raschle et al., 2015).**

## Functions of the amygdala

The functions of the amygdala are specifically the perception of emotions and producing behaviors in response to fear and emotional memory, recognition of emotions, pleasure responses, and gender differences (Kronel et al., 2015). It is possible to stimulate the amygdala when facing a potential threat. The amygdala will send information to other parts. From the brain to prepare the body to either confront the situation or move away from it. This fight or flight response is caused by feelings of fear, anxiety, aggression, and anger. It is helpful for the amygdala to function properly in order to react appropriately in threatening or stressful situations. However, sometimes the amygdala can overwork, causing the amygdala to fail to respond properly. This usually occurs in stressful situations. The frontal lobe steps in to override the amygdala to ensure we respond rationally. However, if a stressful situation causes, strong feelings of anxiety, anger, aggression or fear, it may lead to excessive, often illogical and irrational behaviour. (Tang et al. 2020).

In a study (Felix and Tye, 2014), it was found that social behavior is linked to the activity and size of the amygdala, as the basal part of the amygdala, which sends signals to the hippocampus, showed that it is able to specifically modify social behaviors in a bidirectional manner. It was also found that the size of the amygdala is positively related. With the number of social contacts and the number of social groups a person originally belongs to, the more friends and friend groups someone has, the larger their amygdala.

In the field of mental health disorders, a variety of research has shown that the amygdala, especially on the left side, is associated with mental health conditions such as social anxiety, for example, or obsessive-compulsive disorder (OCD), generalized anxiety disorder as well, and post-traumatic stress disorder, (Arehart, 2014), as people with a severe case of social phobia also show significant associations with increased amygdala responsiveness as well. Those who have more neural pathways from the amygdala to the prefrontal cortex are more likely to feel nervous and anxious because these pathways allow the frontal cortex with an increase in threat alerts from the amygdala, (Kronel et al., 2015). In a study, it was shown that individuals diagnosed with depression have hyperactivity in the left amygdala specifically, especially when interpreting emotions from people's faces, especially frightening shapes of faces, and post-traumatic stress disorder. It was found that the functional connection between the amygdala and the prefrontal cortex It has changed in those suffering from Internet addiction, and it was concluded that this type of addiction may be associated with emotional disorders and emotion processing, (Le, 2020).

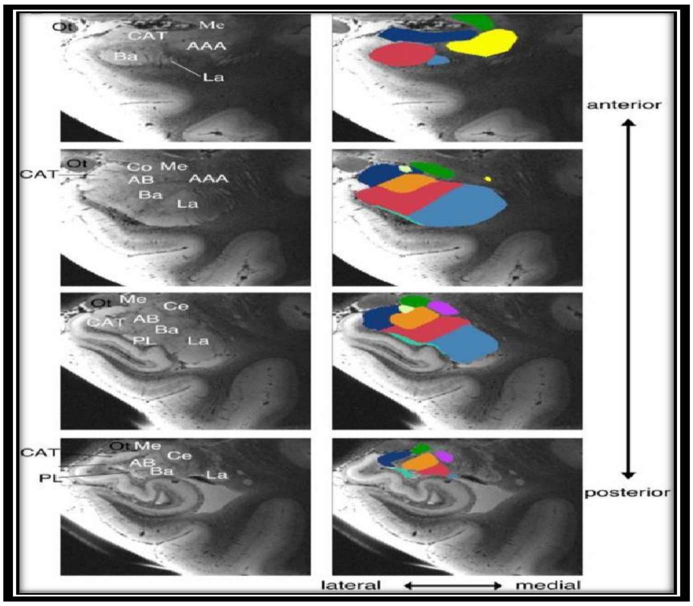

**Figure 3: Imaging the amygdala with a high-performance MR**

Figure (3) shows coronal images taken by ex vivo MRI, roughly showing the boundaries of nine nuclei of the amygdala and clearly visible in the left column. The labels of the resulting nuclei are shown in the right column. The slices extend from the anterior to the posterior amygdala (from the upper to the lower panels in particular). No: lateral; Ba: basal., AB: basal accessory, C: center, I: medial, Co: cortical. CAT: amygdala cortical transition zone. AAA: anterior amygdala area, . PL: paralaminar nucleus, Ot: optic nerve (as landmark) (Saygin et al., 2017).

