CT examination of the manipulation system in the giant panda (*Ailuropoda melanoleuca*)

HIDEKI ENDO[1], YOSHIHIRO HAYASHI[2], DAISHIRO YAMAGIWA[2], MASAMICHI KUROHMARU[2], HIROSHI KOIE[3], YOSHIKI YAMAYA[4] AND JUNPEI KIMURA[5]

[1] *Departments of Zoology, National Science Museum, Tokyo*, [2] *Department of Veterinary Anatomy, Faculty of Agriculture, The University of Tokyo, and* [3] *Animal Medical Center*, [4] *Laboratory of Veterinary Surgery, and* [5] *Department of Veterinary Anatomy, College of Bioresource Sciences, Nihon University, Kanagawa, Japan*

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ABSTRACT

The manipulation mechanism of the giant panda (*Ailuropida melanoleuca*) was examined by means of CT (computed tomography) and 3-dimensional (3-D) Volume Rendering techniques. In the 3-D images of the giant panda hand, not only the bones but also the muscular system was visualised. Sections of the articulated skeleton were obtained. It was demonstrated that the hand of the panda is equipped with separately moulded manipulation units as follows: (1) the radial sesamoid (RS), the radial carpal, and the first metacarpal (R–R–M) complex; and (2) the accessory carpal (AC) and the ulnar (A–U) complex. When the giant panda grasps anything, the R–R–M complex strongly flexes at the wrist joint, the RS becomes parallel with the AC, and the phalanges bend and hold the object. It is shown that the well-developed opponens pollicis and abductor pollicis brevis muscles envelop and fix the objects between the R–R–M complex and the phalanges during grasping.

Key words: Osteology; myology; radial sesamoid bone; Volume Rendering.

INTRODUCTION

Since the beginning of the 20th century, many anatomists have been attracted by the development of the huge radial sesamoid bone (RS) in the giant panda (*Ailuropoda melanoleuca*). The grasping pattern using the RS in the panda has been considered as one of the most extraordinary manipulation systems in mammalian evolution (Lankester & Lydekker, 1901; Pocock, 1939; Gould, 1978). From the detailed morphological data, some reports advocated the theory that the large RS acts as an active manipulator and that the giant panda skilfully grasps bamboo stems between the RS and the opposing palm (Wood-Jones, 1939*a*, *b*; Davis, 1964; Beijing Zoo et al. 1986). This theory was based on limited morphological data and the characteristic RS has been generalised and named the 'Panda's pseudo thumb' or 'Greifballen' (Schneider, 1952; Bourlière, 1955; Lessertisseur & Saban, 1967; Chorn & Hoffmann, 1978). We recently pointed out, employing CT and MRI, that the radial sesamoid bone does not actually act as an active manipulator and that the double pincer-like functional units and hammock-like muscle apparatus represent an effective grasping mechanism (Endo et al. 1999). Here, we report observations on both the skeletal and muscular systems in 3-dimensional (3-D) reconstructions and processed images to clarify the action of manipulation in the giant panda.

MATERIALS AND METHODS

The carcass of an adult female giant panda was donated to National Science Museum, Tokyo, from Ueno Zoological Park (Tokyo, Japan). After pathological dissection, it had been stored in a −20 °C cold room until the CT examination. After removing the skin, CT scanning methods were applied to the forelimbs to elucidate the bone movements and muscle

Correspondence to Dr H. Endo, Department of Zoology, National Science Museum, Tokyo, Shinjuku-ku, Tokyo 169–0073, Japan.

