Computerized Tomography and Morphological studies on the brain of the Rat *(Rattus Norvegicus)* and its blood supply.

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Abstract
This survey is applied on the brain of the Rat using Computerized Tomography (CT) and Latex neoprene injection technique to recognize brain problems and provide anatomical data. Eight carcasses of rats, the specimens were carried out from local markets to the Department of anatomy in veterinary medicine, Cairo University. The brain of three carcasses were separated from the whole body for morphology, three specimens were injected with latex to observe the distribution of arterial blood supply and two others for C.T. The brain of rat measured about 2 cm long, 0.75 cm width in the widest part and about 6 gm. weight. Anatomically it could be divided into cerebrum, cerebellum and brainstem. The main blood supply of the brain is the internal carotid arteries and the basilar artery. The communication of the internal carotid and the basilar arteries formed a network of anastomosing vessels, polygonal shape-like arterial anastomosis, rostrally and caudally closed which known as circle of Willis and placed at the base of brain where it surrounded the optic quiasm and the tuber cinereum.

Keywords: Rat, Brain, Blood supply, Computerized Tomography, Morphology, Circle of Willis.

Introduction
Rodent's brain is strikingly similar to humans in their anatomy, physiology and genetics over 95% of the mouse genome is similar to human genome **(**George Paxinos, 2015**)**. The brain is the control center of the vital activities that are necessary for survival specialized in coordinating activities in relation to changes in the internal and external environments (Chikera S. Ibe 2014). The adult brain in rat can be divided into the cerebrum, cerebellum and brainstem. The cerebrum attaches to the brainstem by the cerebral peduncles, while the cerebellum attaches to the brainstem by the cerebellar peduncles (De lahunta and Glass 2009). The cerebrum was the largest part of the brain and located caudal to the Olfactory bulb, rostral to the cerebellum and dorsal to the brain stem (Olude *et al.* 2016) and it

consisted of the two cerebral hemispheres or neocortex that divided by a longitudinal fissure and separated from the cerebellum by a transverse fissure. It was devoid of prominent gyri and sulci. The olfactory bulbs were large in size owing to their importance in the sense of smell of the rodent. It is visible from the dorsal view and gave off the medial, lateral and middle olfactory tracts (Chikera S. Ibe 2014**).** In rats, asymmetry of the olfactory bulb has been reported, with the right side larger than the left (Heine and Galaburda 1986).

The hind brain (brain stem) comprises of the cerebellum, pons and medulla oblongata. The cerebellar hemisphere had a distinct unpaired vermis and located caudal to the cerebrum. The pons of the rat was almost inconspicuous. The central canal of the spinal cord continued rostrally to the medulla oblongata. The mesencephalic tectum composed of the *corpora quadrigamina* which was composed of a pair of rostral colliculi and a pair of caudal colliculi; a transverse and longitudinal fissure separated both. The caudal colliculi were visibly bigger than the rostral colliculi, indicating a more acute sense of hearing than sight (Hebel and Stromberg 1986) and (Olude *et al.* 2016). The cerebral blood circulation depends on two nourishing systems; the carotid system and the vertebra-basilar system. The carotid system is the main responsible for the irrigation of the anterior of the cerebral hemispheres by the anterior and middle cerebral arteries and the anterior choroidal artery while the vertebra-basilar system provides the brainstem, the cerebellum and the posterior quarter of the cerebral hemispheres by the posterior cerebral artery (SILVA and FERREIRA 2002). The posterior cerebral arteries in rats often exhibit asymmetrical origin from the basilar artery (Lee, R.M. 1995**)**. The cerebral arterial circle is compound by branches of both internal carotid arteries and basilar artery (Esteves et al. 2013). The internal carotid arteries divided into their rostral and caudal terminal branches (Ferreira and Prada 2005). The basal artery arose from the anastomosis of the terminal branches of vertebral arteries. It divided on both sides into a rostral cerebellar branch and collateral branches that nourish the bulb, pons and part of the cerebellum **(**Alessandra Canazza *et al.* 2014**)**. Computed Tomography (CT) is effective anatomic imaging machine that helps us to identify cross sections of the body in live animal ***(***Shojaei et al. 2012) and aids the diagnosis and clinical managing of many cases (Goh et al. 2005). CT produces an axial slice of the area under investigation and a resultant three-dimensional image. Also, it allows greater differentiation between individual soft tissue structures than diagnostic radiography. This is due to the ability of CT to accurately measure the tissue absorption of X-ray beams as they pass through the patient (Matthew Keane 2017).

