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Evaluation of computed tomography scanning of some normal catfish heads

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ABSTRACT
In the current study, computed tomography has used to describe the head region in four Nile catfish species, Bagridae *Bagrus bajad*; Clariidae *Clarias gariepinus*; Malapteruridae *Malapterurus electricus* and Mochokidae *Synodontis schall.* Computed tomography showed the details of each of the different compositions of soft and hard structures. The cranial head sections revealed the extent of the anterior fontanelle, jaws and hyoid apparatus. The caudal sections revealed the presence of the electric organ of *M. electricus*, Air Breathing Organ of *C. gariepinus*, the lateral fontanelles and nuchal shield in *S. schall*. CT scanning is the most suitable modality for early detection of congenital abnormalities in farmed fish and this may help to improve the production. Therefore, the aim of this work is to provide an anatomical description of the head regions of the Nile catfish, as the normal anatomy is the key to proper diagnosis.

Keywords: Bagridae; Clariidae; Malapteruridae; Mochokidae; Electric Catfish; CT.

1. Introduction

Egypt ranked as the fourth largest inland fishery producer in Africa and the 11th in the world in 2008**.** Egyptian general authority for fisheries resources development (GAFRD) reported 693,815 Tones of total aquaculture production in 2008 and 705,490 Tones in 2009. Freshwater fishes comprised 69.5 and 68.5% of all aquaculture production in Egypt in 2008 and 2009, respectively. Fresh water fishes, including Nile catfishes have a high socioeconomic value at least 378,000 people in Egypt depending directly on the activities related to the harvesting and farming of freshwater fishes (Bignoli and Darwall, 2012).

There is widespread use of hormones and food additives to increase fish-meat production. Moreover, some congenital abnormalities appeared on fishes (El Asely, Abbas and Shaheen, 2007 and Raslan, 2012). Early detection of these abnormalities may help veterinarians to better control the doses used. In this sense, Computed tomography (CT) recently suggested as an alternative imaging method for the early diagnosis of skeletal deformities, as well as a valuable tool for the current research on the causes and prevention of these anatomical disorders (Gisbert, Darias and Font-i-furnols, 2012).

In the sight of these facts, the aim of the current study was the application of CT to study the normal structures of head region in four exemplar species of the catfish families in Egypt, Bagridae (*B. bajad*); Clariidae (*C. gariepinus*); Malapteruridae (*M. electricus*) and Mochokidae (*S. schall*).

2. Material and methods

The present investigation was carried out on 40 heads of apparently healthy catfishes, ten of the following each species: *Bagrus bajad*, *Clarias gariepinus*, *Synodontis schall* and *Malapterurus electricus*. These specimens obtained from the Alobour fish - market during June and July. Two heads from each species used for gross anatomical study; cross-sections at different levels of heads as well as sagittal sections carried out to study the position and relations of the skull bones. Computed tomography performed at 130 Kv and 14 mAs by using Hitachi-CXR 4Multi-Slice CT scanner. Continuous transverse series of CT scan obtained every 0.5 cm thickness. The images printed by using Hitachi-digital printer and photographed.

The research complied with protocols approved by the appropriate institutional animal care committee and adhered to the legal requirements of our country. The nomenclature used in this study written according to Adriaens and Verraes (1998) and Diogo (2007).

3. Results and Discussion

Most of the hard structures appeared very clearly in the computed tomography scanning except the oral teeth. Soft structures such as eyes, heart and brain appeared slightly clear in CT images, except the air-breathing organ of *C. gariepinus*. Four levels had taken at the common landmarks, the rostral end (Fig 1), and the eye (Fig 2), the caudal border of the first branchial arches (Fig 3) and the caudal border of the operculum (Fig 4).