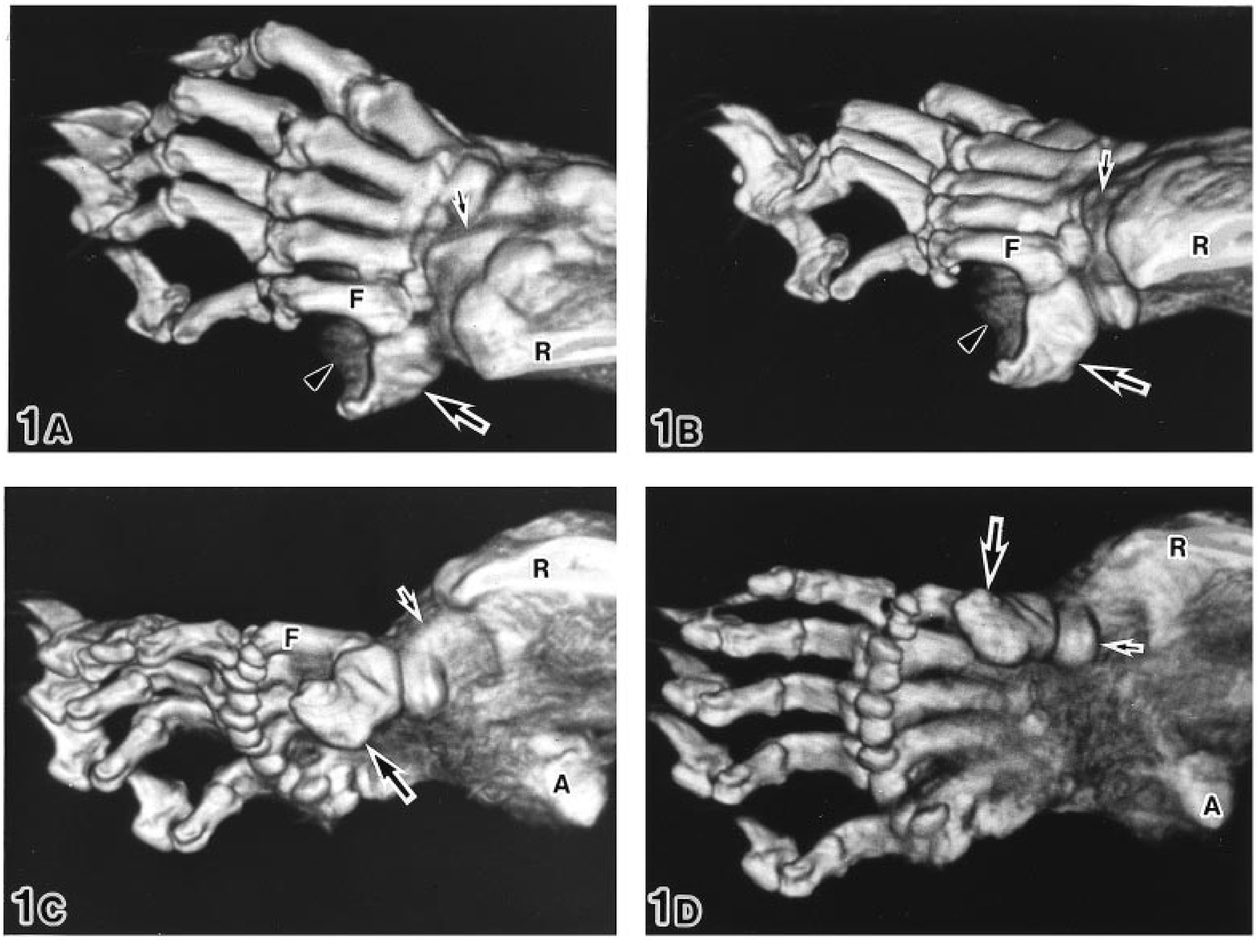

Fig. 1. Three-dimensional reconstructed CT images of the right hand and wrist of the giant panda. Images of the opened state are rotated (*A–D*). The radial sesamoid in the medial part of the hand is huge. The RS and the AC protrude at obviously different angles from the palmar plane (*C*, *D*). Large arrow, radial sesamoid; small arrow, radial carpal; F, first metacarpal; arrowhead, bundles of opponens pollicis and abductor pollicis brevis bundles; A, accessory carpal; R, radius. A distal part of the radius is cut out at the digital level to show other bones clearly.

