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Gross anatomical studies on the pelvic girdle of blue and yellow macaw (*Ara ararauna*)

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Abstract

In the present study, gross anatomical structure of pelvic bone of blue and yellow macaw was analyzed. The pelvic bone of blue and yellow macaw is a large, inverted shovel shaped structure. It consists of two hip bones (ossa coxae), each of which was made up of an ilium, an ischium and a pubis. The space between the pelvic bones was occupied by rhomboid shaped lumbosacral mass. The ilium was longest (8.5 cm) and largest bone of os coxae in blue and yellow macaw. The pre-acetabular part was 4.5 cm long and 1.5 cm wide and the post-acetabular part was 4.0 cm long and 0.8 to 1.0 cm wide. The pre and post-acetabular parts of the ilium were separated by a short ridge above the level of acetabulum. The caudal end of the ilium showed a thin, elongated, straight and caudally extended caudal process, projecting ventrally. The canalis ilioneuralis was not formed. The acetabulum was formed by ilium, ischium and pubis. Caudodorsal rim of acetabulum showed the anti-trochanter, a bony prominence with sharp edges carrying a triangular facet. The ischium was roughly triangular, thick bony plate. The ventral border of the ischium below and behind the level of posterior rim of the acetabulum, showed a small oval foramina, the foramen ovale with broad caudal end. Behind this foramen, the ventral border of ischium formed synostosis with the pubis. Behind this a large Ischio-pubic Incisure was noticed. The pubis was a thin, rod-like bone which followed the ventral border of the ischium and projected beyond it caudally and bent slightly medially. The pectineal process was rudimentary.

Keywords: Ilium, ischium, pubis, acetabulum, anti-trochanter

Introduction

The blue and yellow macaw (scientific name: *Ara ararauna*) is a large parrot with natural habitat at Eastern Panama south to Paraguay, Southern Brazil and Northern Argentina [3]. The anatomy of avian species has many unique adaptations for flight. The bones in birds are light in weight but their musculature is powerful. The circulatory system and air sacs in respiratory system in birds facilitates very high metabolic rates and oxygen supply for flying. The morphology of the bones in birds is different depending on species, habitat and mainly flight capability [4]. The os coxae of the birds is large in size and is related to their bipedal standing posture because their hind limbs are their only equipment for support and walking. The ventrally-open pelvis forms a dorsal, roof-like covering for a large part of the body cavity and the organs contained therein [14]. The pelvis of different birds shows marked structural diversity which indicates the different demands on it. There is only scanty information available on basic anatomical studies of skeletal system of psittacine species of birds. Barring a very few [19], the morphometric studies of blue and yellow macaw is scanty. Hence, the present study was conducted to contribute very useful gross morphological and morphometrical information on the pelvic girdle of this species.

Materials and Methods

The carcass of three blue and yellow macaws were utilised for the present study. After the post-mortem examination the carcasses were allowed for biological maceration. The soft tissues were eaten by maggots. The disintegrated skeleton was cleaned with fresh water and soaked in 10-15% NaHCO₃ solution for whitening. The skeleton was then dried and morphological and morphometric studies were performed. Vernier caliper and ruler were used for morphometry.

Results and Discussion

The pelvic bone of blue and yellow macaw was large. It consisted of two hip bones

(ossa coxae), each of which was made up of an ilium, an ischium and a pubis, as reported in birds ^[14]. The ilium was a thin, long plate of bone, the ischium was comparatively thick

plate and the pubis was a slender rod-like bone. The space between the pelvic bones was occupied by rhomboid shaped lumbosacral mass (Fig.1) as reported by in fowl ^[12].

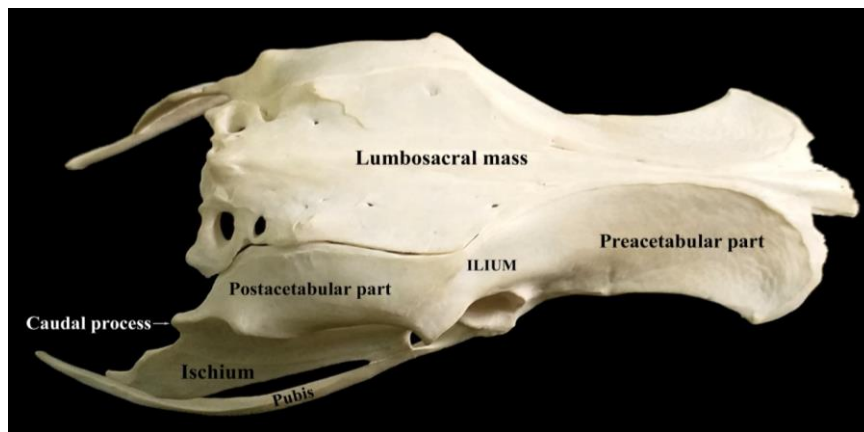


Fig 1: Photograph showing dorsal view of the pelvic girdle of blue and yellow macaw

The pelvis was elongated, narrow in the preacetabular part and broad in the postacetabular part (Fig.1). It is in agreement with the earlier observations in duck and goose ^[14] and in peahen ^[21].