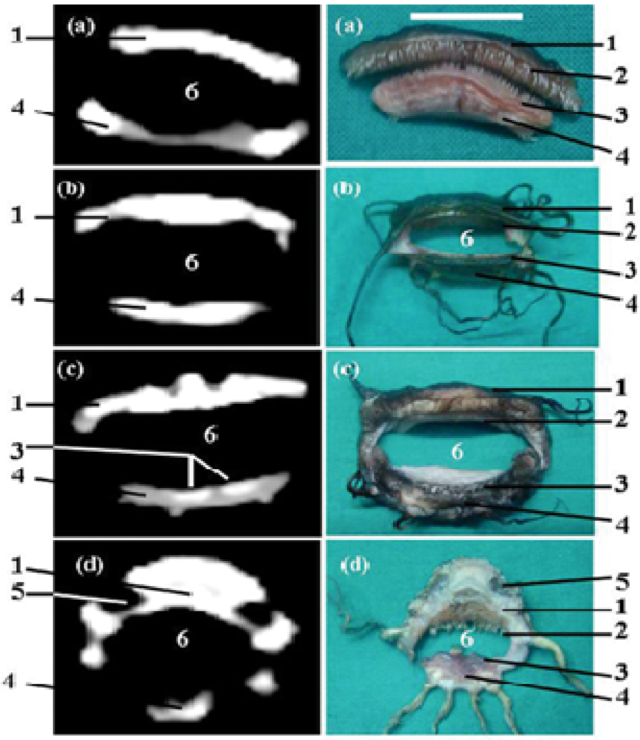

Fig 1: A photograph of transverse sections of head at the level of rostral end (Snout) in *B. bajad* (a), *C. gariepinus* (b), *M. electricus* (c), and *S. schall* (d) with their C.T images showing (bar = 1cm):

1- The upper jaw, Os premaxillare, 2. Premaxillary tooth plate.
3. Dentary tooth plate, 4. The lower jaw, Os dentale.
5. Cranial nostril, the cranial nasal opening. 6- The oropharyx.

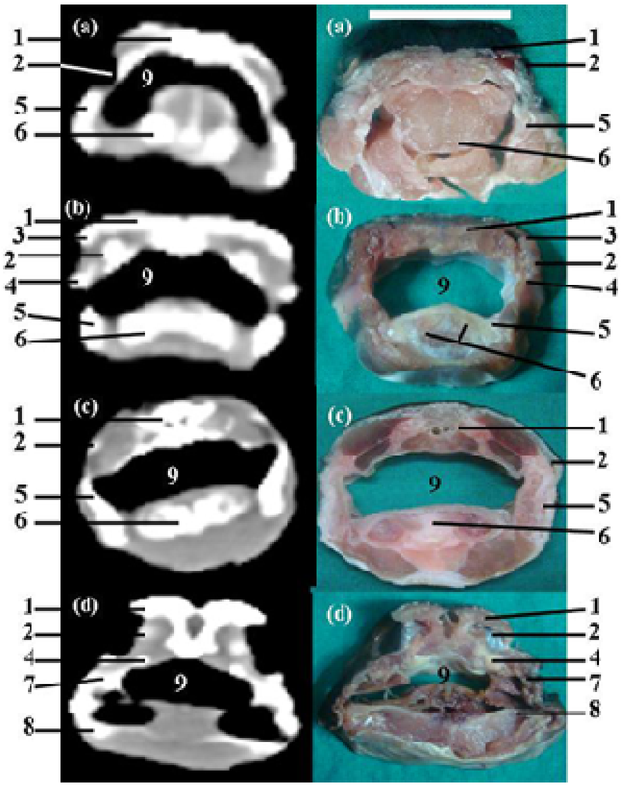

Fig 2: A photograph of transverse sections of head at the level of eye in *B. bajad* (a), *C. gariepinus* (b), *M. electricus* (c), and *S. schall* (d) with their C.T images showing (bar = 4 cm):
1. Os frontale, 2. The eye, 3. Supraorbital process of Os infraorbitale IV.
4. Os infraorbitale II, 5. Os angulo-articulare, 6. Os ceratohyale posterior.
7. Os quadratum. 8. Branchiostegeal rays, 9. The oropharynx,