actions involved in grasping. The distal part of the limbs was serially sectioned by a medical diagnostic CT scanner (CT-W450-10A; Hitachi Medical Corporation, Japan) from medial to lateral planes in parallel with the first metacarpal bone, and from proximal to distal planes vertical to the first metacarpal, with a thickness of 2 mm and without interslice gaps. The hand was artificially positioned on the CT scanning machine in both opened and gripped states. The carcass hand gripped the centrifuge tube or a plastic stick 30–40 mm in diameter to reproduce the manipulating state. We reconstructed 3-D images of bone movements and muscle actions in the hand and wrist area from the series of CT sections, and made sections of articulated bones in the 3-D fields. We applied Voxel Transmission (Volume Rendering) techniques to visualise the images of bone movements and muscle actions with a 3-D image analyser (PRIMA: Hitachi Medical Corporation, Japan).

RESULTS

The 3-D image series demonstrated that the 3 bones, the radial sesamoid (RS), radial carpal (RC), and first metacarpal (FM) are strongly connected and are actually moulded into single functional unit in the medial side of the hand (Figs 1–3). In the lateral side of the palm, the accessory carpal (AC) does not abduct or adduct independently of the ulna. These 2 bones act as an inseparable structure in the action of manipulation. We termed these double pincer-like functional units the R–R–M complex and the A–U complex respectively in our recent report (Endo et al. 1999).

The immobility between the RS and FM in the R–R–M complex is evident in the 3-D field (Fig. 3). The RS and FM are strongly attached in the articulation and are unable to move independently. In the R–R–M complex, the RC connects with the RS in

