Original Article

Contrast radiographic anatomy of the gastrointestinal tract of white-bellied pangolin

Adepeju T Ogunleye, Adenike O. Olatunji-Akioye, Benjamin O. Emikpe[1], Theophilus A. Jarikre[2], Oladipo O. Omotosho[3], Morenikeji Olajumoke A[4]

Departments of Veterinary Surgery and Radiology, [2]Veterinary Pathology and [3]Veterinary Medicine, Faculty of Veterinary Medicine, University of Ibadan, [4]Department of Zoology, Faculty of Science, University of Ibadan, Nigeria, [1]Department of Veterinary Pathobiology, School of Veterinary Medicine, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract

Context: Pangolins are scaly ant-eating placental mammals threatened with extinction due to over-exploitation and poaching. Aggressive protection by conservationists is moderately successful due to scanty information regarding their physiology.

Aims: Contrast radiography, a diagnostic technique for investigating gastrointestinal diseases may assist conservation efforts to improve the survival of these animals.

Subjects and Methods: Eight rescued white-bellied pangolins of different ages, sexes, and weights were evaluated. Four live ones; with a mean weight of 1.52 ± 0.3 kg were radiographed and measurements taken by Digimizer. Four others had an opportunistic necropsy done and gross measurements of the gastrointestinal tract. Sedation with Ketamine caused uncurling, facilitated handling, and barium was administered orally. Serial dorso-ventral and lateral radiographs, physiological parameters, gastrointestinal dimensions, and contrast images were acquired.

Results: The oral cavity was oval-shaped with no teeth; the long thin tongue runs beside the esophagus and contrast within the stomach 0 min postadmin lends credence to the length of the tongue just proximal to the stomach at the 8th thoracic rib. The plain radiograph revealed stones within the stomach at the 10th thoracic rib. The esophageal length, stomach length, and width radiographically, were 201.38 ± 1.70, 95.42 ± 1.9, and 53.02 ± 16.70 mm while the gross gastric length, diameter, and intestinal length were 7.1 ± 0.12, 13.3 ± 0.4, and 220.21 ± 4.03 cm, respectively. The mean contrast transit time was 1.34 ± 0.65 h-stomach, 0.48 ± 0.48 h-small intestines, and 10.00 ± 5.76 h-large intestines. Compared to mean transit times in dogs, it is longer but shorter when the transit times are compared to mean transit times in rats.

Conclusion: Average transit time of the digestive tract is consistent with the reported average in dogs (3 ± 1.5 h). Implications for feeding and gut health in pangolins can assist in understanding critical care and boost conservation efforts.

Keywords: Gastrointestinal transit time, imaging, pangolin, radiographic anatomy

Address for correspondence: Dr. Adenike O. Olatunji-Akioye, Department of Veterinary Surgery and Radiology, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Nigeria.
E-mail: bonik2001@yahoo.com

Submitted: 19-Oct-2021 **Revised:** 08-May-2022 **Accepted:** 21-Jun-2022 **Published:** 15-Nov-2022

Access this article online	
Quick Response Code:	Website: www.wajradiology.org
	DOI: 10.4103/wajr.wajr_36_21

How to cite this article: Ogunleye AT, Olatunji-Akioye AO, Emikpe BO, Jarikre TA, Omotosho OO, Olajumoke AM. Contrast radiographic anatomy of the gastrointestinal tract of white-bellied pangolin. West Afr J Radiol 2022;29:8-14.