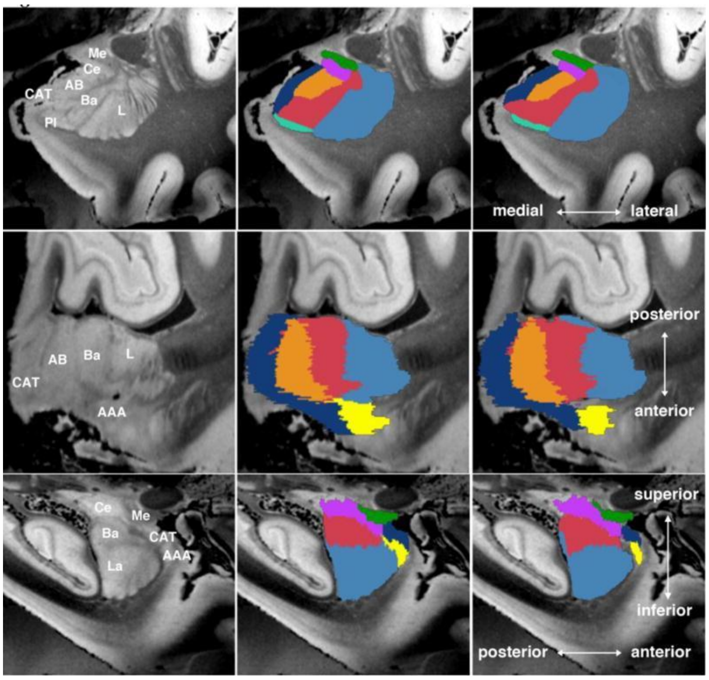


Figure (4) MRI contrast without any labels (left column) and with the manually labeled nuclei it produces identified (middle and right columns). The location and spatial extent of the nucleus were similar between the two independent raters. The nomenclature was also based mainly on the boundaries visible on the coronal slices, but the other two directions (axial and sagittal) are specific for verifying the boundaries of nuclei that have been elongated in those directions such as Co, Cat, Ce, and Me nuclei. (Saygin et al., 2017).

**MATERIALS AND WORKING METHODS**

The data acquisition process was performed using a 3.0 Tesla scanner (Philips Achieva). The examinations were taken using the advanced magnetic resonance imaging device at Al Zahraa Medical Center using a Philips device that features specteocopy testing and examination as well as fiber tioctogrophy examination.

**Figure (5) 3.0 Tesla MRI machine (Philips Achieva).**

The samples were taken from people who did not suffer from any psychological disorders. The total number of samples was 12 samples. 6 males and 6 females were taken randomly.

Their ages ranged from 30 to 60 years. Most of the samples were taken from people suffering from headaches in the head and high blood pressure. All participants underwent an fMRI examination in case of Rest inside the device chamber for approximately 15 minutes, and were asked to fixate their gaze at a specific point inside the device. Whole-brain functional images were collected from 3 mm thick slices using a sensitive gradient inverse helical acquisition sequence (repetition time was 2000 ms, echo time was 30 ms). Seconds) and the field of view is 220 mm and the face angle is 90 degrees. Therefore, to reduce the effects of sensitivity or signal loss in the medial temporal lobe, including the amygdala (according to Stenger et al., 2000), the first four parameters were excluded, and the images were corrected for signal fluctuations with a written code and then corrected for movement. Time series graphs using SPM8, then the image is divided between gray matter, white matter, and cerebrospinal fluid (CSF), and the white matter and CSF regions are identified according to the device's algorithms. After that, the timing was explained across a range of frequencies ranging between 0.01 and 0.10 Hz. (Walter et al., 2003). Then, the connectivity of the left and right parts of the amygdala was determined at rest using an anatomical amygdala mask. After collecting the images, the areas of the amygdala were identified using the computer using the program (Sante DICOM Viewer Lite), and the program's tools were used to illustrate specific areas of the amygdala during rest for the male and female samples under study.

## RESULTS

### Picture of some samples, side view, angle 90:

One of the samples, a 45-year-old male, shows the amygdala in profile, and the arrows show the areas of the amygdala.