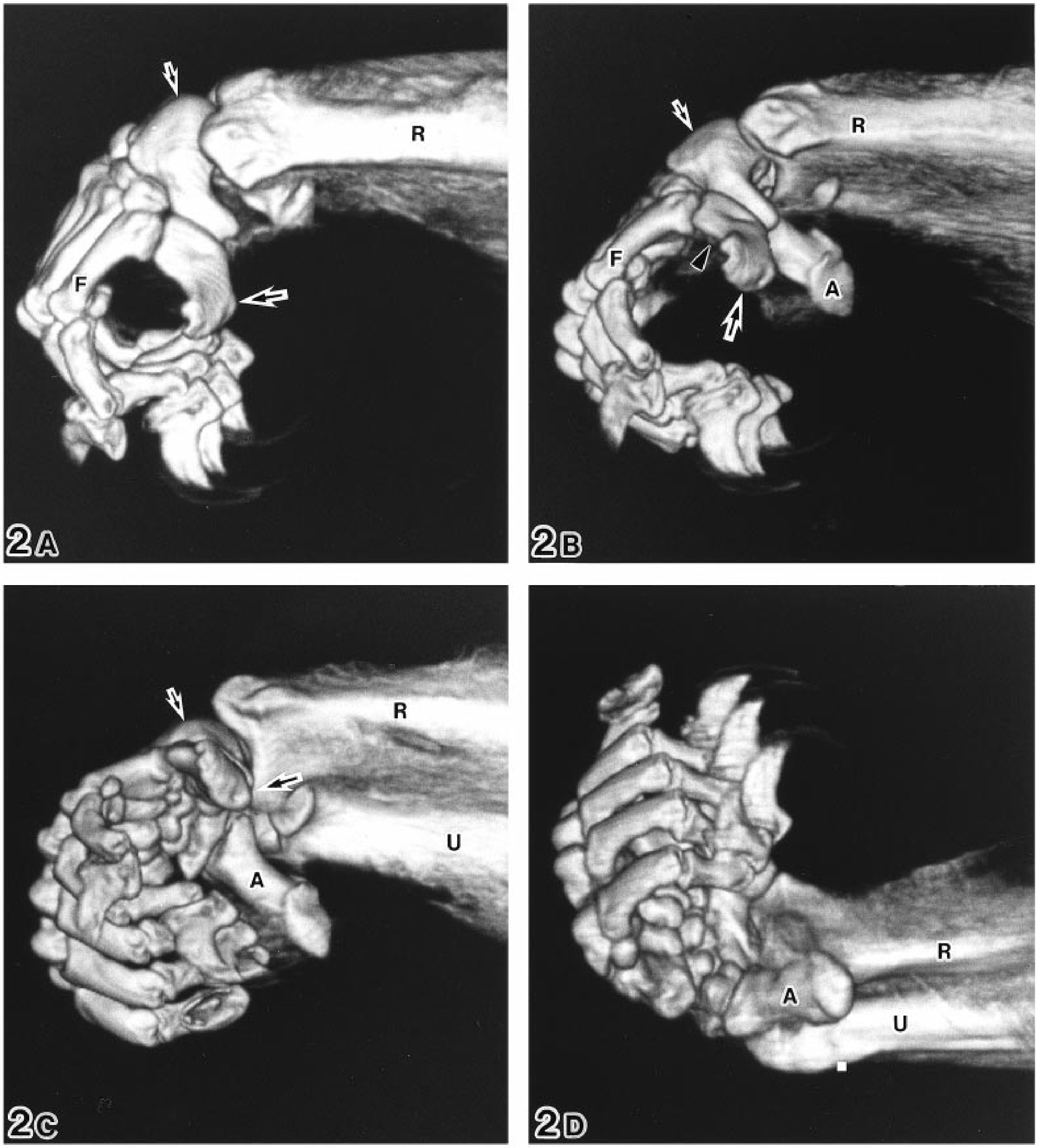

Fig. 2. For legend see page 298.

its proximal area. It possesses an enlarged articulated surface with the distal end of the radius which enables the panda to flex the wrist joint strongly. In the gripping action, the radius-articulated surface of the RC can be observed in the dorsoproximal view (Fig. 2 *A*, *B*, *E*, *F*).

The RS and the AC protruded at obviously different angles from the palmar plane in the opened hand (Fig. 1), whereas the RS and the AC became positioned in a parallel direction as a result of wrist flexion (Fig. 2). Furthermore, the 5 long phalanges are crooked and these distal bones are parallel with the direction of the radius and ulna.

We confirmed the muscle actions of the R–R–M complex in the 3-D reconstructed images (Fig. 2). Well-developed bundles can be seen between the RS and the FM in the opened state. In the action of gripping, however, the muscle images are lacking in