INTRODUCTION

Pangolins are scaly ant-eating placental mammals belonging to the order Pholidota and family Manidae.[1] They have a distinct lizard-like appearance (almost looking like a reptile) with their bodies covered with large, overlapping keratinized scales, except for their face, neck, stomach, chin, and snout. These scales are usually soft on newborn but become hard as the animal matures.[2] There are eight extant pangolin species recognized in the world which are threatened with extinction due to overexploitation, destruction of their habitat, and poaching for their meat and scales in the local and international wildlife trade.[3-5] The important values of pangolins are as medicine and food. In the meantime, the species used for medicine and food in China are Chinese pangolin and Malayan pangolin, while Indian pangolin is seldom used.[3] All pangolin species are listed in the Convention on International Trade in Endangered Species[6] which Nigeria is a signatory to. The African species of pangolins differ from the Asian species by having a double row of scales which starts from two thirds of the waist to the tip of the tail. The Asian species are also distinguished from African species by the presence of hairs which emerge from between the scales. Some African species of pangolins can be found in West Africa while some are distributed in the eastern and southern parts of Africa.[7,8] It is estimated that a pangolin eats about 200,000 ants per day.[9] They are toothless and unable to chew, but they have an extremely long, thin, and sticky tongue which they use to slurp up ants.[9,10] Their tongue extends into the abdominal cavity, and is supported by a specialized hyoid apparatus.[11] They have short and powerful limbs which are covered with scales, with their forelimbs having sharp and clawed digits that are large and used for digging into termite mounds and ant hills.[12] They have a gizzard-like stomach which is specially adapted for grinding food.[8] Pangolins have been reported to be common in many zoos before the 1970s, but many died due to problems with diet. However, the Taipei zoo in Asia has been reported to have successfully conserved over 20 pangolins through their improved feeding and husbandry practices.[13-15]

The wild population of pangolins has reduced drastically as a result of poaching and habitat destruction pushing these animals to the edge of extinction; rescuing pangolins from traffickers and enabling their breeding captivity is an important way of protecting these species from extinction. To further enhance conservation, understanding of the morphology and structure of this animal is critical to disease diagnosis and management, especially with the use of noninvasive diagnostic procedures which include radiography.

Radiography is an essential diagnostic tool in small animal practice. Plain abdominal radiographs may provide useful information in the diagnosis of gastrointestinal diseases, but such information is limited due to the inherently poor subject contrast of soft tissues. Hence, gastrointestinal contrast radiography is often indicated in small animals with the signs of esophageal or gastrointestinal diseases which include dysphagia, regurgitation, vomiting, diarrhea, melena, and abdominal mass not completely defined by palpation or survey radiographs and suspected abdominal organ displacement. Radiographic contrast procedures may be performed using positive (barium sulfate and oral iodine solution) or negative (carbon dioxide and air) contrast media, but the most common gastrointestinal contrast media used in veterinary practice are barium sulfate suspensions and iodine solutions which can be administered orally using stomach tube or rectally to enhance radiographic visualization of the abdominal organs.[16]

The threat of extinction of these animals presents a real challenge for their conservation and an improved understanding of their gastrointestinal tract will enhance their protection. Pangolins are prone to fatal gastrointestinal diseases such as gastric ulcers, hemorrhagic enteritis, and intestinal worm infection[3,17-19] all of which worsen due to the conditions of stress and handling during illegal trade.

Contrast radiography of the gastrointestinal tract of these animals will present an opportunity to better diagnose and appropriately treat them. This study was, thus, carried out to assess the utility of contrast radiography in studying gastrointestinal tract radiographic anatomy and transit time. This will provide a guide for specialized information for researchers and conservationists, to improve the care of rescued pangolins and avoid unnecessary losses due to gastrointestinal emergencies and feeding challenges while in captivity.

SUBJECTS AND METHODS

Four African white-bellied tree Pangolins (*Phataginus tricuspis*) comprising two males and two females with a mean body weight of 1.52 ± 0.33 kg were used for the first part of this study. The pangolins were rescued from illegal trade markets in the Lagos, Ogun, and Osun states of Nigeria. They were kept briefly in a simulated natural environment at the University of Ibadan. The study was carried out on the pangolins within 48 h of acquiring them because of their fragility when kept in captivity; they were thereafter released into a reserved forest in a conservation center.

Anesthesia

The pangolins were sedated with 20 mg/kg Ketamine hydrochloride intramuscularly[20,21] before administering barium sulfate and also before the X-rays could be taken because the pangolins usually curl up at the slightest touch. The barium sulfate was administered directly into the stomach using a 20 ml syringe attached to an improvised stomach tube at a dosage of 10 ml/kg orally while ensuring the presence of a gag reflex. A digital X-ray equipment (Allengers®) was used to create dorso-ventral and right lateral view images of the pangolins using machine settings of 81 Kvp, 40 mAs.