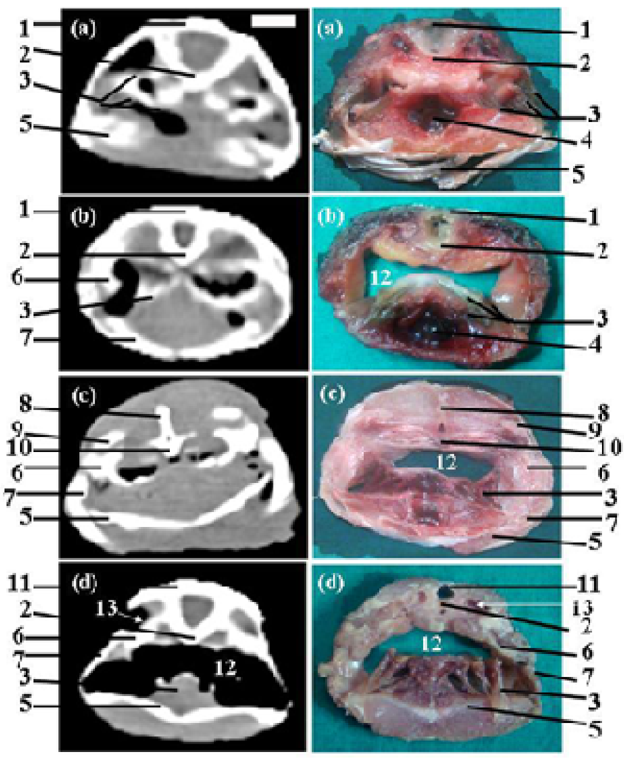

Fig 3: a photograph of transverse sections of head at the level of caudal border of the first branchial arch in *B. bajad* (a), *C. gariepinus* (b), *M. electricus* (c), and *S. schall* (d) with their C.T images showing (bar = 1cm):
1. Os parieto-supraoccipitale, 2. Os basisphenoideum, 3. Branchial arches II, III, and IV.
4. The Heart, 5. Branchiostegeal rays, 6. Os hyomandibulare
7. Os operculare, 8. Os frontale, 9. Os infraorbitale IV, 10. Os parashenoideum.
11. Neurocranium, 12. The oropharynx, 13. The lateral fontanelle (In S. schall only).