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Materials and methods

The current work was conducted out on eight apparent healthy male rats to study gross morphological characteristics of the rat's brain and arterial blood supply. Their average body weight was about 150 gm and obtained from local markets and transported to the laboratory of Anatomy and Embryology Department, Faculty of Veterinary Medicine, Cairo University. All experimental protocols are approved by the Institutional Animal Care and Use Committee acclimation policy. **Before exsanguination**, the animals should be anaesthetized with chloroform inhalation **(**Olude, M.A. 2016**).**

I. Latex neoprene injection technique:

Immediately after euthanasia, physiologic saline solution was used to perfuse the brain through the common carotid artery, in order to flush the brain free of blood (Chikera S. Ibe 2014). Animals are perfused by transthoracic cannulation of the left ventricle (Esteves et, al. 2013), after clamping the descending thoracic aorta and opening the right atrium with an incision left ventricle was probed and acetone, distilled water at 37 °C and a solution of Neoprene Latex "450" stained with a specific red pigment were injected in sequence into it. To fix the brain, we isolated the head and made an aperture at the dorsal wall of the cranium and the whole specimen was fixed by Warm phosphate buffered saline was then perfused for 1–2 min, followed by 10% formalin (pH 7.4 at 37°C) According to (Tarkan Calisaneller) et al. 2009) for 3 min, and then a 5% gelatin (USB Corporation, Cleveland, OH) /saline solution with India ink (Ferreira and Prada 2005). Brains are removed carefully from the skulls by forceps to avoid piercing the underlying brain tissue (Gage et al. 2012) or bone cutter for largest rodent and stored in the formalin solution. To take the photographic data we used a semi-professional Nikon Coolpix P100 camera. The declination of anatomical elements followed by Nomina Anatomica Veterinaria (2005) was used for the nomenclature.

II. Computed Tomography (CT):

The CT examination applied on two freshly brain rat by using Hitachi- CXR 4Multi-Slice CT scanner. The brain maintained in dorsal, lateral and ventral positions. Computed tomography was performed at 130 kilovolt and 80 mA then Continuous transverse and sagittal series every 5-6mm. The images were printed by using Hitachi-digital printer and photographed (Adel 2011).

Results

The brain of rat (Figs.1, 2, 3) is measured about 2 cm long, 0.75 cm width in the widest part and about 6 gm weight. Anatomically it is divided into cerebrum, cerebellum and brain-stem (Figs.1, 2, 4). The most rostral part of the brain is the olfactory bulbs (Figs.1, 2, 3, 4/a) which are modified in rat laid on the ethmoidal fossa and give its sensory nerves to the nasal cavity through the cribriform plate. The olfactory bulbs are prominent, visible from the dorsal view, very large in size and asymmetrical where the right side is larger than the left, so they play an important role in the sense of smell of the rat (Figs.3/a.).

The cerebrum (Figs. 1, 2, 3, 4, 5, 6, 7/b) is the largest part of the brain which is bounded rostrally by the Olfactory bulb, caudally by the cerebellum and ventrally by the brain stem. It is separated from the cerebellum by a transvers fissure (Figs.1, 2, 3/g) while it was connected with the brainstem by the cerebral peduncles. The two cerebral hemispheres are separated from each other's by a longitudinal fissure (Figs.1, 2, 6/f). The gyri and sulci are less prominent (Figs 1, 2). The cerebellum (Figs.2, 3, 5,6,7/d) is consisted of two cerebellar hemispheres which is highly coiled with a distinct unpaired vermis, it is located caudal to the cerebrum and dorsal to the fourth ventricles in the region of the pons and rostral portion of the medulla oblongata and attached to the brainstem by the cerebellar peduncles.