Examination of live pangolins

The first pangolin was a male, which was administered barium sulfate orally and X-rayed immediately after, and a dorso-ventral image was recorded at 0 min after the barium meal.

Two female pangolins were thereafter, administered barium sulfate, X-rayed and dorso-ventral images recorded at 55 min, 1 h 20 min, 2 h 16 min, 20 h 55 min, and 21 h 15 min after the barium meal.

The fourth pangolin (a male) was administered barium meal, X-rayed and a dorso-ventral image was recorded at 3 h 7 min and the right lateral image was recorded at 3 h 9 min, a second dorso-ventral image was taken at 5 h 1 min and a second right lateral image was taken at 5 h 3 min after the barium meal.

These exposures were based on convenience (A human center was used, and animals were only allowed after hours).

Gut anatomy measurements

Opportunistic necropsies were performed on four other pangolins that died in transit. Excessive stress due to handling and wound sustained during trade contributed to the cause of death. Gross measurements of the gut sections were performed and compared with *in situ* anatomic estimates obtained from radiographs by the Digimizer.

Statistical analysis

The quantitative results of esophageal length, stomach diameter, and intestinal length obtained were analyzed for mean and standard error using the Statistical Package for The Social Sciences (SPSS version 16) Statistics for Windows, version x. 0 (SPSS Inc., Chicago, Ill., USA). Radiographs were evaluated by a Radiologist Dr Adenike O. Olatunji-Akioye (AOOA) and gastrointestinal tract measurements from radiographs were done using Digimizer® and gross measurements of the gastrointestinal tract, gastric diameter, and intestinal length were also done by a pathologist, Dr TA Jarikre on pangolins brought in dead.

RESULTS

Sedation caused the pangolin to unroll to facilitate radiography [Figure 1a]. The oral cavity is an oval-shaped cavity located between cervical vertebrae C2-C7 and about 20 cm in length. Contrast medium was present in the cervical esophagus at 0 min after feeding. Pangolins have an extremely long tongue which runs with the esophagus and extends into the abdominal cavity just before the stomach at the level of the 8th–10th rib.[11,22] This was proven by the appearance of contrast immediately after feeding barium since one of the functions of the tongue is to assist in swallowing. The plain radiograph [Figure 1b] demonstrates the presence of mineral opacity within the stomach which suggests the stomach is not divided into separate crop and gizzard like in chickens, but the fusiform-shaped stomach has distinct regions. The stomach appears to begin at the level of the 9–10th thoracic vertebra with the widest fundic part and narrows into the pyloric portion [Figure 2a and b].

The stomach has a fusiform shape and appears to have a wide proximal part (fundus) and a narrow distal part (pylorus). The small intestinal loops appear to be tightly coiled and form perhaps the longest part of the tract [Figure 2c]. It retained the contrast for between less than an hour to about an hour and a half. The slightly larger-sized large intestine appears as a short length of a tubular structure [Figure 2d]. The terminal portion is consistently full of feces.

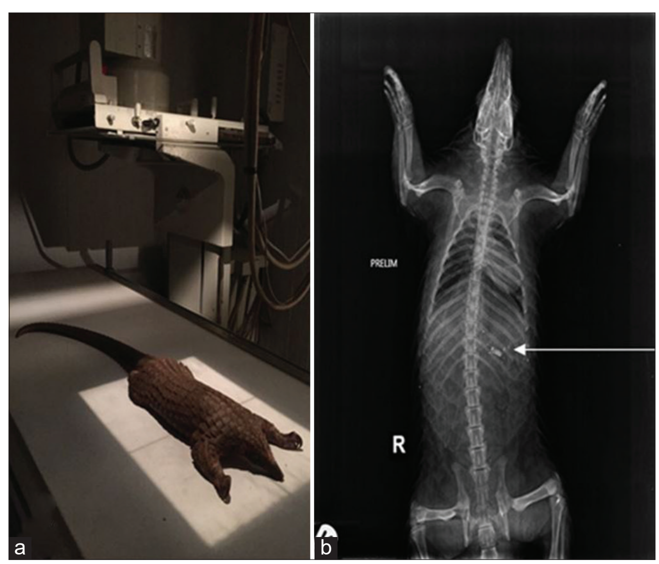

Figure 1: (a) Sedated and uncurled white-bellied pangolin on radiographic table (b) Plain radiograph of pangolin in A (white arrow-stones within the stomach)

