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NEWS AND PERSPECTIVES

Intracranial arachnoid cysts in a chimpanzee (*Pan troglodytes*)

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Abstract An intracranial arachnoid cyst was detected in a 32-year-old, 44.6-kg, female chimpanzee at the Primate Research Institute, Kyoto University. Magnetic resonance imaging (MRI) and computed tomography (CT) were performed and the cognitive studies in which she participated were reviewed. MRI revealed that the cyst was present in the chimpanzee's right occipital convexity, and was located in close proximity to the posterior horn of the right lateral ventricle without ventriculomegaly. CT confirmed the presence of the cyst and no apparent signs indicating previous skull fractures were found. The thickness of the mandible was asymmetrical, whereas the temporomandibular joints and dentition were symmetrical. She showed no abnormalities in various cognitive studies since she was 3 years old, except a different behavioural pattern during a recent study, indicating a possible visual field defect. Detailed cognitive studies, long-term observation of her physical condition and follow-up MRI will be continued.

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Introduction

An arachnoid cyst is an accumulation of intra-arachnoid fluid, which can be congenital or secondary to inflammation, brain trauma, haemorrhage, chemical irritation or tumours (Cincu et al. 2007). In humans, most arachnoid cysts are detected during the first two decades of life (Gosalakkal 2002). They are often asymptomatic and are encountered as incidental findings of neuroimaging (Spansdahl and Solheim 2007). Arachnoid cysts can cause headaches, seizures, craniomegaly, developmental delays and, rarely, hemiparesis as well as various defects specific to the location of the cysts. The aetiology of congenital cysts remains unclear, but they are considered to be developmental anomalies of the arachnoid membrane, which resulted in the accumulation of cerebrospinal fluid (CSF)-like fluid. Arachnoid cysts are mainly supratentorial (90 %) and are occasionally present in the posterior fossa (10 %). The most common supratentorial site is the middle cranial fossa (60 %) and other sites include the quadrigeminal plate, sellar region and convexity (Cincu et al. 2007).

Intracranial arachnoid cysts have also been reported in cattle (Lee et al. 2009) and dogs (Vernau et al. 1997; Kitagawa et al. 2003; Dewey et al. 2007; Wyss-Fluehmann et al. 2008), whereas spinal arachnoid cysts are more common in dogs and cats (Skeen et al. 2003). However, arachnoid cysts in non-human primates have rarely been documented. In the present report, we describe magnetic resonance imaging (MRI) and computed tomography (CT) findings in a female chimpanzee with an intracranial

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arachnoid cyst and briefly review the cognitive studies in which she participated.

Case report

An intracranial arachnoid cyst was detected in a 32-year-old, 44.6-kg (at the time of initial MRI), female chimpanzee named Pendesa at the Primate Research Institute, Kyoto University (KUPRI). The chimpanzee was kept in an indoor–outdoor enclosure in a social group comprising 2 males and 4 females: see (Matsuzawa 2003, 2006) for further information concerning the social group.

The chimpanzee was born at the Japan Monkey Centre (JMC) in 1977 and was transferred to KUPRI in 1979 when she was 2 years old. She participated in various cognitive research studies since then, but has never been used for medical research. All studies after 1986 were conducted under the guidelines provided by the KUPRI after the approval of institutional Animal Welfare and Care Committee. She was diagnosed with atopic dermatitis in 2000, which has been controlled with an oral antihistamine (Salatine, Nipro Genepha Corporation, Saitama, Japan) and topical application of jojoba oil during the dry seasons. No neurological signs were noted before MRI (General Electrics Signa Profile MRI scanner, 0.2 T, GE Yokoo Medical Systems Co., Tokyo, Japan) was performed for research purposes.

Results

The chimpanzee was anesthetized with ketamine hydrochloride (100 mg/mL Ketalar®, 3.5 mg/kg; Sankyo-Parke-Davis & Co., Inc., Japan) and medetomidine hydrochloride (0.035 mg/kg; Domitor®; Meiji Seika Kaisha, Ltd., Tokyo, Japan). Anaesthesia was maintained with isoflurane (Isoflu; Dainippon Sumitomo Pharma Co., Ltd., Osaka, Japan) delivered in oxygen through a precision vaporizer and a rebreathing circuit. MRI was performed to study the morphology of chimpanzee's brain (Sakai et al. 2011), which revealed an arachnoid cyst in the right occipital convexity (Fig. 1a–c). The cyst was located in close proximity to and possibly communicated with the posterior horn of the right lateral ventricle, but no evidence of ventriculomegaly was observed. T1- and T2-weighted MRI signals in the cyst were similar to those in CSF. These images were viewed and discussed with both veterinary and human neurologists.