On the dorsal surface of the brain stem between the cerebrum and cerebellum, the corpora quadrigemina is presented (Figs 2,3/k) which is composed of a pair of rostral colliculi and a pair of caudal colliculi separated by the transverse fissure, each pair of colliculi is separated by the longitudinal fissure. The caudal colliculi (Fig.1/m) are oval and larger than the rostral colliculi which are conical in shape (Fig.1/l) While on the ventral surface of the brain the olfactory bulb (Figs.1,3/a) is continued caudally by the olfactory tract (Fig.4/o), the piriform lobe (Fig.4/u), the brain stem includes midbrain, pons (Fig.4/c), the trapezoid body and finally the medulla oblongata (Figs2, 3, 4, 5/e).

The main blood supply of the brain is the internal carotid arteries (Fig.4/15) and the basilar artery (Fig.4/7) in the foramen magnum. The terminal branches of right and left vertebral arteries anastomoses with each other's to form the basilar artery which passes rostrally on the ventral surface of the medulla oblongata where it gave branches to medulla oblongata, internal ear, pons and cerebellum then it is divided on both sides into a rostral cerebellar branch (Fig.4/6) and two terminal branches that provide the posterior quarter of the cerebral hemispheres.

The Internal carotid artery (Fig.4/15) is originated from the common carotid artery and responsible for the irrigation of the anterior three-quarters of the cerebral hemispheres by the anterior and middle cerebral arteries, it passes through the carotid foramen entered the cranium where it divided at the cerebral peduncles into two terminal branches, a rostral and a caudal one. The rostral cerebral artery (Fig.4/2) makes an anastomosis with another one by the rostral communicating artery (Fig.4/13) and is traveled rostrally to the pyriform lobe and sent several collateral branches to these two structures, the right and left internal ethmoidal arteries (Fig.4/1) were emitted in a rostral sequence where it gave several branches to the olfactory bulbs then passed through the cribriform plate of the ethmoid bone and spread out on the nasal cavity. The caudal communicating artery (Fig.4/4) spreads out to the cerebellum, where it anastomosed with the terminal branches of the basilar artery. These communications formed a network of anastomosing vessels, polygonal shape-like arterial anastomosis, rostrally and caudally closed which known as circle of Willis (Fig.4/8) and placed at the base of brain. From this circle, the caudal cerebral arteries (Fig.4/5) are aroused caudally to supply caudal part of the cerebrum while the middle cerebral artery is aroused rostrally. The middle cerebral artery (Fig.3, 4/3) is the main branch supply the dorsal surface of the cerebral hemispheres.

Discussion

The aim of this study is to identify the different anatomical regions and the distribution of the arterial blood supply of the brain through Dissection, Latex injection and Computed Tomography (CT) which an effective anatomic imaging machine that helps us to identify cross sections of the body in live animal, this in accordance to (Shojaei et al., 2012) and aids the diagnosis and clinical managing of many cases. The brain of rat measured about 2 cm long, 0.75 cm width in the widest part and about 6 gm weight. Anatomically it could be divided into cerebrum, cerebellum and brainstem this similarly observed by (Delahunta and Glass 2009). In agreement with (Chikera S. Ibe, 2014), the most rostral part of the brain is the olfactory bulbs which were very modified in rat laid on the ethmoidal fossa and give its sensory nerves to the nasal cavity through the the cripriform plate. Similar to the observation of (Heine and Galaburda, 1986**),** the olfactory bulbs were very large in size, asymmetrical where the right side larger than the left, prominent and visible from the dorsal view, so they are very important in the sense of smell of the rat.