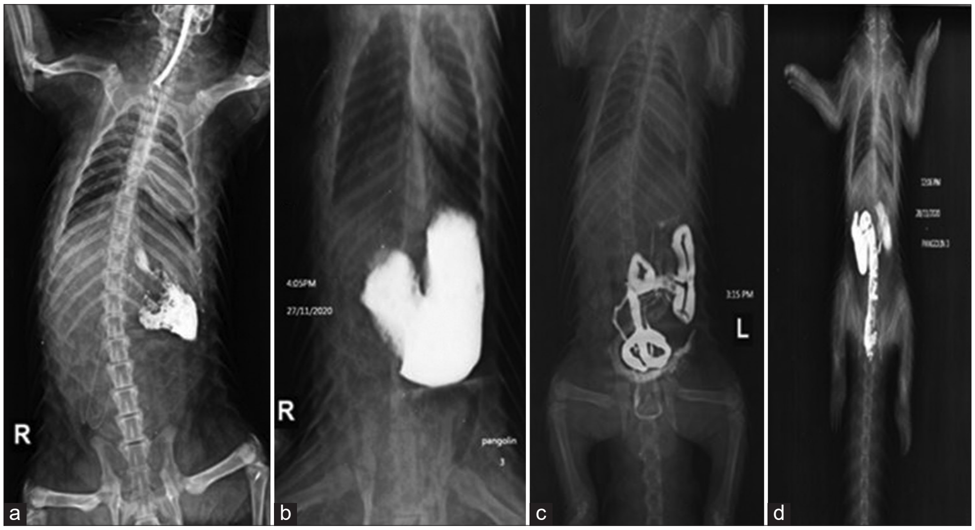

Figure 2: (a) oesophagus and stomach of white-bellied pangolin outlined by contrast media. Contrast appeared in the stomach immediately it was fed to the pangolins. This confirms the tongue extends from the abdomen (the contrast terminates where the pangolin tongue terminates within the abdomen, seen along the length of the air-filled trachea). The oesophagus is outlined by the contrast. It runs deep at the thoracic inlet and appears again at the level of the 8-10th rib. Contrast in widest part of stomach determined to be fundus. Stomach was observed consistently at level of 10th thoracic rib. (b)-Dorsoventral view of fusiform shaped stomach outlined by contrast media (c)-Dorsoventral view of small intestinal loops outlined by contrast media. (d)-The large intestines appear to consist of few loops and a predominantly uniformly sized rectum which was consistently full of feacal material

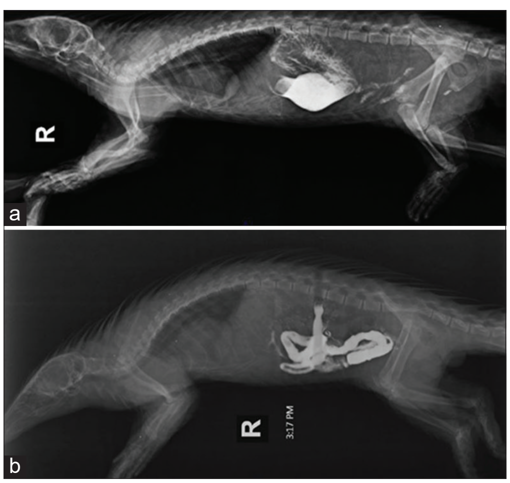

Figure 3: (a) Lateral view of distal stomach of white-bellied pangolin outlined by contrast media. The shape of the stomach appears to be outlined by the contrast. Contrast is seen in narrow pyloric part of the distal stomach. (b) Lateral view of Intestinal loops of African white- bellied tree pangolin. The several loops of the small intestines are outlined by contrast media

The pangolins used in this study were mostly adults with the exception of one pangopup, five were males and three females weighing 1.61 ± 0.57 kg. They were mostly brown in color with two being light brown, but the pangopup is dark brown. They measured an average of 90.75 ± 10.99 cm and body temperature ranged from 32.8°C to 34.2°C [Table 1]. The time it took the contrast agent to traverse different segments of the gastrointestinal tract is shown in Table 2. Contrast appeared within the esophagus and stomach at zero to 55 min, at 3–5 h in the small intestine and above 20 h in the large intestine.