**Figure 6. Amygdala, side view of a male.**

**Figure 7. Amygdala, side view of a female.**

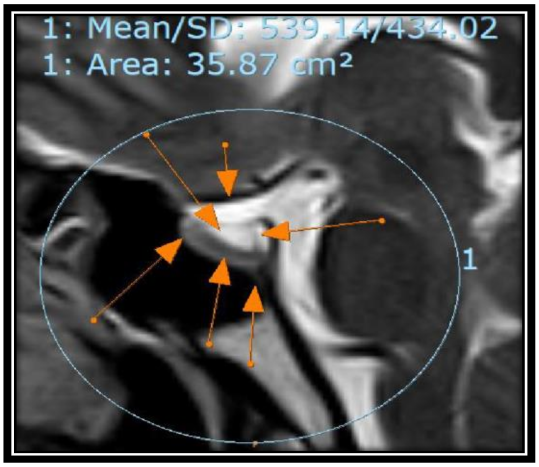


**Figure (8): Enlarged side view of the amygdala**

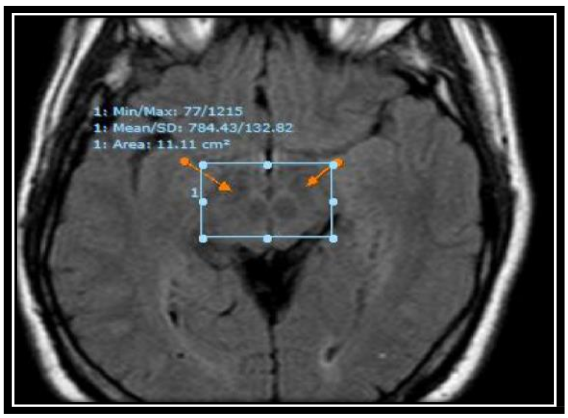


**Figure (9): A superficial view of the brain showing the location of the amygdala**

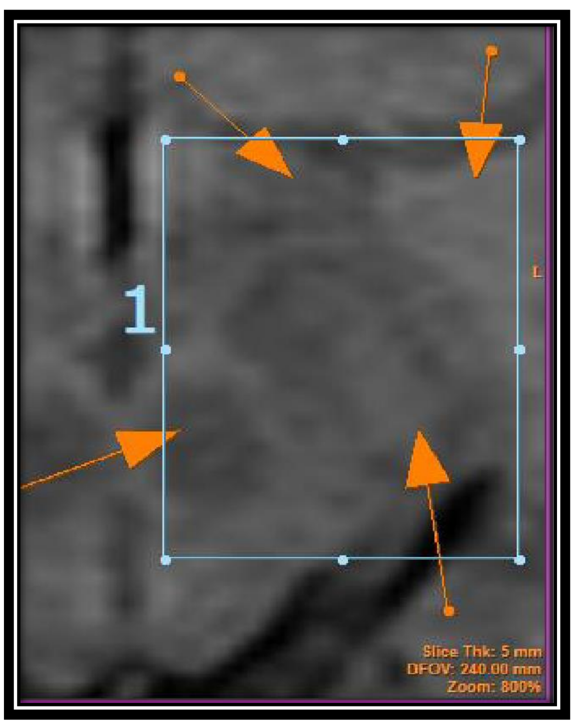

**Figure (10) is an enlarged area of the amygdala, showing the dark and light areas and the amygdala nuclei.**

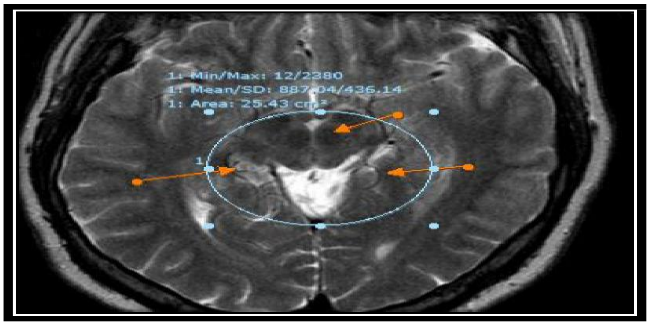


**Figure (11) A sample image of a surface view of the amygdala and some parts of the brain surrounding it.**

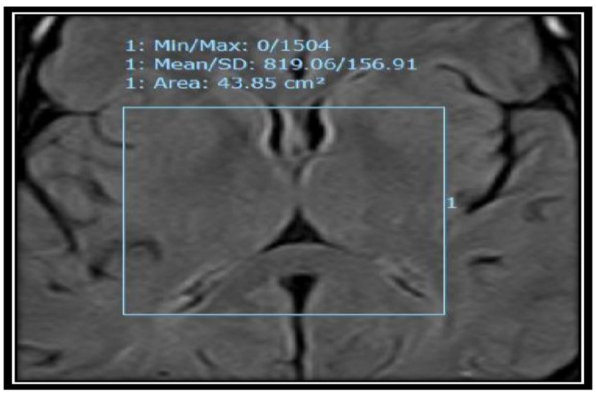


**Figure (12) of separate close-up samples showing the amygdala at rest:**

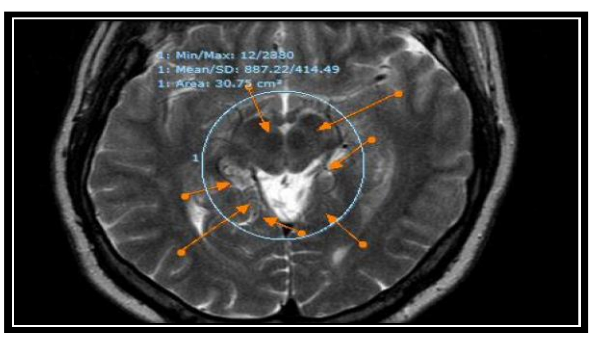


**Figure (13) of the amygdala, some parts of the posterior lobe, and other areas surrounding the amygdala**

## DISCUSSION

It is clear from the pictures (6, 7, 8) that the amygdala is almond-shaped and located in the temporal lobe, as is known, and is located directly below the uncus. This study showed that the amygdala is diverse and complex in structure and includes about 13 nuclei or neural regions. It is also divided into internal and somewhat extensive nuclear communications. It has been shown that these nuclei are functionally divided into five main groups: the lateral basal nuclei, the cortex-like nuclei, the central nuclei, the other amygdala nuclei, and the extended amygdala. According to studies, the amygdala is one of the components of the limbic system, which is responsible for controlling emotions, behavior, and fear, in addition to forming emotional memory. From an anatomical point of view, it has been shown through this study that the amygdala is located on the anterior border of the hippocampal formation and the anterior side of the inferior horn of the lateral ventricle, where it merges with the cortex surrounding the amygdala, which forms part of the uncus surface of the brain.

It has been shown, according to the study, that the amygdala contains neural circuits to carry out its various functions through two main output paths. The first is the dorsal path through the stria terminalis, which in turn extends almost to the septal area and the hypothalamus. The other is the ventral path through the ventral tonsil path, which ends in the septal area as well. (Images 9, 10), hypothalamus, and it has also been shown that the dorsal medial thalamic nucleus. The amygdala also has connections with the basal ganglia circuit as well via its projections to the ventral pallidum, where these projections are specifically transmitted back to the cortex via the dorsal medial nucleus of the thalamus. The lateral basolateral circuit also includes the amygdala, the orbitofrontal and anterior temporal cortex, and the thalamus as well, and the section is large, specifically cells from the dorsomedial nucleus, which acts as a relay back to the orbitofrontal cortex. This is in line with the study of (Rajmohan and Mohandas Mohandas, 2007).