In accordance to (Olude *et al.,* 2016), the cerebrum was the largest part of the brain which pouded rostraly by the Olfactory bulb caudally by the cerebellum and ventrally by the brain stem. It was separated from the cerebellum by a transvers fissure while it was connected with the brainstem by the cerebral peduncles. The two cerebral hemispheres were separated from each other's by a longitudinal fissure, on the ventro-lateral aspect the rhinal sulcus was found and the gyri and sulci were very less prominent.

The cerebellum consisted of two cerebellar hemispheres which was highly coiled with a distinct unpaired vermis, it was located caudal to the cerebrum and dorsal to the fourth ventricles in the region of the pons and rostral portion of the medulla oblongata and attaches to the brainstem by the cerebellar peduncles, this similarly observed by (Hebel and Stromberg 1986; Olude *et al.,* 2016).

Similar to the observation of (Alessandra Canazza *et al.,* 2014), the main blood supply of the brain is the internal carotid arteries and the basilar artery. in the foramen mag-num the terminal branches of right and left vertebral arteries anastomose with each other's to form the basilar artery which passes rostrally on the ventral surface of the medulla oblongata where it gave branches to medulla oblongata, internal ear, pons and cerebellum then it divided on both sides into a rostral cerebellar branch and two terminal branches that provided the posterior quarter of the cerebral hemispheres.

In accordance to (Silva and Ferreira, 2002), the Internal carotid artery is originated from the common carotid artery and responsible for the irrigation of the anterior three-quarters of the cerebral hemispheres by the anterior and middle cerebral arteries, it passes through the carotid foramen entered the cranium where it divided at the cerebral peduncles into two terminal branches, a rostral and a caudal one. The rostral cerebral artery makes an anastomosis with another one by the rostral communicating artery while the caudal communicating artery spreads out to the cerebellum, where it anastomosed with the terminal branches of the basilar artery. In agreement with (Esteves et al., 2013) (Ferreira and Prada (2005), these communications formed a network of anastomosing vessels, polygonal shape-like arterial anastomosis, rostrally and caudally closed which known as circle of willis and placed at the base of brain where it surrounded the optic quiasm and the tuber cinereum. From this circle, the caudal cerebral arteries aroused caudally to supply caudal part of the cerebrum, the middle cerebral artery aroused rostrally which the main branch supply the dorsal surface of the cerebral hemispheres, the rostral cerebral artery which travelled rostrally to the pyriform lobe and sent several collateral branches to these two structures, the right and left internal ethmoidal arteries were emitted in a rostral sequence where it gave several branches to the olfactory bulbs then passed through the cribriform plate of the ethmoid bone and spread out on the nasal cavity.

Conclusions

This study provided anatomical information about the brain of rat and its blood supply which to a great manor similar to the human brain, this will help in clinical diagnosis of brain problems through using Computerized Tomography (CT), also provides a guide for pet clinics which deal with Rats, Mice and Guinea pig.

Acknowledge

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Ethical Standards

The study was conducted in accordance with the Vet. Cu. IACUC number 01122022540 of Cairo University.

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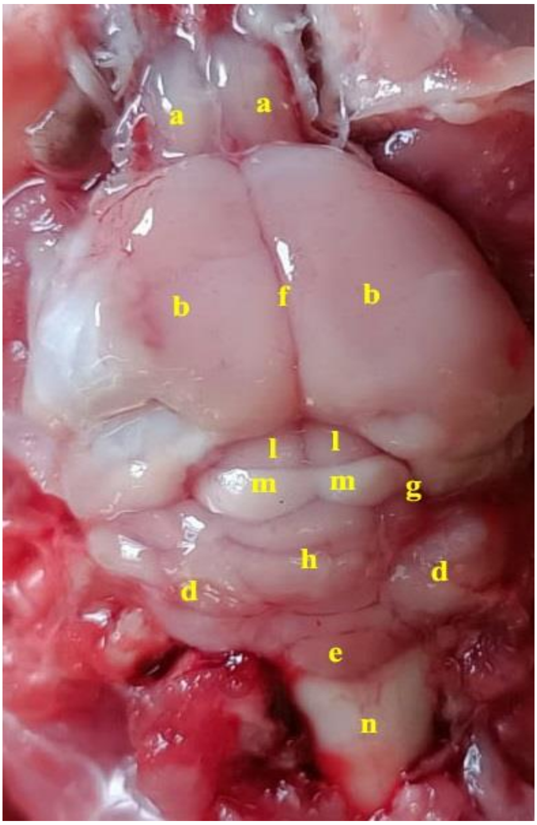