In radiographed pangolins, the mean esophageal length was 201.38 ± 1.70, gastric length and width were 95.42 ± 1.97 and 53.02 ± 16.70, respectively [Table 3]. Gross measurements from pangolins that died were of the entire gastrointestinal tract (220.21 cm), while gastric and intestinal lengths were 7.1 (13.3) cm and 213.13 cm. Contrast transit time in the white-bellied pangolin was determined to be 0.00 h in the esophagus, 1.34 ± 0.65 in the stomach, 0.48 ± 0.48 in the small intestines, and 10.00 ± 5.76 in the large intestines. The total transit time was 11.82 ± 4.10 and the mean contrast time was 2.96 ± 2.36 [Table 4]. Gross measurements from pangolins that died were of the entire gastrointestinal tract (220.21 cm), while gastric and intestinal lengths were 7.1 (13.3) cm and 213.13 cm [Table 5].

DISCUSSION

The paucity of literature on the pangolin presents a challenge for both conservationists and researchers due to its endangered status. A need for valid reference materials detailing information that is useful as a guide for clinicians who are presented with cases is of urgent necessity to enable appropriate handling to aid conservation efforts. Body weight measurements [Table 1] are reportedly essential in categorizing pangolin into age classes[23] but differ between breeds as the white-bellied pangolin appears

Table 1: Physical parameters of the white-bellied pangolin evaluated in this study

Pangolin ID	Age	Sex	Weight (kg)	Colour	Full length (cm)	Temperature (°C)
Pangolin 1	Adult	Male	2.33	Light brown	105	34.2
Pangolin 2	Adult	Male	1.54	Brown	86	34.1
Pangolin 3	Pangopup	Female	0.72	Dark brown	70	33.6
Pangolin 4	Adult	Female	1.49	Light brown	93	33.4
Pangolin A	Adult	Male	2.48	***	102	***
Pangolin B	Adult	Male	1.19	Brown	96	33.4
Pangolin C	Adult	Male	1.54	Brown	86	34.1
Pangolin D	Adult	Female	1.60	Brown	88	32.8

***Died before the physiological parameters could be taken. Pangolins 1–4 were live, while pangolins A–D were the dead ones

Table 2: Contrast location in different segments of gastrointestinal tract of white-bellied pangolin at different time points

Research animal	Contrast in esophagus	Contrast in stomach	Contrast in small intestine	Contrast in large intestine
Pangolin 1	0 min	0 min	N/A	N/A
Pangolin 2	N/A	N/A	3 h, 7 min and 5 h, 1 min	5 h
Pangolin 3	N/A	55 min	N/A	20 h, 5, 5 min
Pangolin 4	N/A	1 h, 20 min and 2 h, 16 min	N/A	21 h, 15 min

NA – Not available

Table 3: Mean radiographic measurements of esophagus and stomach of white-bellied pangolin

Pangolin organ	Measurement (mm) (mean±SD)
Esophagus length	201.38±1.70
Stomach length	95.42±1.97
Stomach width	53.02±16.70

SD – Standard deviation

Table 4: Mean contrast transit time of gastrointestinal segments of white-bellied pangolin

Parameter	Time (h)
Esophagus	0.00±0.00
Stomach	1.34±0.65
Small intestines	0.48±0.48
Large intestines	10.00±5.76
Total contrast transit time	11.82±4.10
Mean contrast transit time	2.96±2.36

to differ in the range from the Indian breed significantly. The proper diagnosis of disorders of the gastrointestinal tract in animals is largely dependent on images obtained from the contrast gastrointestinal transit time in healthy animals.[24] In this study, vital information was acquired that will hopefully enhance the handling and care of this species for conservationists, researchers, and even clinicians. The gastrointestinal transit time is also significant in the formulations of appropriate feeds by pet nutritionists and conservationists.[25]