It has also been shown, according to the study, the presence of the basolateral nucleus (BLA), a cortex-like structure in the dorsal amygdala, and according to studies, some parts of the amygdala have more specific functions. It regulates behavioral responses in addition to physiological responses to stress (Gilpin et al., 2015), image (11, 12, 13) It has also been shown that part of the amygdala, which is the central amygdala (CeA), plays a crucial role in physiological responses to psychological stressors, according to a study (Li et al., 2012), which is associated with frightening stimuli and repetitive stressful stimuli, including fear and anxiety.

It was also clear in the study that the amygdala is that there is a slight difference in the size of the amygdala between males and females. It was found that males have a somewhat larger amygdala than females, while the activity of the amygdala in females was more during rest. This may be due to the presence of receptors in the female amygdala. Sex hormones, such as estrogens, have been researched. A greater or lesser amount can cause long-term changes in the amygdala and its neurotransmitters (image), and this is consistent with a study (Hamann, 2005), which confirmed that there are slight differences between the size of the amygdala between the sexes, but it does not affect behavior in any way. In any case, the study also showed that the age of people after 30 to 60 years has no effect on the size of the amygdala in the rest period and in the absence of any psychological or neurological disorders. This may be similar to the study (Keshavarzi et al., 2014) which proved that psychological disorders, in particular Sadness, feelings of fear, and negative emotions lead to a change in the physiology of the amygdala, and the age of adults who do not suffer from psychological disorders has no relationship to the size and physiological change in the amygdala.

## CONCLUSION

It is clear that imaging with an advanced magnetic resonance imaging device (3 Tesla) of the amygdala results in high-resolution images, and it is possible to distinguish the areas of the amygdala by identifying the dark and light areas, differentiating between the nuclei of the amygdala and dividing them into several regions for the purpose of studying them further.

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