Ilium

The ilium of blue and yellow macaw was longest (8.5 cm) and largest bone of os coxae. The pre-acetabular part was 4.5 cm long and 1.5 cm wide and the post-acetabular part was 4.0 cm long and 0.8 to 1.0 cm wide (Fig.1). It is in agreement with the earlier observations in pigeon ^[14] and peahen ^[21], who recorded that the pre-acetabular part was larger than the post-acetabular part. In contrary, the post-acetabular part was longer and narrower and the pre-acetabular part was shorter and wider in duck and goose ^[14] and in emu ^[1].

The gluteal surface of the pre-acetabular part was concave, quadrilateral in shape, sloping downwards and facing laterally (Fig.1), as observed earlier in peahen ^[21] and in Indian eagle owl ^[17]. The post-acetabular part was narrow and facing dorsally (Fig.1) as observed in coturnix quail ^[5], barn owl ^[2] and Indian eagle owl ^[17]. In peahen the post-acetabular part was convex anteriorly and flat posteriorly ^[21] and in emu, the ilium was lying vertical to the long axis of the body ^[16]. The pre and post-acetabular parts of the ilium were separated

by a short ridge above the level of acetabulum which was the continuation of the convex dorsal border of the pre-acetabular part (Fig. 1). In peahen, the ridge began from the craniomedial angle of ilium and extended up to its posterior extremity ^[21]. In coturnix quail it terminated just caudal to acetabulum ^[13]. But in emu, there was no line of demarcation was observed between pre and post-acetabular parts ^[1].

The medial surface of the pre-acetabular parts of ilia was fused to spinous and transverse processes of the synsacrum. On further examination of ilium of blue and yellow macaw it was noticed that the ventral openings of canals ilioneuralis were also closed by the bony trabeculations which showed numerous foramina (Fig. 2). Hence, in blue and yellow macaw, the canalis ilioneuralis was not formed. Similarly in peahen the ilioneural canal was not formed ^[21]. In Indian eagle owl, four large foramina were observed on either side of median plane for the passage of spinal nerves ^[17]. But in chicken, the canalis ilioneurales were produced, which were bounded by the ilium and the spinal and transverse processes of the synsacrothoracic vertebrae ^[14]. The earlier studies revealed that in Guinea fowl the canalis ilioneuralis was formed but in pigeon, the ilium was not fused with the dorsal spines of lumbosacral mass, so that dorsally opened narrow canalis ilioneuralis was noticed ^[11].

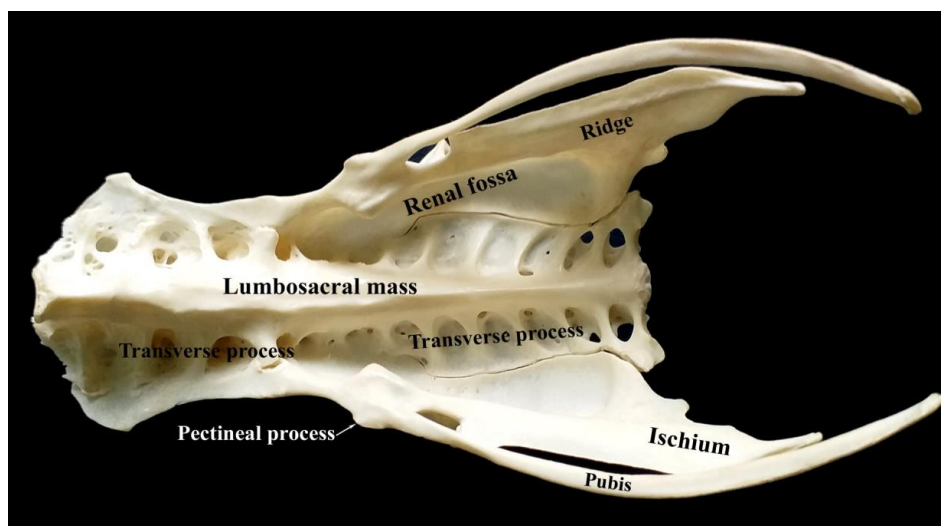


Fig 2: Photograph showing ventral view of the pelvic girdle of blue and yellow macaw