Anesthesia was determined for handling, which counteracted their tendency to curl up with ketamine hydrochloride at a dose rate of 20 mg/kg. The oral cavity was observed as an oval-shaped cavity with the absence of teeth. The cervical portion of the oesophagus was seen at the level of C2-C7 and the long and thin pangolin tongue appeared to be beside it. This was demonstrated at necropsy as well as radiographically where contrast fed to the pangolins immediately appeared in the stomach. The tongue appears to end proximal to the abdominal cavity at the level of the 8th rib. The plain (survey) radiograph revealed the presence of mineral opacity of about 0.5 cm within the stomach which appears to be the presence of stones which help with grinding the insects ingested. This is in agreement with the report that the pangolin stomach contains small stones that help in grinding their food.[15,26] The stomach was seen consistently at the level of the 10th rib and the fusiform shape is demonstrated which agrees with the description of the shape of the pangolin stomach described by Krause and Leeson and Xu et al [Figure 3a].[27,28] The small intestines appear to be tightly coiled and an increase in width at the large intestinal portion which is the distal end for a short length [Figure 3b]. The radiographic anatomy of the large intestine revealed shows no distinction of the different parts in agreement with studies. The most caudal part of the large intestine is easily discerned by being consistently filled with fecal material.

Death in pangolins causes significant weight loss.[29] Results of gastric measurements from deceased pangolins were comparable to results from gastric radiographic measurements and suggest the reliability of the measurements as these were done postmortem [Tables 3 and 5]. The result of the contrast transit time from this study that gastric emptying time in white-bellied pangolin is between 2 h 16 min and 3 h which is shorter compared to the gastric emptying time in dogs which is between 7 and 15 h and also shorter compared to the gastric emptying time in rats which is 4 h.[24,30] The diet of pangolins differs from the omnivorous diets of dogs and rats and suggests a more efficient digestion of the complex chitin present in the insects that make up the pangolin diet. The small intestinal transit time in this study is between 3 and 5 h which is longer compared to the small intestinal

Table 5: Gross measurements of gastrointestinal tract of African white-bellied tree pangolins that died during rescue

	GIT (cm)	Gastric (diameter) (cm)	Intestinal length (cm)
Pangolin A	218.12	7.1 (13.1)	211.1
Pangolin B	226.2	7.2 (13.8)	219.0
Pangolin C	221.5	7.2 (13.5)	214.3
Pangolin D	215.0	6.9 (12.8)	208.1

GIT – Gastrointestinal tract

transit time in dogs which is between 2 and 4 h but shorter compared to the small intestinal transit time in rats, which is 8 h.[24,30] The longer small intestinal transit time from this study supports the report that pangolins have an adaptive longer intestinal tract compared to carnivores.[15] The large intestinal transit time is between 5 and 21 h which is shorter compared to the large intestinal transit time in dogs which is between 7 and 42 h.[24] It took an average of 2.96 ± 2.36 h for contrast to travel from the mouth to the large intestine in this study which is consistent with the average time reported[31] in dogs (3 ± 1.5 h). This again shows the superior efficiency of digestion and food transport in the pangolin compared to dogs. This is probably an adaptation to the long period spent immobile during the day and a short period of activity during the night.

The contrast radiographic and transit times obtained from this study will guide carers to understand the time lag between feeding and will aid in the radiologic diagnosis and proper clinical management of gastrointestinal pathologies such as gastric ulcers, hemorrhagic enteritis, and other digestive tract lesions in African pangolins which had not been documented before. The use of barium contrast imaging in the diagnosis of gastric mucosal erosions will be enhanced due to an understanding of transit times. While endoscopy is the imaging modality of choice, barium contrast studies are able to detect benign gastric ulcers.[32] The radiological reference provided in this research is recommended for clinicians (in handling gastrointestinal conditions in pangolins), researchers (as a scientific reference), and conservationists (to aid in the formulation of appropriate feed for pangolins) in conservation centers.

Study limitations

The limitations included the fragile nature of the pangolins and being unable to predict when they would arrive and in what state. There was also the challenge of access to radiographic facilities. Working with the Pangolin Conservation Guild Nigeria (PCGN), constituted a challenge, limiting the time of access to the pangolins. Understandably, the Society had the welfare of the pangolins uppermost in mind, and so required that all research be done as quickly as possible so the pangolins could be released into protected spaces.