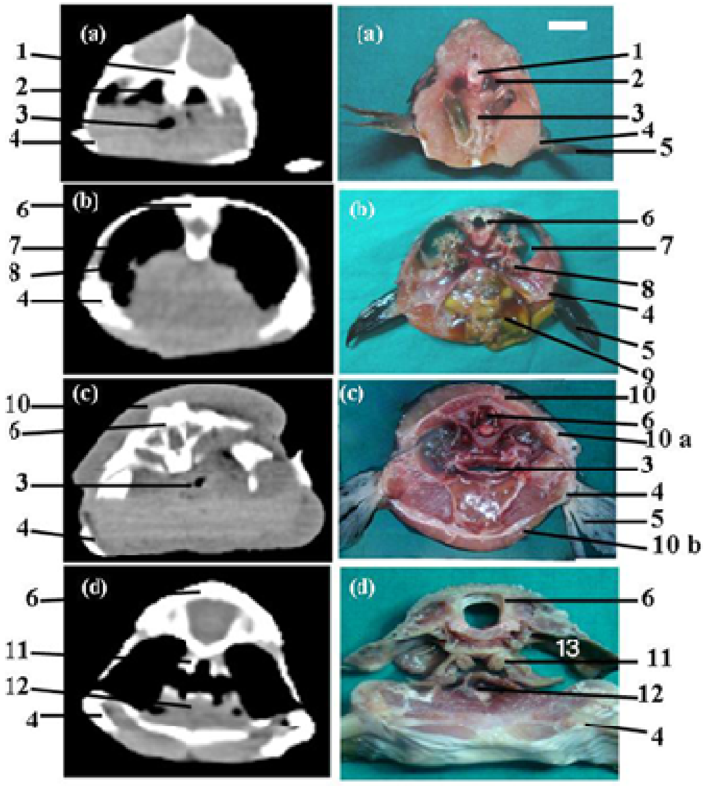

Fig (4): a photograph of transverse sections of head at the level of caudal border of the operculum in *B. bajad* (a), *C. gariepinus* (b), *M. electricus* (c), and *S. schall* (d) with their C.T images showing(bar = 2.5cm):
1. Weberian apparatus, 2. The cranial kidney (Head kidney), 3. The Esophagus.
4. The pectoral girdle, 5. The pectoral fin, 6. Neurocranium.
7. Suprabranchial cavity (In *C. gariepinus* only), 8. Arborescent organ, the air breathing organ (In *C. gariepinus* only).
9. Intestinal tract, 10. The electric organ (In *M. electricus* only), 10. a – The sub-electric fascia, 10 b – The external electric fascia.
11. Pharyngeal teeth, 12. The Heart, 13. Nuchal shield (In *S. schall* only).

The first structures appeared on the CT scans were the upper and the lower jaws. The upper jaw formed by two premaxillary bones that joined each other medially to form the maxillary symphysis. It connected laterally to the distal end of the rod like maxillary bones. The premaxilla covered externally by a thick fold of skin, the upper lip that carried the maxillary barbels at the dorsal ends of the labial commissar (Fig 1). In *S. schall,* the upper lip was very thick and hard. In the four studied species, the maxillary barbels were the longest barbels and their bases received by the proximal ends of the maxillary bones. *B. bajad* has the longest maxillary barbels as they reach the caudal border of the pelvic. These results came in agreement with those reported by Burgess (1989) and Singh, and Kapoor (1967). The large sized barbels have an important role in search of food, as they carry cutaneous taste buds particularly abundant at their distal ends (Singh and Kapoor, 1967).

The bones of the lower jaw were the dentary, anguloarticular and coronomeckelian, which fused to form the mandible (Fig 1). The two mandibles fused medially to form the mandibular symphysis. The thick skin that covered the mandible externally formed the lower lip, which carried the outer and inner mandibular barbels. The outer pair located at the ventral ends of the labial commissure, while the inner one located medial to it. In *S. schall,* the two pairs of mandibular barbels branched and feather like. The above-mentioned observations are nearly similar to that reported by Burgess (1989), Adriaens and Verraes (1998) and Diogo (2007).

Each one of the four studied species has two sets of tooth plates, the oral and the pharyngeal. The oral tooth plates were the premaxillary (Fig 1-2), dentary (Fig 1-3) and the vomerine tooth plates. In *B. bajad,* the premaxillary, mandibular and the vomerine tooth plates were carried villiform teeth. In *M. electricus* and *S. schall,* the premaxillary formed of villiform teeth while the vomerine tooth plate was absent. In *S. schall,* the premaxillary tooth plate formed of cardiform teeth while that of *M. electricus* carried villiform teeth. In *C. gariepinus,* the premaxillary tooth plate formed of villiform teeth; while the vomerine carried conical teeth and the mandibular plate has both types of teeth. These results were similar to those stated by Adriaens and Verraes (1998) and Diogo (2007). The pharyngeal tooth plates were one pair, which embedded in the roof of the branchial cavity. In *B. bajad*, *C. gariepinus* and *M. The electrics*, the pharyngeal tooth plates carried villiform teeth while in *S. schall,* they formed of cardiform teeth (Fig 4 -11).

B. bajad is a piscivores because it feeds mainly on small sized African catfishes, mullets and cichlid species, in addition to shrimp *Leander serratus,* fish, eggs and aquatic insects (Bakhoum and Fatas, 2003). *B. bajad* seems to have liable feeding apparatus to the readily available preys in their habitat. In *S. schall,* the upper head length was longer than the opercular head length by about 0.5 cm, which refers to the sub-terminal position of its mouth. In the other three species, the mouth was terminal in position. In *S. schall,* the hard-protruded upper lip and the brush like cardiform teeth may help in grasping mollusks from the underlying rocks or even by the aid of the sub-terminal position of the mouth suck them from the sediments of the bottom (Helfman, Collette, Facey and Browen, 2009).