We acquired three-dimensional (3D) T1-weighted whole brain images using the 3D fast gradient echo imaging sequence. The images were analysed using the following series of manual and automated procedures: (1) analyses using Analyze 9.0 software (Mayo Clinic, Rochester, MN, USA) and conversion to cubic voxel dimensions of 0.55 mm using a cubic spline interpolation algorithm, (2) re-alignment of brain image volumes to a standard anatomical orientation with the transaxial plane parallel to the anterior commissure–posterior

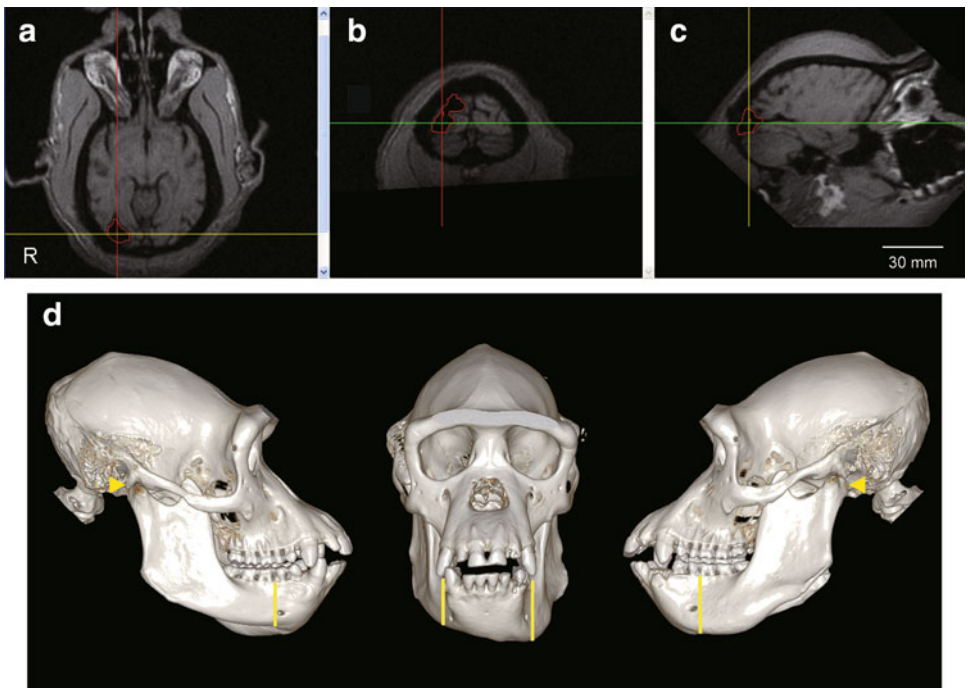

Fig. 1 T1-weighted coronal (**a**), axial (**b**) and sagittal (**c**) MRI showing a right occipital arachnoid cyst with a total volume of 2.8 cm^3 (contoured area) (**d**) 3D reconstructed CT images of the skull. The thickness of the mandible was asymmetrical (*yellow bar*), whereas the temporomandibular joints (*arrowhead*) and dentition were symmetrical

commissure line and perpendicular to the interhemispheric fissure, (3) manual tracing and measurement of the entire arachnoid cyst by one of the image analysts (T.S.) in consultation with a veterinarian (J.S.) and (4) calculation of the absolute volume of the arachnoid cyst from an automatic count of the number of voxels per cm^3 using Analyze 9.0 software, which resulted in a total volume of 2.8 cm^3.

One year after the initial MRI, the chimpanzee was anesthetized as mentioned above except that sevoflurane (Sevoflo; Dainippon Sumitomo Pharma Co., Ltd., Osaka, Japan) was used instead of isoflurane and CT was performed using the Asteion CT scanner (model no. TSX-021B; Toshiba Medical Systems Corporation, Tochigi, Japan), which revealed an arachnoid cyst that did not appear to change in size over the preceding 1 year. The chimpanzee's skull was smooth, and CT did not reveal apparent signs indicating previous skull fractures. However, the thickness of her mandible was asymmetrical, whereas her temporomandibular joints and dentition were symmetrical (Fig. 1d). These images were viewed and discussed with a human dentist.