CONCLUSION

Average transit time of the digestive tract in white-bellied pangolins was determined to be 0.00 h in the esophagus, 1.34 ± 0.65 in the stomach, 0.48 ± 0.48 in the small intestines and 10.00 ± 5.76 in the large intestines. The total transit time was 11.82 ± 4.10 and the mean contrast transit time was 2.96 ± 2.36. This is consistent with the reported average in dogs (3 ± 1.5 h). The esophageal length, stomach length, and width radiographically, were 201.38 ± 1.70, 95.42 ± 1.9, and 53.02 ± 16.70 mm while the gross gastric length, diameter, and intestinal length were 7.1 ± 0.12, 13.3 ± 0.4, and 220.21 ± 4.03 cm, respectively. These reference values will serve to positively impact feeding and gut health in pangolins and assist in understanding critical care and boost conservation efforts.

Acknowledgment

The Pangolin Conservation Guild Nigeria (PCGN).

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Boakye MK, Pietersen DW, Kotze A, Dalton DL, Jansen R. Ethno-medicinal use of African pangolins by traditional medical practitioners in Sierra Leone. J Ethnobio Ethnomedic 2014;10:76.
2. Meyer W, Liumsiricharoen M, Suprasert A, Fleischer LG, Hewicker-Trautwein M. Immunohistochemical demonstration of keratins in the epidermal layers of the Malayan pangolin (*Manis javanica*), with remarks on the evolution of the integumental scale armour. Eur J Histochem 2013;57:e27.
3. Wu SB, Ma GZ, Tang M, Chen H, Liu NF. The status and conservation strategy of Pangolin Resource in China. J Nat Resourc 2002;17:174-80.
4. Boakye MK, Pietersen DW, Kotze A, Dalton DL, Jansen R. Knowledge and uses of African Pangolins as a source of traditional medicine in Ghana. PLoS One 2015;10:e0117199.
5. Heinrich S, Wittmann TA, Ross JV, Shepherd CR, Challender DW, Cassey P. The Global Trafficking of Pangolins: A Comprehensive Summary of Seizures and Trafficking Routes from 2010e 2015. Petaling Jaya, Selangor, Malaysia: TRAFFIC, Southeast Asia Regional Office; 2017.
6. CITES. Convention on International Trade in Endangered Species of WildFauna and Flora. 2017. Available online at: http://www.cites.org/eng/app/appendices.php [Last accessed on 2021 May 20].
7. Sodeinde OA, Adedipe SR. Pangolins in South West Nigeria. Current status and prognosis. Oryx1994;28:43-50.
8. Ofusori DA, Caxton-Martins EA, Adenowo TK, Ojo GB, Falana BA, Komolafe AO, *et al*. Morphometric study of the stomach of African pangolin (*Manis tricuspis*). Sci Res Essay 2007;2:465-7.
9. Ofusori DA, Caxton-Martins EA. A comparative histological investigation of the gastrointestinal tract in pangolin, bat and rat. J Cell Anim Biol 2008;2:079-83.
10. Reiss KZ. Feeding in myrmecophagous mammals. In: Schenk K, editor. Form Function and Evolution in Tetrapod Vertebrates. San Diego, CA: Academic Press; 2000. p. 459-85.

