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INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND STUDIES
ISSN: 2640 7272
Volume:03; Issue:05 (2020)

RESPIRATORY ORGANS IN VERTEBRATES: FUNDAMENTAL DIFFERENCES IN THE BREATHING MECHANICS OF DIFFERENT BIRD AND SKELETAL ADAPTATIONS TO LOCOMOTION

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ABSTRACT

The lungs are specialised organs that are responsible for collecting oxygen from the surrounding air. These may be found in mammals, as well as birds and reptiles. The shape of the lungs can also vary from one species to another, but in general, they are made up of a network of branching tubes known as bronchioles that end in alveoli, which are the air sacs that contain the alveoli. In the alveoli, oxygen diffuses from the air into the blood vessels that surround them, and carbon dioxide diffuses from the blood into the alveoli to be breathed. Oxygen also diffuses in the other direction. This fundamental kind of unicameral lungs and the buccal pumping ventilation that was discovered in these lungs may also be found in more recent amphibians. The process of aspiration is a form of ventilation that has been established by terrestrial vertebrates. It is quite efficient. The lungs of almost all living reptiles today are segmented into three rows of lung chambers each. This results in an increase in the exchange surface area that is directly proportional to the increased metabolic demands of these reptiles. Both the avian respiratory system, with its volume-constant lungs and highly compliant air sacs, and the mammalian broncho-alveolar lung, with its very low compliance, are derived from multicameral lungs. The avian respiratory system has volume-constant lungs, and the mammalian respiratory system has very low compliance. The lung of an animal with a mammalian respiratory system has relatively poor compliance, whereas the lung of an animal with an avian respiratory system has a volume-constant lung..

Keywords: Respiratory , Organs , Vertebrates, Mechanics , Bird , Skeletal , Adaptations , Locomotion

INTRODUCTION

Respiratory organs in vertebrates:

The transfer of gases, chiefly oxygen and carbon dioxide, between an animal and its surrounding environment is facilitated by the respiratory organs found in vertebrates. These organs can be found in a variety of locations and have varying structures depending on the type of vertebrate they belong to..

1. Fishes: Gills are specialised respiratory organs that take oxygen from water and are found on fish. Gills are what give fish its name. Gills are found on the sides of a fish's head and are made up of a succession of thin, flat filaments that are coated in small blood vessels. Gills are essential for respiration. As water passes over the gills, oxygen diffuses from the surrounding water into the blood vessels, and carbon dioxide diffuses from the blood vessels into the surrounding water..

2. Amphibians: Gills and lungs work together in the respiratory system of an amphibian. They have gills as larvae, which are used for breathing in water; as they mature, however, they acquire lungs, which are used for breathing in air on land. The lungs of frogs are little more than simple sacs; in contrast, the lungs of mammals have a far more complicated interior structure..

3. Reptiles: The lungs of reptiles are more complicated than those of amphibians, but their respiratory systems are simpler than those of mammals. The lungs of reptiles are elongated and include a network of internal tubes, both of which enhance the surface area accessible for the process of gas exchange..

4. Birds: The respiratory systems of birds are superior to those of reptiles and mammals in terms of overall efficiency. Their lungs are composed of several air sacs, which are linked to the lungs and contribute to an increase in the flow of air throughout the respiratory system. In addition, birds have a network of air sacs that are distributed throughout their bodies. These air sacs help to provide oxygen to the muscles of the bird so that it can continue to fly..

5. Mammals: Lungs of mammals are highly specialised organs that facilitate the effective exchange of gases. The lungs are made up of millions of extremely small air sacs known as alveoli, and these alveoli are surrounded by a network of capillaries. In the capillaries and the alveoli, an exchange of oxygen and carbon dioxide takes place. The alveoli are responsible for this process..

CIRCULATORY SYSTEM OF VERTEBRATES:

Throughout the bodies of vertebrates, the circulatory system is in charge of carrying oxygen, nutrition, hormones, and waste products to and from the various parts of the body. It is made up of a cardiovascular system, blood arteries, and blood..

1. Fishes: The solitary, two-chambered heart of a fish is responsible for pumping blood via the gills and the remainder of the body to the rest of the animal. Because fishes' blood is pumped in a single circuit, this means that it only travels through the gills once before being distributed to the rest of their bodies..

2. Amphibians: The heart of an amphibian consists of three chambers, and it pumps blood both to the lungs and to the rest of the body. As a result of the oxygenated blood and the deoxygenated blood being partially mixed in the heart, the efficiency of the gas exchange in the lungs is decreased..