The cranial border of the ilium was convex. The dorsal border was convex and closely placed in the middle, whereas in front and behind the dorsal borders were little deviated, in the pre-acetabular part (Fig. 1). Sarma and co-workers studied the os coxae of Indian eagle owl and found that a lumbo-sacral mass was formed with the fusion of pre-acetabular os coxae with its dorsal spinous processes. They also found a very sharp and prominent crest on dorsal part of os coxae of Indian eagle owl on either side of lumbo-sacral mass. The crests on both sides were very close to each other anteriorly but they widened apart posteriorly. The maximum width was seen at the level of acetabulum. The crest of pre-acetabular part continued as lateral border of post-acetabular part^[17]. The post-acetabular parts of the ilium were separated widely

from each other by the bony plate formed by the fused transverse process of the synsacrum (Fig.1). In birds, the post-acetabular part of ilium and synsacrum joined caudally syndesmotically to the transverse processes of these vertebral^[14]. In peahen, only the caudal two-thirds of medial border united with the transverse processes of lumbar and sacral vertebral of synsacrum^[21]. In emu, the medial surface of the ilium was completely fused with synsacrum^[1]. The examination of pelvic bone of blue and yellow macaw showed a prominent ridge at the lateral border of the post-acetabular part of ilium behind the ischiatic foramen which continued up to the tip of the caudal process (Fig. 3). This ridge separated the ilium and ischium.

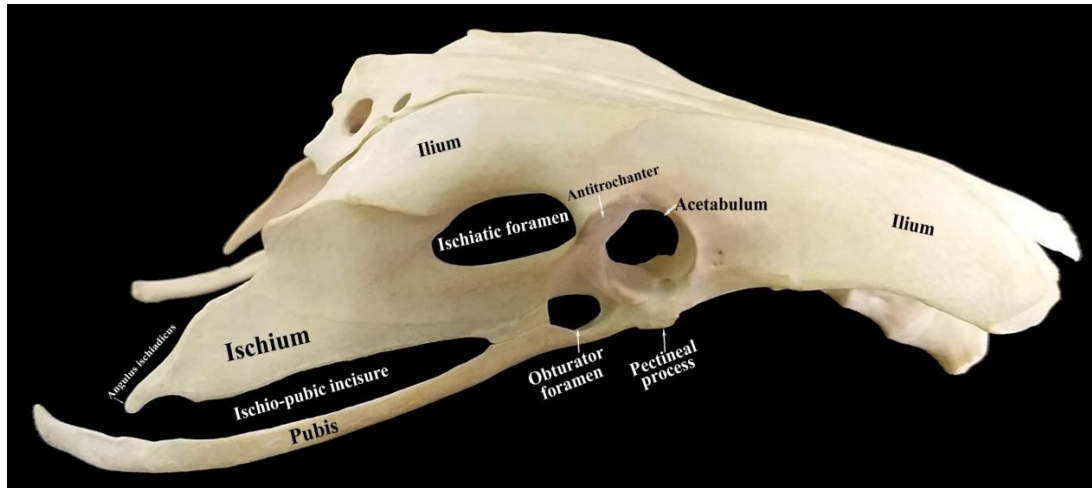


Fig 3: Photograph showing lateral view of the pelvic girdle of blue and yellow macaw

The caudal part of the ilium showed a thin, elongated, straight and caudally extended process, projecting ventrally. Its ventral surface, was fused with the ischium (Fig.3). The caudal process was very distinct and projected dorsally in fowl and^[14], distinct in spot-billed pelicans^[20], but not very distinct in peahen^[21].

The ventral surface of the ilium showed a deep depression on each side of the synsacrum for accommodating kidneys. Caudally it showed a shallow recess with pneumatic foraminae between the post-acetabular ilium and the ischium. This is in accordance with the earlier observations in cattle egret^[15] and Indian eagle owl^[17]. It was also reported that in cattle egret that the renal fossa contained a cranial smaller part the ischiatic fossa, middle pudendal fossa and caudal

invagination as the caudal renal recess^[15]. In contrary, in emu^[13] and in bar-headed goose^[18], no renal fossa was present.

On the pelvic surface of the ilium of blue and yellow macaw, at the caudal end of renal fossa and at the junction of ilium and ischium, two to three large and few small pneumatic foramina were noticed (Fig.4). It extended into thickened caudal border of the ilium and into the ischium indicating that the pneumatisation is present only in ischium. It is in agreement with the earlier findings of very low incidence of pneumatisation in the os coxae of domestic fowl^[8]. In contrary, large number of air cavities were reported in the pelvic bone of peahen^[21].