11. Naples VL. Morphology, evolution and function of feeding in the giant anteater (*Myrmecophaga tridactyla*). J Zool 1999;249:19-41.
12. Montgomery GG. Movements, foraging and food habits of the four extant species of neotropical vermilinguas (Mammalia; Myrmecophagidae). In: Montgomery GG, editor. The Evolution and Ecology of Armadillos, Sloths, and Vermilinguas. Washington, DC, USA: Smithonian Institution Press; 1985. p. 365-77.
13. Yang CW, Chou CS, Chao MS. The feeding of the Chinese pangolin (Manis pentadactylapentadactyla) at Taipei Zoo. Association of Zoos and Aquariums Annual Proceedings. 23–28, Minneapolis, MN. 1999: 501-7.
14. Yang CW, Chen S, Chang CY, Lin MF, Block E, Lorentsen R, Dierenfeld ES. Rare occupants in zoos—pangolins. Aspects of digestive anatomy and physiology. Zoo Biology. 2007;26:223-30.
15. Lin MF, Chang CY, Yang CW, Dierenfeld ES. Aspects of digestive anatomy, feed intake and digestion in the Chinese pangolin (*Manis pentadactyla*) at Taipei zoo. Zoo Biol 2015;34:262-70.
16. Brawner WR Jr., Bartels JE. Contrast radiography of the digestive tract. Indications, techniques, and complications. Vet Clin North Am Small Anim Pract 1983;13:599-626.
17. Clark L, Van N, Phuong TQ. A long way from home: The health status of Asian pangolins confiscated from the illegal wildlife trade in Vietnam. In: Pantel S, Chin SY, editors. Proceedings of the Workshop on Trade and Conservation of Pangolins Native to South and South-East Asia. Singapore: TRAFFIC Southeast Asia; 2008. p. 111-8.
18. Cen L, Xu L, Xu H, Xiang Y, Xue Z. Protection and cultivated technology of pangolin. Asia Pac Tradit Med 2010;6:12-5.
19. Hua L, Gong S, Wang F, Li W, Ge Y, Li X, *et al.* Captive breeding of pangolins: current status, problems and future prospects. Zookeys. 2015:99-114.
20. Robinson PT. The use of ketamine in restraint of a black-bellied pangolin (*Manis tetradactyla*). J Zoo Anim Med 1983;14:19-23.
21. Heath ME. Hematological parameters of four Chinese pangolins (*Manis pentadacytla*). Zoo Biol 1986;5:387-90.
22. Adeniyi PA. Morphometric analysis of tongue and dentition in hedgehogs and pangolins. Eur J Anat 2010;14:149-52.
23. Perera P, Algewatta HR, Karawita H. Protocols for recording morphometric measurement of Indian Pangolin (*Manis crassicaudata*). MethodsX 2020;7:101020.
24. Boillat CS, Gaschen FP, Hosgood GL. Assessment of the relationship between body weight and gastrointestinal transit times measured by use of a wireless motility capsule system in dogs. Am J Vet Res 2010;71:898-902.
25. Olayinka-Adefemi F, Ogbole GI, Olatunji-AkioyeA. Estimation of gastrointestinal transit time in the West African Mud Turtle, Pelusioscastaneus (Schwinger 1812) using contrast radiography. West Afr J Radiol 2017;24:147-51.
26. Cheng H, Wang H, Shau FJ. Study on the anatomy and histology of the stomach of *Manis pentadactyla*. Beijing Sci Museum Res 1986;36:9-15.
27. Krause WJ, Leeson CR. The stomach of the pangolin (*Manis pentadactyla*) with emphasis on the pyloric teeth. Acta Anat (Basel) 1974;88:1-10.
28. Xu N, Min Y, Wu S, Zhang F. The stomach morphology and contents of the Chinese Pangolin (*Manis pentadactyla*). J Zoo Biol 2020;03:13-20.
29. Nguyen V, Clark L, Phuong T. Husbandry Guidelines Sunda Pangolin (Manis Javanica) Carnivore & Pangolin Conservation Program Cuc Phuong National Park, Vietnam 2014.
30. Clemens ET, Stevens CE. A comparison of gastrointestinal transit time in ten species of mammals. J Agric Sci Camb 1980;94:735-7.
31. Meyer W, Liumsiricharoen M, Suprsert A, Fleischer LG, Hewicker TM. immunohistochemical demonstration of keratins in the epidermal layers of the Malayan pangolin (Manis Javanica), with remarks on the evolution of the integumental scale armour. Eur J Histochem 2013;57:e27. doi: 10.4081/ejh.2013.e27. PMID: 24085276; PMCID: PMC3794358.
32. Ackerman N. Imaging the GI tract. Proceedings of the 27th World Small Animal VeterinaryAssociation Congress, 2002. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=11147&catId=29497&id=3846216&ind=103&objTypeID=17. [Last accessed on 2021 May 20].