3. ReptilesThe number of chambers in the hearts of reptiles can range from three to four, depending on the species. Crocodilians and other reptiles have a four-chambered heart that is split into two sets of atria and two sets of ventricles. This helps to keep oxygenated blood and deoxygenated blood from mixing with one another..

4. Birds: Birds have a cardiac structure that consists of four chambers and is very effective. The anatomy of the heart is comparable to that of a mammalian heart, but it has been modified to accommodate the increased metabolic needs of flying.

5. Mammals: The heart of a mammal has four chambers, and it pumps oxygenated blood to the body and deoxygenated blood to the lungs. Mammals are classified as animals. By having two sets of atria and two sets of ventricles, the heart is able to maintain a separation between the blood that is oxygenated and the blood that is not oxygenated. The circulatory system of animals is extremely effective, which enables them to receive oxygen at a rapid rate and distribute it throughout their bodies' tissues..

OBJECTIVES OF THE STUDY

1. To study on respiratory organs in vertebrates
2. To Study On Circulatory System Of Vertebrates

RESEARCH METHOD

Protocol For Discovery And Histochemistry

At day 25 and day 94, two specimens were taken: one for the purpose of histochemical analysis, and the other for the purpose of biomechanical testing. In order to carry out the histochemistry test, a sample was taken at each of the time intervals that followed. After the de-feathering and removal of the internal organs, the superficial thoracic muscles had to be removed very carefully in order to expose the rib cage. This was done so that the rib cage could be seen. The specimens that were prepared were stained using a procedure that was borrowed from Miller and Tarpley's methodology for examining bone and cartilage in mice. This approach was obtained from their book "Methods for Investigating Bone and Cartilage in Mice." The prepared specimens were examined using this technique in order to identify bone and cartilage (1996). After a period of 72 hours during which the samples were submerged in an Alcian blue solution (Acros Organics, Geel, Belgium; its absorption serves as an indicator of the presence of cartilage), the samples were then maintained in ethanol containing 90% for a duration of 24 hours. This process was repeated three times. After that, the skeletons were rehydrated for two hours in a progression of ethanol solutions (at percentages of 70, 40, and 15%, respectively),

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and then they were washed in distilled water. This process was repeated three times. This procedure was carried out a total of three times.

In the subsequent phase, the remaining muscle tissue was macerated by exposing it to a solution containing 1% KOH for a period of time ranging from 24 to 48 hours. This caused the tissue to break down into smaller pieces. Following the application of repeated treatments with 1% potassium hydroxide as necessary, the skeletons were exposed to a solution of alizarin red (Sigma-Aldrich, St. Louis, MO; to determine the presence of bone) for a period of seventy-two hours. This was done in order to determine whether or not the remains contained bone. The skeletons that had been coloured were ultimately placed in a solution that included glycerol at a concentration of one hundred percent, after first passing through a succession of glycerol solutions with concentrations of 20, 50, and 80 percent, respectively. The entirety of the staining procedure was carried out while maintaining a temperature of 22 degrees Celsius at all times (room temperature).

The numbering of the UP starts at the front of the skeleton and continues forward in accordance with each vertebral rib, which is the point from which each of the UP extends (i.e., the most cranial rib is rib 1, UP 1). Following that, coloured skeletons were examined under a light microscope that had a Leica MZ9s attached to it in order to determine whether or not bone and cartilage were present (Leica Microsystems, Milton Keynes, UK). After that, digital pictures of the ribcage and UP were obtained, and the Leica Application Suite Software was utilised so that the analysis could be carried out. As contrasted with the UP on the ribs that are located in the middle, the UP on the ribs that are located farthest anterior and furthest posterior frequently have a form that is less pronounced (Tickle et al., 2007). The relative area of bone and cartilage was determined for the UP in each of the specimens so that a comparison analysis could be carried out on the results. The term "uncinate process" refers to this area, which may be identified as beginning at the fourth vertebral rib and continuing forward (UP). After taking measurements of both the blue stain regions and the red stain areas, a percentage of the total process area was computed using the data collected from both sets of stains...