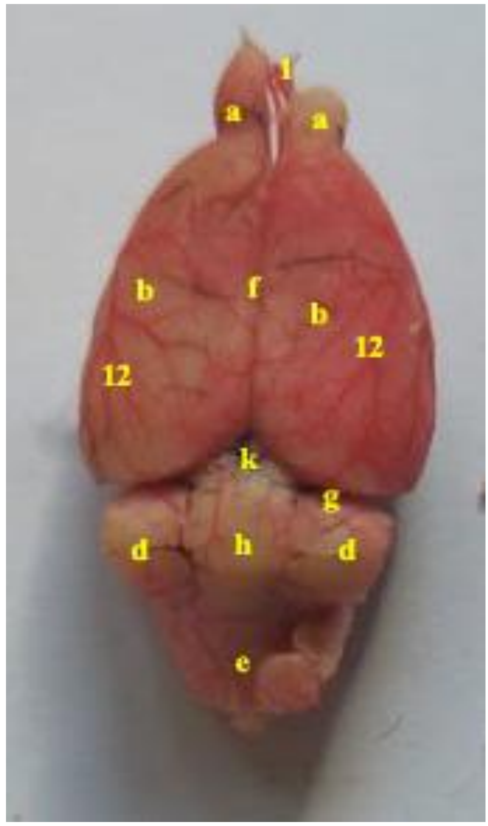


Fig (1): A photograph showing the dorsal view of the brain in rat (left)
a. Olfactory bulb, b. Cerebral hemisphere, f. Longitudinal fissure, e. Medulla oblongata, h. Vermis cerebelli, l. Rostral colliculi, m. caudal colliculi, d. cerebellar hemisphere, g. transverse fissure, n. spinal cord

Fig (2): A photograph showing the arterial blood supply of dorsal view of the brain in rat. (right)
a. Olfactory bulb, b. Cerebral hemisphere, f. longitudinal fissure, g. Transverse fissure, h. Vermis cerebelli, d. Cerebellar hemisphere, k. Corpora quadrigemina, e. Medulla Oblongata, 1. Internal ethmoidal artery, 12. collateral branches of middle cerebral artery.

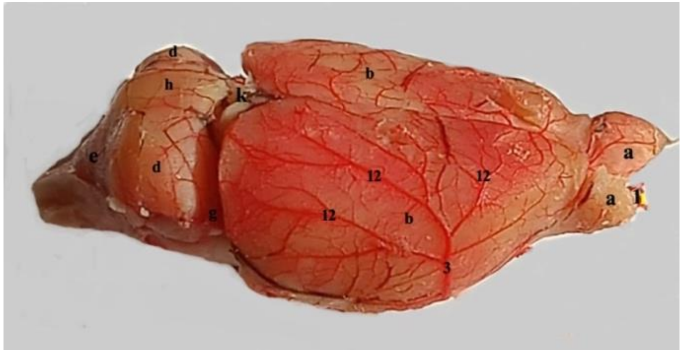


Fig (3): A photograph showing the arterial blood supply of the lateral view of the brain in rat

a. Olfactory bulb, b. Cerebral hemisphere, h. vermis cerebelli, d. Cerebellar hemisphere, e. medulla oblongata, 1. Internal ethmoidal artery, 3. middle cerebral artery, 12. collateral branches of middle cerebral artery, k. corpora quadrigemina, g. transverse fissure.