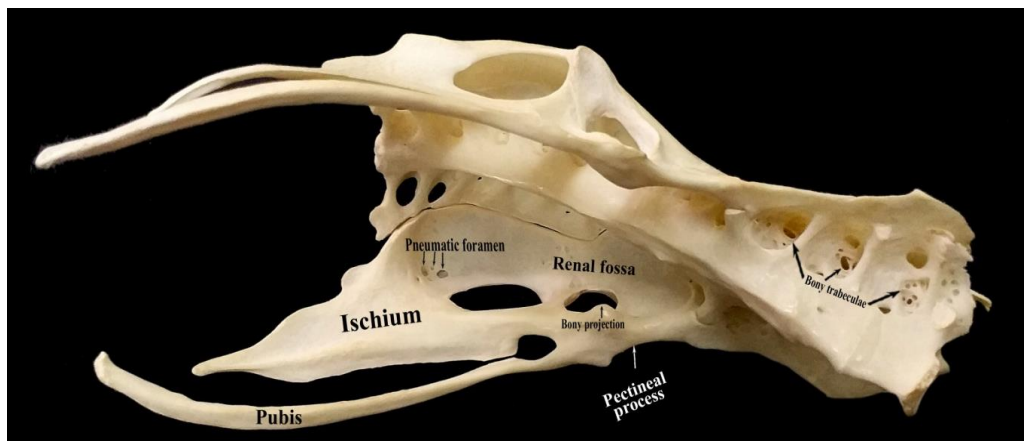


Fig 4: Photograph showing ventrolateral view of the pelvic girdle of blue and yellow macaw

The acetabulum was formed by ilium, ischium and pubis in blue and yellow macaw as in other birds. It was perforated and circular in outline (Fig.3) as observed in fowl [9]. In fowl and duck, the pubis is not involved in the formation of acetabulum [14].

In blue and yellow macaw, the floor of the acetabular ring was broadest, the anterior part was slightly broader, whereas the dorsal and caudal parts of the rim were thin (Fig. 3). The medial (inner) border of the floor of acetabulum cranially showed a small bony projection (Fig. 4) in the present study. The acetabulum was 1.0 cm in diameter. Caudodorsal rim of acetabulum showed a bony prominence with sharp edges carrying a triangular facet, the anti-trochanter as observed in Indian eagle owl [17] and cattle egret [15].

Hertel and Campbell Jr found that the hip joint was formed by antitrochanter in birds, which is unique among all vertebrates. In birds, a significant portion of the femoral pelvic articulation is located outside the acetabulum [7]. Another special feature in birds is the acetabular articulation between the neck of the femur and the antitrochanter. The function of antitrochanter is to provide support so as to prevent abduction of the hind limb and also to absorb stresses on the head of the femur during bipedal locomotion. The drum-in-trough-like form of the antitrochanter-femur articulation facilitates transfer of long axis rotational movements of the femur to the pelvis. In ostrich, the antitrochanter was more obvious [22]. The antitrochanter-femur articulation reinforces weak adductor muscles and limits abduction of the limb [12].

Ischium

The ischium was roughly triangular, thick bony plate. The cranial part of ischium was narrow and participated in the formation of acetabulum (Fig.3), as observed in birds [14]. It was placed ventral to the ilium extending from acetabulum up to the caudal border of os coxae in peahen [21], Guinea fowl and pigeon [11], and Indian eagle owl [17].

In emu, the ischium was a long, round to flat bone, present on the ventral aspect of the ilium. It was separated from the ilium by a long and large sized ischiatic incisure [10]. The caudal extremity was slightly broadened and fused with caudo-ventral end of the ilium by cartilage, but it did not contact with the pubic bone [1]. In ostrich, the ischium was long, narrow and divergent caudally. Its caudal end was flat and slightly extended beyond the ilium [22].

The dorsal border of the ischium behind the acetabulum, enclosed along with the ventral part of the post-acetabular part of lateral border of the ilium, a large, oval foramina, with a pointed caudal end, the foramen ischiadicum (Fig.3), as reported in duck and goose [14] and in Indian eagle owl [17]. This foramen transmitted the ischiatic nerve in birds [12]. In peahen, this foramen was notched caudomedially [21]. In emu, the foramen ischiadicum was in the form of a long ilio-ischiatic incisure [1].

The lateral surface of the ischium of blue and yellow macaw showed a ridge, starting from behind the obturator foramen and extending upwards to the middle of the dorsal border (Fig. 3).