In *C. gariepinus*, *M. electricus* and *S. schall,* the cranial nostrils (Fig 1-5) were located slightly caudal to the upper lip, while those of *B. bajad* found near the tip of the snout at the rostral border of the upper lip. 0.5 – 1 cm, located the caudal nostrils caudal to the rostral pair. In the four species, the cranial nostrils were tubular in shape. In *C. gariepinus,* the caudal nostrils were oval, while those of *B. bajad* were round and in both of them; pair of nasal barbels were present. The caudal nostrils in *M. electricus* and *S. schall* were tubular in shape and the nasal barbels were absent, these nearly similar to (Burgess, 1989 and Helfman *et al*., 2009).

The eyes (Fig 2-2) of the Nile catfishes were dorso-lateral in position and ovoid in shape. The lateral placement assumed to indicate pelagic habitat, while the dorsally increased displacement reflected a more sedentary mode of life (Turan, Yalcin, Turan, Okur and Akyurt, 2005). Nile catfishes were benthopelagic, i.e., it feeds near or on the bottom (Burgess, 1989) and the dorso-lateral position of their eyes is suitable for this habitat.

The diameter of eyeball of *S. schall* was 1.53 cm ±0.15, in *C. gariepinus* and *B. bajad* it was 0.50 cm ±0.10, while *M. electricus* has the smallest orbital diameter among the examined species 0.30 cm ±0.10. The orbital diameter increased due to many factors as differences in turbidity among rivers, water depth and food availability (Matthews, 1988). Because of their very small eyes, *M. electricus* hunt and navigate almost exclusively by using their electric organ discharges (Rankin and moller, 1986). The spectacle, a clear covering overlay cornea found in *M. electricus* only. In *B. bajad*, there was a very narrow adipose eyelid around the orbital margin.

The bones of the skull roof in *C. gariepinus*, *B. bajad* and *S. schall* were the mesethmoid, frontal (Fig 2-1) and parietosupraoccipital (Fig 3-1). In *M. electricus* they were the mesethmoid, the frontal, parietal and supraoccipital. In *S. schall* a nuchal shield (Fig 4-13) presented caudal to the parietosupraoccipital bone. The nuchal shield consisted of three plates, a small round anterior nuchal plate, a large quadrate middle nuchal plate and two smaller triangular posterior nuchal plates. The mesethmoid was the most-cranial bone, related medial to the lateral ethmoid bone and together enclosed the nasal bone.

The fontanelle was an open area in the head and covered by a tough membrane (Hollinshead and Rosse, 1985) and Gray (2000) in man and (Adams, 1996) in dogs. Fontanelles are common in catfishes and important in taxonomy (Burgess, 1989). The frontal bones (Fig 2-1) were the larger bones in the skull; at the midline of the head, the two frontals bounded the anterior fontanelle. The anterior cranial fontanelle or the frontal fontanelle was a median open area closed dorsally by a tough membrane and skin. It was slit like in *B. bajad* and *M. electricus,* while in *C. gariepinus* and *S. schall,* it narrowed caudally by a bony bar, which divided it into a wide slit like part rostrally and a narrow part caudally.

The presence of nuchal shield caudal to the parietosupraoccipital bone, and the two lateral fenestrae, are two characteristic features of the old world family Mochokidae (Pinton and Otero, 2010) and the new world family Doradidae (Birindelli, Fayal and Wosiacki, 2011). The current findings disagree with those reported by Birindelli *et al*. (2011) in the definition of the gaps as fenestrae. As *S. schall*, has two lateral fontanelles at the junction between the sphenotic, pterotic and the parietosupraoccipital bones. Herein, there no any anatomical structures passed through them, and these gaps were only covered by though membranes as the usual fontanelles.