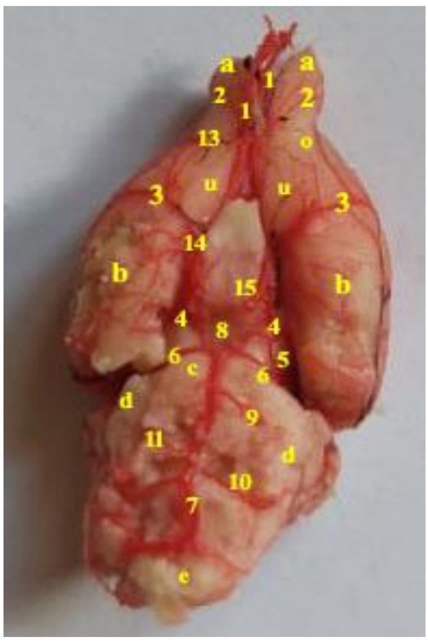


Fig (4): A photograph showing the arterial supply of the ventral view of the brain in rat.

1. Internal ethmoidal artery, 2.Rostral /anterior cerebral artery, 3.Middle cerebral artery, 4.Caudal communicating branch, 5.Caudal/posterior cerebral artery, 6. Rostral cerebellar artery, 7 .Basilar artery, 8. Circle of Willis, o: Olfactory tract, 13.rostral communicating artery of anterior cerebral artery, 15.internal carotid artery, d. Medulla oblongata, 9.pontine artery, 10.caudal cerebellar artery, 11. medullary branch, a. Olfactory bulb, b. cerebral hemisphere, c. pons, d. cerebellar hemisphere, u: piriform lobe, 14.rostral communicating branch

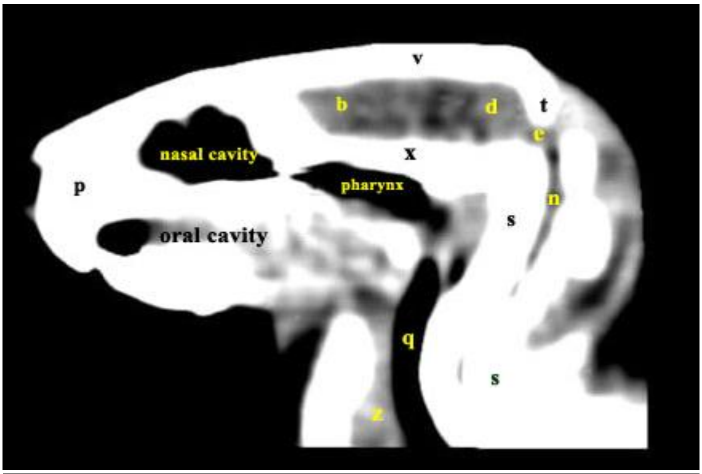


Fig (5): A photograph showing the sagittal head of rat by C.T.
a cerebrum, t. Foramen magnum, d. cerebellum, x. Floor of cranial cavity, e. medulla oblongata, n. spinal cord, q. Trachea, z. esophagus, p. Incisive bone, s. vertebral column, v. Frontal bone