The ventral border of the ischium below and behind the level of posterior rim of the acetabulum, showed a small oval foramina with broad caudal end. Behind this foramen, the ventral border of ischium formed synostosis with the pubis. Behind this a large ischio-pubic incisures (Fig. 3). It is in accordance with the earlier observations in fowl [14], Guinea

fowl and pigeon [11], and Indian eagle owl [17]. But in duck and goose, the pubo-ischiatic incisure was not divided but was a narrow elongated oval incision [14].

The dorsal free border of the ischium was convex, sloping downwards, and extended as a thin, long bony process with pointed end (Fig. 3), as observed in pigeon [11], and Indian eagle owl [17]. The pointed end of angulus ischiadicus is united by a cartilage with pubis in fowl, duck, goose and pigeon [14]. The ventral end of the caudal border of the ischium called angulus ischiadicus was blunt and did not fuse with the pubis in peahen [21]. In emu, the caudal extremity of the ischium was slightly broad and fused with the caudo-ventral end of the ilium, and remained separate at the caudodorsal region of the pubis [1]. In ostrich, the caudal end of the ischium was fused with the pubis.

In blue and yellow macaw the medial surface of the ischium was slightly concave. It showed two ridges, the dorsal one beginning from the projection and the medial border of the floor of the acetabular rim and extending dorsally up to the beginning of the free caudal border of the ischium, another ridge starting from behind the obturator foramen and extending up to the tip of the pointed caudal end of the ischium (Fig. 2). The ventral border of the ischium was sharp. The caudal border of the pelvis was formed by the ilium and ischium, as reported in other birds [14].

Pubis

In blue and yellow macaw the pubis was a thin, rod-like bone which followed the ventral border of the ischium, projected beyond it caudally and bent slightly medially (Fig. 1) and it formed a connective tissue connection with the short angulus ischiadicus in fowl and pigeon [14]. In duck and goose, the pubis extended considerable distance beyond the caudal border of the ilium and ischium, and formed a syndesmotical junction with the plate-like angulus ischiadicus and increases in width from here onwards. In goose, it terminated in a shovel-like process which was curved medially.

The pubis did not project beyond the ilium and ischium in Japanese quail [13]. In Indian eagle owl the caudal end of the pubis was bent medially to meet with its fellow of opposite side [17]. The pubis was narrow anteriorly and wide posteriorly, as in blue and yellow macaw.

The cranial half of the pubis was thin, whereas the caudal half was slight thick. The lateral surface was convex and the medial surface was concave. Its cranial end participated in the formation of acetabulum. In pigeon and goose the pubis participated in the formation of acetabulum, but in fowl and duck it was fused with the ischium below the acetabulum [14].

In ostrich, the pubis was a long slender bone, dorsally concave in front and convex behind [22]. Its caudal extremity extended beyond the ilium and ischium and bent medially and formed pubic symphysis. The pubic symphysis supported the weight of the abdomen. The caudal one third of pubis also fused dorsally with the ischium. In emu, the ischio-pubic incisure was large, and incompletely divided by a blunt projection of ischium into oval obturator foramen cranially and an elongated slit caudally [1].

The pectineal process was rudimentary in blue and yellow macaw (Fig.4), as observed peahen [21]. The pectineal process was long thorn-like in the fowl, absent in pigeon, and rudimentary in duck and goose [14] and served as the origin for pectineus muscle [6]. The pectineal process was small in Guinea fowl and absent in pigeon [11]. The pectineal process

was also absent in Indian eagle owl^[17], Japanese quail^[13] and in spot-billed pelicans^[20]. In emu the pectineal process was slightly broader towards the cranial extremity of pubis to participate in the formation of acetabulum^[10]. The authors also informed that, under development of this process might lead to paralysis of hind limb.

Conclusion

The pelvic girdle of blue and yellow macaw was large, inverted shovel shaped structure. It consisted of two hip bones (ossa coxae), each of which was made up of an ilium, an ischium and a pubis. The space between the pelvic bones was occupied by rhomboid shaped lumbosacral mass. The caudal process was thin and fused with the ischium. The canalis ilioacromialis was not formed. The acetabulum was formed by ilium, ischium and pubis. Caudodorsal rim of acetabulum showed the anti-trochanter. The ischium was roughly triangular, thick bony plate. The ventral border of the ischium below and behind the level of posterior rim of the acetabulum, showed foramen ovale, behind this foramen, a large Ischio-pubic incisure was noticed. The pubis was a thin, rod-like bone which followed the ventral border of the ischium and projected beyond it caudally and bent slightly medially. The pectineal process was rudimentary. Minor but noticeable differences present in the pelvic bone of blue and yellow macaw is due to the adaptations for their flying and terrestrial habits.

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