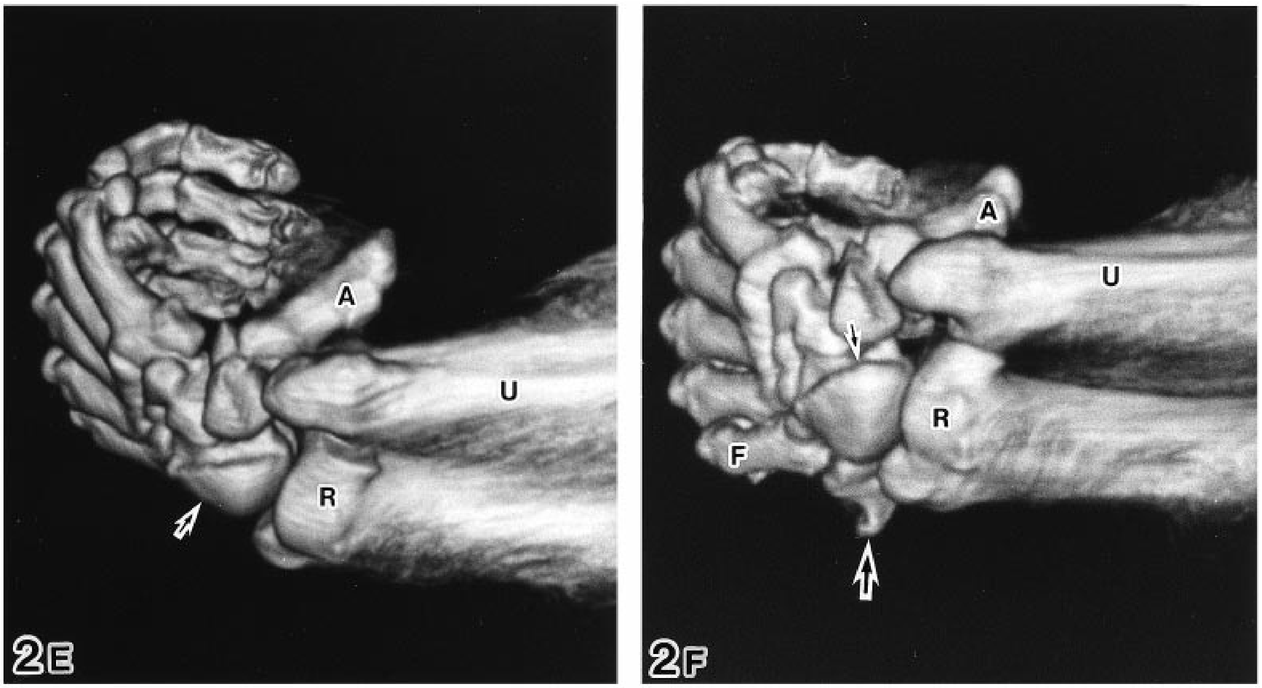

Fig. 2. Three-dimensional reconstructed CT images of the right hand and wrist of the giant panda. Images of the gripped state are rotated (*A–F*). The hand grasps the plastic stick in the palmar area. The radial carpal bone possesses an enlarged articulated surface with the distal end of the radius (*A*, *B*, *E*, *F*). The radial sesamoid and the accessory carpal become positioned in a parallel direction as a result of wrist flexion (*B*, *C*). The 5 long phalanges are strongly crooked to grasp the object. Well-developed muscle bundles are no longer evident in the space between the RS and the FM unlike the situation in Fig. 1. The thin images mean that the muscle bundles surround the stick and conform to the circular shape of the stick. Large arrow, radial sesamoid; small arrow, radial carpal; F, first metacarpal; arrowhead, the thin images of opponens pollicis and the abductor pollicis brevis bundles; A, accessory carpal; R, radius; U, ulna.