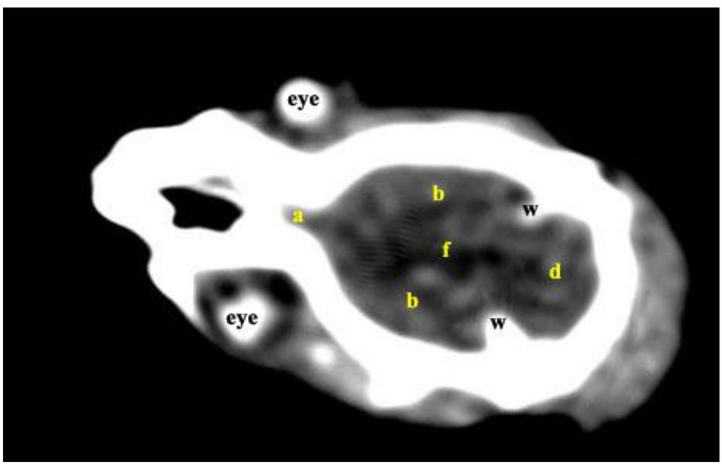


Fig (6): A photograph showing the dorsal view of the brain in rat by C.T
a. Olfactory bulb, b. cerebral hemisphere, f. longitudinal fissure, d. Cerebellar hemisphere, w. petrosal crest

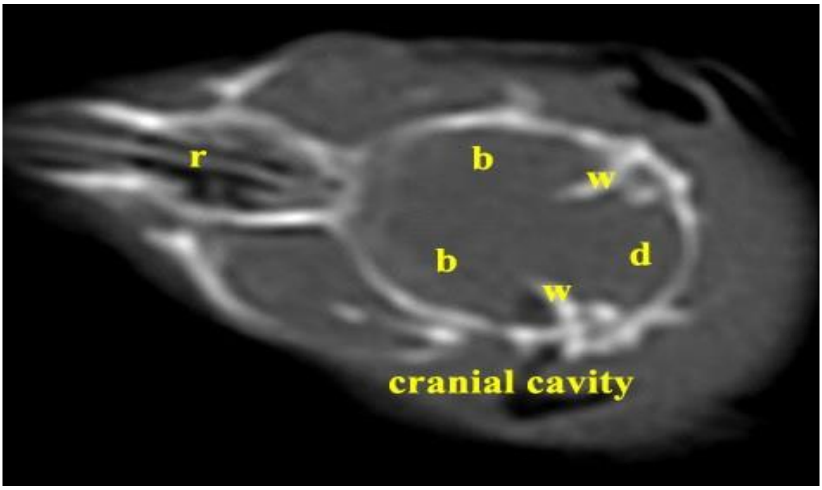
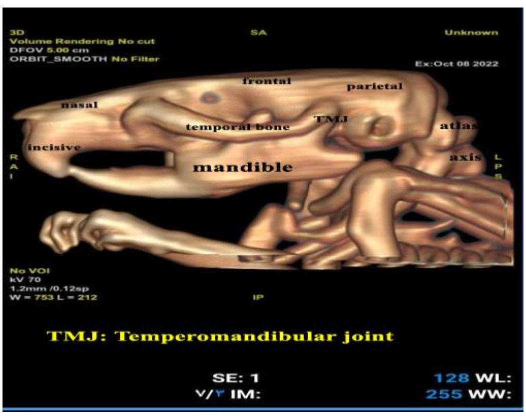


Fig (7): A photograph showing the dorsal view of the head in rat by C.T
a. cerebral hemisphere, w. petrosal crest, r. nasal cavity, d. cerebellum



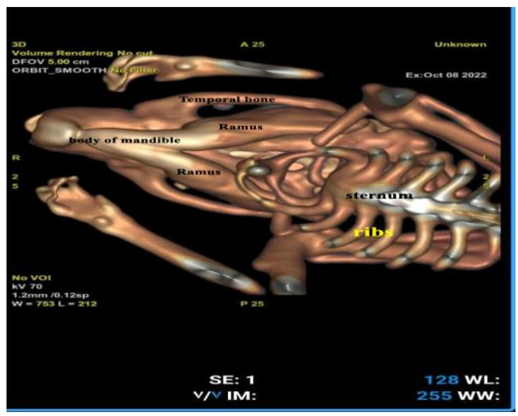


Fig (8): A photograph showing the cranial bones and articulation with mandible (left)
Fig (9): A photograph showing the ventral aspect of the skull in rat. (right)