Mechanical Evaluation

Nanoindentation was utilised as the instrument for measurement in order to ascertain the value of the elastic modulus at the bottom of the UP. The data obtained from the rib histochemistry was utilised in the procedure, and vertebral rib 4 was dissected from the right-hand side of typical specimens taken on days 25 and 94. After being dehydrated for twenty-four hours in ethanol with a concentration of ninety-five percent, the specimens were then embedded in a noninfiltrating polyester resin. (Kleer set; Metprep Ltd., Coventry, UK). Using atomic force microscopy, the surface topography of the samples was scanned so that accurate estimations of the materials' mechanical parameters could be made. This made it possible to pick areas of the samples that had a relatively smooth surface for the indentation operation. After that, an evaluation of the materials was carried out with the assistance of a nanomechanical instrument known as a TriboScope, which was supplied by Hysitron Inc. in Minneapolis, Minnesota. Nanoindents were created by exerting a maximum loading force of 5,000 N on a tetrahedral diamond Berkovich indenter tip. This resulted in the formation of the nanoindents. As a direct consequence of this, the nanoindents were produced. The combination of the indenter's sensing of force and displacement results in the production of a nanoindentation curve. This part of the curve is known as the loading phase, and it occurs when the tip is driven into the material with the maximum amount of force. During the holding phase, the tip will gradually make its way into the material. During the unloading step, the tip is separated from the material being processed (force on the sample is released; Hengsberger et al., 2001). Following that, the equations that Oliver and Pharr had created were utilised by applying them to the unloading force-displacement curve in order to calculate the lowered modulus (1992, 2004). In order to facilitate the process of computing the elastic moduli, it was assumed that the Berkovich tip had an elastic modulus of 1,140 GPa and a Poisson ratio of 0.07. Because cartilage and bone in the UP of persons of differing ages are found in a variety of configurations, the elastic moduli were determined by applying separate Poisson ratios. This was done due to the fact that cartilage and bone are present in different arrangements. We chose a value of 0.3 for bone (Rho et al., 1997; Zysset et al., 1999), which is consistent with the values that have been published, and we used a value of 0.5 for cartilage (Mak et al., 1987; Wong et al., 2000). Both of these values are in accordance with the values that have been published.).

DATA ANALYSIS

Ossification and morphology of the vertebral ribs at the appropriate times

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There were seven vertebral ribs in turkey embryos and chicks, but only five of them were joined to a sternal rib in pairs. Vertebral ribs 1 and 2 were not joined to a sternal rib. In all of the specimens, the UP was found on ribs 2 through 6. On vertebral rib 1, an extremely brief UP was seen in specimens collected on days 15, 19, 20, 25, and 31. On rib 7, the UP was not present in any of the specimens. Because of their smaller size and different form, UP 2 and 6 only play a supporting function in the ventilation system (Tickle et al., 2007). Uncinate process 4 was regarded to be typical due to the simplicity with which it could be compared to other uncinates, as well as the fact that the time of ossification and morphology were comparable in UP 3, 4, and 5..

Days 14 to 21

Until day 18 of incubation, the rib cage had the appearance of cartilage, but at that point, all of the vertebral ribs had already begun to ossify. Ossification of the vertebral ribs had been completed by day 21, with the exception of the ventral tip, capitulum, and tuberculum. On day 19, bone development was observed in the sternal ribs that correspond to the vertebral ribs number 5 and 6. On day 20, the sternal ribs that were associated with vertebral ribs 4 and 7 started the process of ossification, whereas on day 21, the sternal rib that was paired with vertebral rib 3 started the process of bone proliferation. Throughout this time span, the sternum did not change from its cartilaginous state in any way. By day 17, the typical adult morphology of the UP had already been established, but they retained their cartilaginous nature. In comparison to the UP on the ribs 3, 4, and 5, the UP on the 2 and 6 looked to be bent and were on the shorter side. The uncinate process number 3 had a straight configuration with a flared base, but the UP 4 and 5 had an L-shaped configuration with a protruding tip (Figure 1A, 2). During these phases, the uncinate process 4 was composed exclusively of cartilaginous tissue (Figure 1A, 2A, 2D).).

Days 22 to 28

On day 22, process 5 was initiated, which marked the beginning of ossification of the UP. By day 23, UP 2 through 5 had begun to develop bone. Due to the fact that the time of the ossification of process 2 differed between specimens, bone development in some birds was not discovered until after they had hatched. The cartilaginous tip and base of the process were reached by bone proliferation that started in the middle of the process. In Figure 2B, we can

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see that both the vertebral and sternal ribs have undergone extensive ossification. On day 24, however, the formation of the sternal bone begins in the cranial aspect of the keel. During this time, rapid ossification brought the bone area of process 4 up from 13 to 37% of the total (Figure 1B, 1C, 2D).).