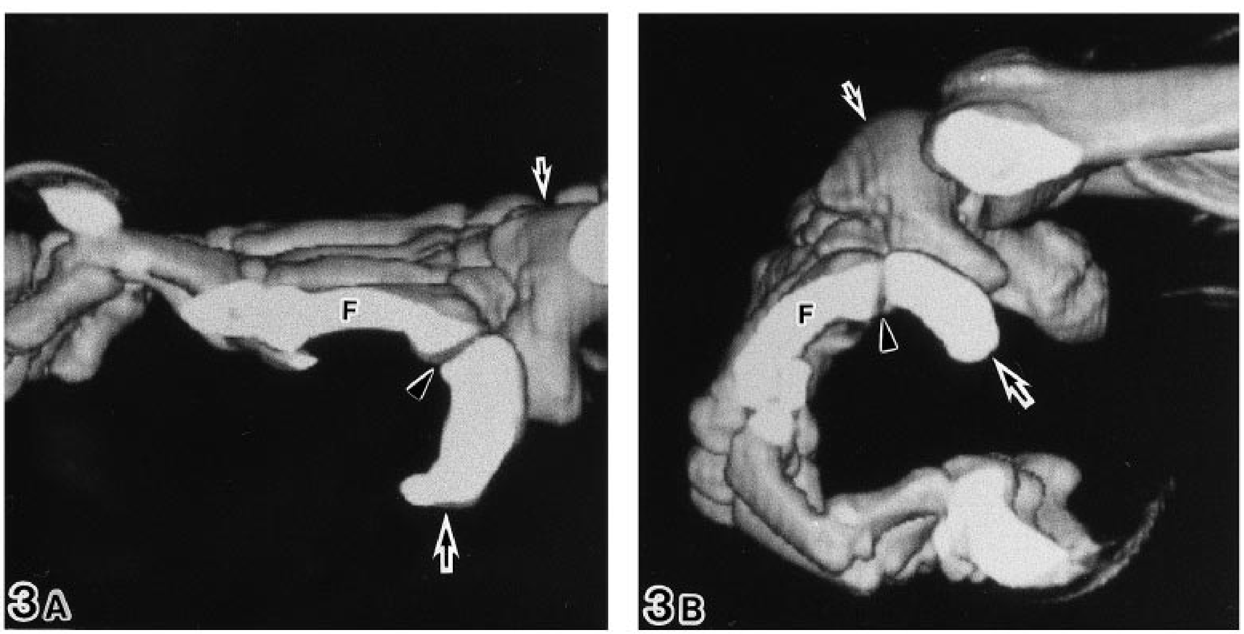

Fig. 3. Sections of the right hand in parallel with the first metacarpal processed from the 3-D CT images. Medial aspects of opened (*A*) and gripped (*B*) states. Proximal direction to the right. The radial sesamoid (large arrow) is strongly attached to the first metacarpal (F) in the articulation area (arrowhead). Small arrow, radial carpal.

the space between the RS and the FM. We identified only thin images of muscles in the inter-bone space between the RS and the FM.

DISCUSSION

It is true that the data are dependent on postmortem observations, but we were able to examine the mobility of the articulations and muscles carefully in the carcass and avoid experimental artifacts in reproducing the exact gripped state.

From the present observations we demonstrated that the phalanges, the metacarpals, the RS and the AC clearly grasp objects in the space on the palmar side of the hand during the action of gripping. The RS and AC are not active manipulators independent of the bones with which they articulate in any gripping state, but constitute functional complexes. We can conclude that the giant panda flexes and extends the doubler pincer-like apparatus, the R–R–M complex and the A–U complex, during the action of grasping. In this refined system, the giant panda is equipped with the virtual but functional opposability between the phalanges and the double pincers. Because the AC strongly articulates both with the ulna and the ulnar carpal (Davis, 1964), we suggest that the A–U complex actually includes the ulnar carpal as a functional unit.

Pocock (1939) and ourselves (Endo et al. 1996) suggested that the RS may not be independently mobile and we pointed out that the RS is only a supporting process opposite the flexing digits. The digital section data of Figure 3, revealing the immobile attachment between the RS and FM, is consistent with these suggestions. Many reports documented that the muscles attached to the RS, i.e. abductor pollicis longus, abductor pollicis brevis and opponens pollicis possess well-developed bundles (Wood-Jones, 1939*a*; Davis, 1964; Beijing Zoo et al. 1986; Endo et al. 1996). Thin images of muscles can be seen in the R–R–M complex in the present 3-D CT data. They demonstrate that both the abductor pollicis brevis and opponens pollicis adjust the inter-bone space of the R–R–M complex to grasped objects and serve as a fixation mechanism for items grasped between the RS and the FM. The muscle direction oriented between the RS and the FM, which has been demonstrated from macroscopic observations (Davis, 1964; Endo et al. 1996), is also consistent with the fixation action of abductor pollicis brevis and opponens pollicis shown in Figures 1 and 2. These findings indicate 3-dimensionally the hammock-like function of these 2 muscles, which was assumed in our recent study (Endo et al. 1999).

The giant panda belongs phylogenetically to the family Ursidae (Corbet & Hill, 1991; Talbot & Shields, 1996). This species evolved from typical bear-like carnivores that did not display first metacarpal and digit opposability in their hand structure. The adaptation for a herbivorous diet required the species to skilfully manipulate bamboo stems in Asian forests. We suggest that the panda could not arrive at any solution other than the double-pincer mechanism. The traditional view of the 'panda's pseudo thumb' has been established since the beginning of the 20th century (Lankester & Lydekker, 1901; Pocock, 1939; Wood-Jones, 1939*a*, *b*; Bourlière, 1955; Davis, 1964; Lessertisseur & Saban, 1967; Beijing Zoo et al. 1986). We point out that the huge RS is really only a component of a functional unit necessary for manipulation in the hand of the giant panda.

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