Evaluation of the metabolic status in extant Amniota based on nasal structures

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Dinosaurs are one of the best known, most intensively studied and most successful clades of tetrapods. Since they were recognized as a distinct lineage of vertebrates in the 19th Century, one of the main research focuses on dinosaurs has been their physiology, especially concerning the question “Were dinosaurs warm-blooded (endotherm) or cold-blooded (ectotherm)?” Endothermic animals regulate their body temperature by internal heat production, whereas ectotherms depend on external heat sources. Deciphering the metabolic status of dinosaurs would help improve our understanding of their ecology and evolutionary changes leading to extant birds.

One potential “Rosetta stone” for thermal physiology is the nasal turbinate. It is a scroll-like structure in the nasal cavity and is present only in endotherms (birds and mammals) among extant tetrapods. This structure increases the surface area and volume of the nasal cavity for efficient heat and water exchanges between the respiratory mucosa and inhaled- and exhaled-air, thus compensating for extra heat and water losses caused by efficient lung ventilation in endotherms. Because the degree of development of the nasal cavity is expected to be correlated with the form and size of the nasal cavity, characteristics of the latter are potentially informative in evaluating the metabolic status of amniote animals, especially fossil forms.

Before tackling the question on dinosaur metabolism, it is necessary to establish a quantitative relationship between the metabolic condition and size of the nasal structure in extant amniotes so that could be applied to extinct species.

In the present study, heads of more than 40 extant species were CT-scanned and their nasal cavities were digitally reconstructed three-dimensionally based on the scanned data. The surface area and volume of the nasal cavity were then measured as size parameters of this structure. These values were plotted against the skull volume for comparison between endotherms and ectotherms.

The result shows a clear difference in the slope of the regression lines between endotherms and ectotherms. As expected, endotherms have significantly larger nasal cavities than ectotherms, likely reflecting the existence of the nasal turbinates. In contrast, however, there is no significant difference detected in the slope of the regression lines between them when those size parameters of the nasal cavity was plotted against the whole body weight. One possible explanation for such a difference is that, because the head region houses the brain, an organ metabolically highly consumptive, and endotherms tend to have a relatively larger brain than ectotherms, so the skull volume may be more tightly correlated with metabolic conditions than the body weight. The body weight also tends to have a lager margin of the error than the skull volume because the former sometimes needs to be estimated rather than being directly measured (e.g., cases of alcohol-preserved specimens).

These results suggest that it may be possible to infer metabolic conditions of amniotes based on the size of the nasal cavity. Applying the above relationship to the fossil record of non-avian dinosaurs will contribute to clarifying the evolutionary changes in metabolism toward fully endothermic extant birds.

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