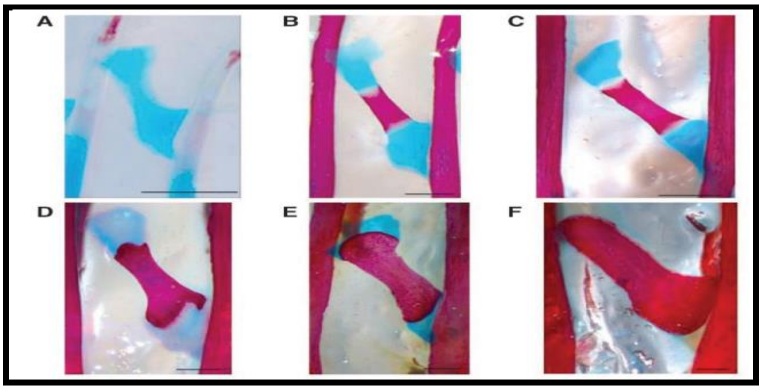

Figure 1 Pattern of ossification of uncinate process 4 from 19 to 94 days old. (A) d 19 embryo, stained Alcian blue, 25; (B) d 25 embryo, Alizarin red staining locates the ossification site, 20; (C) d 28 chick, additional bone development obvious, 20; (D) d 36 chick, 20; (E) d 49 bird, 12.5; and Scale bars indicate 1 millimetre.

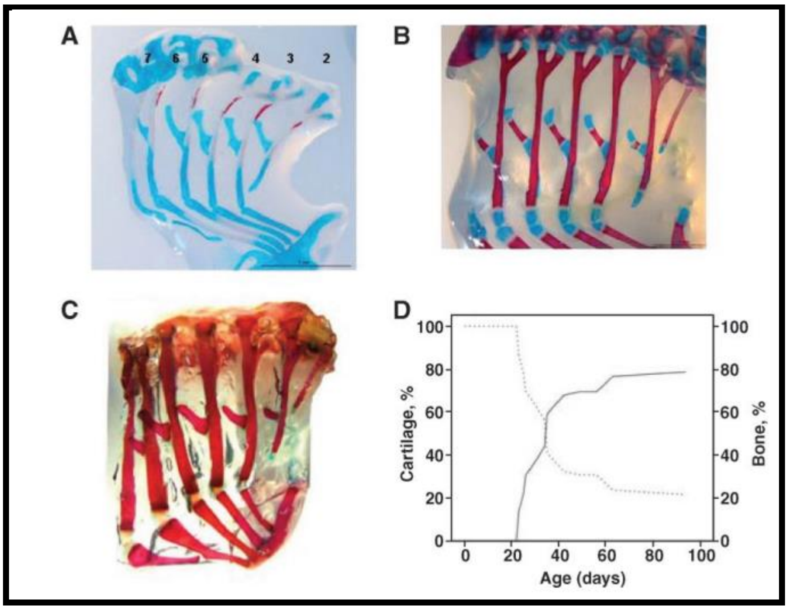

Figure 2 Skeletons that serve as examples, illustrating how ossification develops during the course of ontogeny. (A) the uncinate processes (UP) of the d 19 embryo are cartilaginous, whereas ossification has begun in the vertebral ribs (rib 1 is missing), 8.

(B) the d 28 chick has extensive bone growth in the ribs, whereas ossification is apparent in UP, 6.3. (C) the d 90 bird has reached an advanced stage of ossification in the ribs and UP The anterior region is located to the right. The numbering of ribs begins at the front of the body. 5 millimetre scale bar (D) For the uncinate process 4, the percentage of cartilage (shown by the dotted line) and bone (represented by the solid line) from day 14 to day 94.

The shape of the UP in adult birds is connected to the sternum's adaptations to the various modes of movement that birds engage in. The UP are short in birds that walk or run, intermediate in nonspecialists, and lengthy in diving species; the length of the UP is proportional to the length of the sternum (Tickle et al., 2007). There may be basic variations in the ventilatory mechanics of different species of birds associated to morphological adaptations to different modes of movement in birds. [Citation needed] (Tickle et al., 2007). For instance, the mass of the flight muscles accounts for up to 35% of the total BW in certain species of flying birds (Dial et al., 1988), which may have an effect on the timing of UP ossification. [Citation needed] On the other hand, it is not known for certain if the pattern of ossification also alters throughout ontogeny in species that are specialised to swimming, flying, or running.

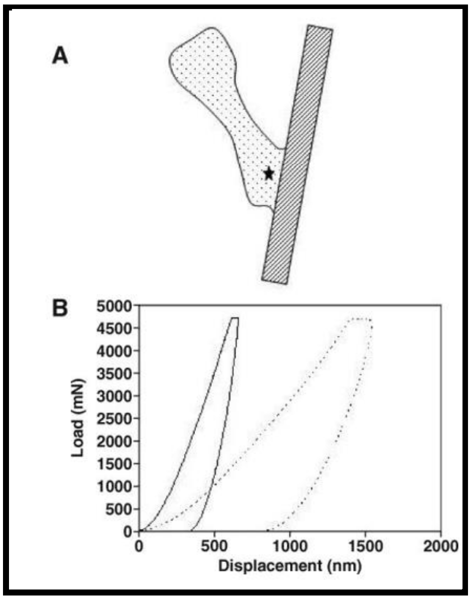

Figure 3 (A) The site (star) chosen for nanoindentation is shown on the diagram of uncinate process 4 and the surrounding vertebral rib. (B) Exemplary load displacement curves produced by indents in uncinate process 4 from d 25 (broken line) and d 94