The posterior cranial or the parietal fontanelle bounded by the parietosupraoccipital bone In *C. gariepinus* and *B. bajad,* while it was absent in *M. electricus* and *S. schall.* In *C. gariepinus* the posterior fontanelle was narrow and slit like, while in *B. bajad* it has the same shape and depth of anterior fontanelle but slightly shorter than it. The lateral fontanelle (Fig 3-13) presented in *S. schall* only; it was a paired fontanelle near the junction between the sphenotic, pterotic and the parietosupraoccipital bone. The posterior fontanelle or the parietal foramen may exposes pineal gland to direct sunlight (Adriaens et al., 1998). The normal position and the shape of fontanelles are important for differential diagnosis between congenital abnormalities and some infectious diseases as the open lesions of fontanelle caused by *Edwardsiella ictaluri* in the channel catfish (Jarboe, Browser and Robinette, 1984).

The hyoid bar consists of five pairs of bones, its arrangement from lateral to medial, the interhyal; anterior ceratohyal; posterior ceratohyal (Fig 2-6); dorsal hypohyal; and ventral hypohyal, in addition a single bone the parurohyal presented at the ventral midline of the head. These results came in accordance with those reported by Adriaens *et al.* (1998) and Diogo (2007).

The bony support of the opercular region composed of three bones, the preopercular, the opercular (Fig 3-7) and the interopercular. The preopercular bone was C- shaped and articulated proximally with the hyomandibula (Fig 3-6) and distally with the quadrate (Fig 2-7). The interopercular was a small triangular bone. It was attached by connective tissue to the lateral surface of the posterior ceratohyal. In *C. gariepinus*, the opercular bone located horizontal and ventral to the head, which is similar to that observed by Adriaens *et al*. (1998).

Air-breathing organ or Arborescent (Tree like) organ was a characteristic structure found in *C. gariepinus* only (Fig 4-8). It was located in the suprabranchial chamber caudodorsal to gills (Fig 4-7). The dorsal process of the fourth infraorbital bone bounds the suprabranchial cavity dorsally, the cliethrum caudo- distally and the epibranchial segments of branchial arches cranio-distally (Fig 2-3).

The above-mentioned structures are commonly present in air breathing species as *Heterobranchus* and *Heteropneutes* (Evans and Claiborne, 2005). Studies on air breathing organ (Abd-Elmaksoud, Kassab, Sayed-Ahmed, and Fayad, 2008 and Ikpegbu, Nlebedum, Nnadozie and Agbakwuru, 2013) concerned only its internal and external structures, so this study tried to focus on the bony boundaries of the suprabranchial cavity, its lining, and communication. The suprabranchial cavity lined with a sac like membrane, which has one opening rostro-ventrally. That opening directed toward the branchial cavity and guarded with three modified gills or gill fans (Abd-Elmaksoud *et al*. 2008 and Ikpegbu *et al*. 2013). The current study has suggested that the modified gills are not functionally like gills, but they are true valves. This is because of their position at the only opening between the suprabranchial cavity and the gill chambers. In addition, these modified gills formed of a web like membrane, which tightly closed the opening and prevent entrance of water or exit of air. The normal appearance of the air-breathing organ is important for diagnostic purposes. Abd-Elmaksoud *et al*. (2008) reported that the core of this organ formed of elastic cartilage, a vascular layer of connective tissue and covering epithelium. In this work, the organ appeared tree like in fresh sections only, but due to its low-density soft structure, it did not appear perfectly in the CT sections (Fig 4-8).

In *M .electricus*, the caudal sections of the head have revealed the presence of the electric organ (Fig 4-10). The electric organ was a modified subcutaneous muscle supplied by the electric nerves. The branches of the electric nerve divided the organ into uniting or plates. The lateral part of the organ was thicker than the dorsal and ventral parts. It separated from the overlying skin by a tough membranous external electric fascia (Fig 4-10b), while the sub-electric fascia (Fig 4-10a) separated it from the underlying musculature, these findings agree with those described by Stuart and Kamp (1934).

4. Conclusion

Computed tomography scanning was easily applicable on catfishes and CT images showed the details of each of the different compositions of soft and hard structures of the heads. The peculiar structures such as the nuchal shield of *S. schall* and the electric organ of *M .electricus* appeared slightly clear, while the air-breathing organ not appeared. The results of the present study may serve as reference data for computed tomography scanning of disorders of Nile-catfish heads.

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