She has not shown any developmental delays or other behavioural abnormalities, but researchers and her caretakers have noticed that she frequently rocked back and forth while sitting.

Table 1 lists the cognitive studies in which Pendesa participated since she was 3 years old. She participated in various cognitive tests using visual and auditory modalities, but showed no inferiority to the other chimpanzees in any respect, except in a colour classification task (Matsuno et al. 2004). She performed the colour classification task when she was 23 years old and showed less stable classification compared with a female chimpanzee named Ai (Matsuno et al. 2004, review in Matsuno et al. 2006). Ai and Pendesa were the same age and both reared by human. Although they had similar history, only Ai had learned symbolic colour names through long-term training. In this task, Matsuno et al. adopted a "nonlinguistic" test to directly compare colour classification by these two chimpanzees. They were shown 124 test colours and asked to match to 9 standard colours, not to symbols. As a result, Pendesa showed significantly less consistent classifications.

The results of the recent cognitive study (conducted when she was 33 years old) indicate that Pendesa had different behavioural patterns, suggesting a possible defect in her left visual field (Kaneko et al. 2013). In this study, the detectability of the small light spot presented on several locations of visual field was measured while monitoring the gaze positions by infra-red remote eye-tracker. As a result, the detectability was close to zero around the bottom-left quadrant of visual field.

Discussion

An arachnoid cyst was detected in the right occipital convexity in a clinically healthy, adult, female chimpanzee during MRI for research purposes. One year later, CT confirmed the presence of the cyst and asymmetrical thickness of the chimpanzee's mandible. Although it is difficult to differentiate arachnoid cysts and epidermoid cysts or dermoid cysts (i.e., if the content of the cyst was cerebrospinal fluid or something else) without diffusion weighted images, in the present case, arachnoid cyst was the most consistent with our MRI and CT images (shape, size and the location of the cyst), history and symptoms.

In humans, occipital convexity arachnoid cysts are rare, but two case reports have documented symptomatic arachnoid cysts in elderly women (Tucker et al. 2006; Suzuki et al. 2009). The cyst volume slowly increased over time in one case; the cyst was located close to the patient's posterior horn of the right lateral ventricle, which may have been related to the cystic growth (Suzuki et al. 2009). The other woman with a cystic lesion in the right occipital convexity presented with a visual field defect and headache. A visual field examination showed left lower quadrantanopia. Surgical treatment was performed and her headache and visual field defect improved (Suzuki et al. 2009).

In the present case, an arachnoid cyst was located in the right occipital convexity, which was considered to be mostly in V1 area (Bailey et al. 1950). Neither the researchers nor caretakers noticed any developmental delays or other behavioural abnormalities until recently except frequent to-and-fro rocking while sitting. The chimpanzee has participated in various cognitive studies measuring a wide range of visual and auditory functions without any intervals since she was 3 years old. She showed no abnormalities or inferiority in performance and was occasionally even better than other chimpanzees in various tasks, except for the colour classification task (Matsuno et al. 2004). Matsuno and colleagues interpreted that Pendesa classified colours less stably because she had less training and limited understanding of colour names. It was unlikely that her colour classification ability was affected by the presence of the arachnoid cyst. More recently, the left visual field defect was suggested in a cognitive study (Kaneko et al. 2013). This suspected left quadrantanopia was consistent with a defect that was predicted from the cyst location.

Arachnoid cysts can be congenital or secondary to inflammation or brain trauma (Gosalakkal 2002; Cincu et al. 2007). In the present case, a history of brain trauma was not recorded after the chimpanzee was transferred to KUPRI at the age of 2 years, although her history before this period was not clear. Apparent signs of previous skull