(solid line) turkeys are shown. The fact that the unloading curve for the d-94 specimen is steeper than the one for the d 25 specimen suggests that the process is more rigid. The slope of the unloading phase for each sample is utilised as an input into the equations developed by Oliver and Pharr (2004), which are then used to compute the mean elastic modulus.).

DISCUSSION

The mechanical model that was developed for this paper suggests that the uncinate process functions as a lever, increasing the mechanical advantage of the Mm. appendicocostales. This is especially true when the ribs are at a low angle to the backbone, as this assists the Mm. appendicocostales in rotating the dorsal ribs forward, which in turn pushes the sternum down and causes the lungs to expand. This view is supported by the findings of the real mechanical advantage of the four representative species that were assessed, which was based on the model. In every instance, the mechanical advantage improved by a ratio of two to four in comparison to what it would have been if there had not been an uncinate process present; however, the impact was felt to a lesser extent in the diving species, which is the razorbill. These findings can help shed light on the two main findings of the morphometric study, which are: first, that the anterior and posterior uncinates are shorter than the intermediate ones; and second, that the uncinates and sternum of diving birds were relatively longer than those of walking birds, with non-specialist birds having uncinates and sternum of intermediate length. The morphometric study was conducted on birds. When it comes to birds, the sternum serves as the attachment point for the major flying muscles, including the pectoralis and the supracoracoideus (Duncker, 1971). Some birds' pectoralis muscles can make up as much as 35 percent of their total body mass (Dial et al., 1988). During the process of breathing, this enormous muscular mass, together with the viscera of the abdominal cavity, must be pushed up and down (Brainerd, 1999). The entrainment of wing beat with sternal motions (Jenkins et al., 1998) and the fact that birds can suffocate if the movements of the sternum are limited both underscore the significance of the movements of the sternum (Ludders et al., 2001). According to Codd et al. (2005), there is a functional relationship between the sternal and uncinate morphology and the breathing mechanics in birds. The uncinate processes also act as a brace for the insertion of the M. obliquus externus, which pushes the sternum dorsally to induce expiration. The sternum of walking birds is shorter, which coincides with this group having the shortest length processes, whereas the sternum of diving birds is longer, which connects with this group having the longest length processes. It is possible that differences in uncinate morphology translate into anatomical differences in the associated musculature, such as the Mm. appendicocostales and M. obliquus externus. This would imply that different patterns of muscle activity facilitate breathing; however, this is something that still needs to be determined..

CONCLUSION

There is a correlation between the style of locomotion and the morphology of the rib cage, specifically the length of the uncinate processes. It is possible that the uncinates play a smaller role in the breathing process of walking species because their length is shorter. If this is the case, then muscles like the Mm. intercostalis externi may play a significant role in the inspiration process of walking birds. Whether or not this is the case is something that needs to be investigated further. The lengthening of the ribs, rib cage, and sternum that is related with streamlining in diving species shows that there may also be variations in the way that they breathe. The insertion of the Mm. appendicocostales towards the end of the tip of the processes may further improve the mechanical advantage for moving the elongated ribs during breathing in diving birds because of the increased length of the processes. This is because diving birds have an increased length of the processes. Our comprehension of the anatomical variances in musculature that are connected with variations in uncinate morphology may be improved by further research in the future. It is yet unknown if the uncinate processes serve any other roles; for instance, the role that the uncinate processes play in maintaining the stability of the scapula while the wing is retracted is not something that has been investigated in this study. Additionally, the 'finger-like' projections of the M. obliquus externus abdominus insert onto the base of the processes, and in the opposite manner, the M. serratus superficialis originates at the top of the processes and inserts on the ventral margin of the scapula (Vanden Berge and Zweers, 1993), which suggests that they may act antagonistically against one another. Differences in the morphology of the uncinate appear to be related, either directly or indirectly, to changes in the breathing muscles themselves or in the pattern of muscular activity. It has been revealed that a significant number of axial muscles are engaged in the complicated respiratory process of Aves (Fedde, 1987). This research suggests that there may be fundamental differences in the breathing mechanics of different birds, driven in part by the morphological differences of the rib cage and sternum associated with skeletal adaptations to locomotion.

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