Table 1 Cognitive studies in which Pendesa participated

Task category	Task	Topic	Age[a]	Number of subjects	Reference
Vision	Concurrent discrimination	Self-monitoring of action	–	6	Kaneko and Tomonaga (2012)
Vision	Odd item search	Emergent feature	29	3	Goto et al. (2012)
Vision	Concurrent discrimination	Agency judgment	–	3	Kaneko and Tomonaga (2011)
Vision	Odd item search	Perceptual completion	–	6	Tomonaga and Imura (2010)
Vision	Pre-cue task	Object based attention	–	2	Ushitani et al. (2010)
Vision	Pre-cue task	Cueing effect of human pointing	–	2	Tomonaga and Imura (2009)
Social	Token insertion task	Reciprocal cooperation	29	4	Yamamoto and Tanaka (2009)
Social	Tool transfer task	Helping behaviour	–	9	Yamamoto et al. (2009)
Vision	Matching to sample	Metacontrast and back/forward masking	28	2	Matsuno and Tomonaga (2008)
Vision	Concurrent discrimination	Relative numerosity discrimination	–	2	Tomonaga (2008)
Vision	Concurrent discrimination	Pictorial depth cue perception	24	3	Imura et al. (2008)
Vision	Matching to sample	Dominant perception of concave shape	28	5	Matsuno and Tomonaga (2007)
Vision	Pre-cue task	Gaze cueing effect	–	2	Tomonaga (2007)
Social	Free viewing	Mirror self-recognition	21	10	Hirata (2007)
Vision	Odd item search	Grouping of moving/stationary object	27	3	Matsuno and Tomonaga (2006)
Vision	Matching to sample	Color classification	23	2	Matsuno et al. (2004)
Social	Free viewing	Contagious yawning	26	6	Anderson et al. (2004)
Ecology	Leaf swallowing	Self-medicative behavior	–	11	Huffman and Hirata (2004)
Motor	Hand drawing	Improvement of manual movement	15	2	Iversen and Matsuzawa (2003)
Vision	Free choice task	Visual preference of photo	23	5	Tanaka (2003)
Social	Open field food detection	Tactical deception	20	5	Hirata and Matsuzawa (2001)
Social	Token exchange task	Use of token	–	3	Sousa and Matsuzawa (2001)
Vision	Object choice task	Recognition of human-given cue	18	2	Itakura and Tanaka (1998)
Motor	Hand drawing	Model guided hand drawing	15	2	Iversen and Matsuzawa (1997)
Motor	Hand drawing	Visually guided hand drawing	15	2	Iversen and Matsuzawa (1996)
Auditory	Go/NoGo	Auditory function	7	2	Kojima (1990)
Auditory	Go/NoGo	Consonant perception	9	2	Kojima et al. (1989)
Auditory	Go/NoGo	Vowel perception	9	3	Kojima and Kiritani (1989)

[a] The age of the chimpanzee at which she participated the task. (–) indicates that the age is not stated in the article

fractures were not found, but CT revealed obvious mandibular asymmetry. The causes of mandibular asymmetry can be developmental, traumatic, pathological (e.g., tumour, cysts, infection) or functional (mandibular displacement) (Chia et al. 2008). In this case, traumatic, pathological and functional causes were not found and it appears to be similar to the developmental condition, hemimandibular hyperplasia in humans (Chia et al. 2008). The asymmetry was not obvious from photographs (http://langint.pri.kyoto-u.ac.jp/ai/en/friends/pendesa.html) and it was not clear when the condition developed in her life. Reportedly, patients with congenital arachnoid cysts occasionally have additional malformations (Cincu et al. 2007). Collectively, it is possible that the arachnoid cyst and the mandibular asymmetry were both based on her genetic background. However, if a suspected visual field defect is, in fact, associated with a cyst, it can be contradictory to a congenital cyst because the function is likely to be compensated during development. In such cases, the cyst might have developed at some point after birth and gradually expanded to eventually show symptoms. A histopathological examination can distinguish congenital cysts from secondary cysts because the walls in congenital cysts contain arachnoid cells connected with unchanged arachnoid matter, whereas those in secondary cysts contain arachnoid scarring (Cincu et al. 2007).

It was difficult to assess whether the chimpanzee had headaches. At least, she did not seem to suffer from headaches to the extent that her social life was impaired. Her frequent rocking behaviour was considered to be a stereotype behaviour and was caused by stress during tasks and/or social influences, despite the enriched environment (Matsuzawa 2003, 2006). However, if she did have a left visual field defect, it could be speculated that she was actually using motion parallax to compensate for her impaired visual field.

We believe that this is the first description of an arachnoid cyst causing possible visual defects in a chimpanzee. Precise behavioural testing on visual fields and blindness is in progress. The general behaviour and physical condition of Pendesa will be continuously observed and follow-up MRI will be performed throughout her lifetime to determine the course of the cyst.

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