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Case report: First report of hydrocephalus in free-living grey wolf (Canis lupus) pup

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Case Report

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Abstract

Background:
Hydrocephalus is a neurological disorder characterized by abnormal accumulation of cerebrospinal fluid (CSF) within the brain ventricles. It may be congenital or result from infections or trauma. This condition is relatively well documented in dogs; however, little is known about its occurrence in wild animals. Nevertheless, the justification for treating affected wild individuals is often debatable, which highlights the importance of rapid, accurate diagnosis.

Case presentation: A grey wolf (Canis lupus) pup, approximately two months old, was found near a village in southern Poland. Due to unsuccessful reintroduction attempts, the animal was admitted to a wildlife rehabilitation center. Neurological signs prompted a detailed clinical examination, and computed tomography (CT) of the head confirmed hydrocephalus.
Given the severity of neurological deficits, their presumed congenital origin, and the lack of treatment options compatible with survival in the wild, the prognosis was poor. Euthanasia was therefore considered the most appropriate option based on animal welfare considerations. Reintroduction was deemed impossible, and prolonged captivity did not meet acceptable welfare standards for this species.

Conclusion:
This case highlights the importance of rapid diagnosis in wild animals and contributes to the limited data on hydrocephalus in free-ranging species, supporting decision-making in wildlife rehabilitation centers and improving understanding of mortality factors in wild populations.

Background

Hydrocephalus is a neurological condition characterized by an abnormal accumulation of cerebrospinal fluid (CSF) within the brain's ventricles. It may be congenital, resulting from developmental defects or malformations, or acquired, arising secondary to inflammatory, neoplastic, or infectious processes. In canids, infectious causes of hydrocephalus are typically secondary to inflammatory processes affecting the central nervous system, most notably Canine Distemper Virus (CDV) infection, as well as bacterial, protozoal, or less commonly fungal meningoencephalitis (Dewey and da Costa, 2016; Thomas, 2010). These acquired conditions can obstruct CSF circulation, particularly through the mesencephalic aqueduct or the lateral apertures of the fourth ventricle. The increased volume of CSF in hydrocephalus is more often caused by a decreased resorption than excessive CSF production which can be seen in patients with a choroid plexus tumor (Thomas 2010; Hecht and Adams 2010). Hydrocephalus can affect any species of animal (Lorenz et al., 2004) and represents one of the most common developmental disorders observed in animals (Summers et al., 1995; Thomas, 2010).

In dogs, hydrocephalus is a well-documented condition, particularly in toy and brachycephalic breeds (e.g., Chihuahua, Yorkshire Terrier, Pug), with prognosis ranging from fair in mild cases to poor in severe or untreated forms (Dewey and da Costa, 2016; Thomas, 2010). Among wildlife, hydrocephalus was reported in European brown hare (*Lepus europaeus*) (Abramo and Poli, 1991), hoary fox *(Lycalopex*

vetulus) (Silva et al., 2023), red fox (*Vulpes vulpes*) (Lacitignola et al., 2021), North American black bear (*Ursus americanus*) (Ferguson et al., 2016), brown bear (*Ursus arctos*) (Kübber-Heiss et al., 2009), grizzly bear (*Ursus arctos horribilis*) (Mitchell et al., 2015), Asian black bear (*Selenarctos tibetanus*) (Sorjonen et al., 1982), baboon (*Papio spp*.) (Fox et al., 2011), raccoon dog (*Nyctereutes procyonoides*) (Lee et al., 2021), wolf (*Canis lupus*) (Packard et al., 1985) and Northern fur seal (*Callorhinus ursinus*) (Flower et al., 2023).

Diagnosis of hydrocephalus is based on signalment, clinical examination and advanced brain imaging (Thomas 2010). The gold standard for definitive diagnosis of hydrocephalus is Magnetic Resonance Imaging (MRI), but due to the fact that not always the preferred diagnostic tools are available, other methods of imaging may be helpful, such as Computed Tomography (CT), ultrasound, electroencephalography (EEG). Since we often lack knowledge of the history of disease in wild animals and do not always have the opportunity to perform all necessary tests (e.g. for infectious diseases, genetic tests), we frequently cannot determine the primary cause of hydrocephalus.

However, this is a disease where the sense of treating a wild animal is somewhat questionable, hence the importance of a quick and correct diagnosis. There are reports of surgical treatment in wildlife species such as red fox, Northern fur seal and Asiatic black bear (Serrano-Puerto and Mortera-Balsa, 2025; Flower et al., 2023; Pizzi et al., 2017). The ventriculoperitoneal shunt placement in all wildlife cases resulted in prolonged survival time of the animals but surgery did not resolve the problem permanently and animals were deemed non-releasable.

Because information available on hydrocephalus in wild animals is scarce, presenting this case is essential, both for evaluation of mortality factors in wild animal populations and

especially in the context of decisions made in wildlife rehabilitation centers.

Case presentation

A grey wolf pup, approximately two months old, was found near Rymanów Zdrój village in southern Poland (49°53'N 21°86'E) by a tourist. The animal was reported to the local forest district, which after contacting the Regional Directorate for Environmental Protection (RDOŚ), has made a few attempts to return the pup into its natural habitat. All attempts were unsuccessful. After each release the pup was always found in the close proximity of human premises in the next few hours. Due to failure of the animal release the wolf was transferred to the animal rehabilitation center – Fundacja Dziki Projekt in Gorlice, Lesser Poland Voivodeship (49°39'17"N 21°9'35"E).

At the animal rehabilitation center: the animal was presented with mild dehydration and general weakness; it was thin and relatively too small for its estimated age, but responsive to its surroundings. The pup had a visible, abnormal, dome-shaped skull and a mild ventrolateral strabismus (Fig. 1a, b). Initially, it was suspected that the strabismus was a long-standing physiological strabismus. There were no other abnormalities noted during the examination of the wolf and the pup showed no neurological

symptoms. Blood samples were collected from cephalic vein for hematological (Zoetis Diagnostics Vetscan HM5) and biochemical blood analysis (Zoetis Diagnostics Vetscan VS2) and rapid tests for vector-borne diseases and meanwhile the animal has been given intravenous fluids (Ringer lactate). Fecal samples from rectum were collected and examined based on the flotation method (Fecalyzer, Vetoquinol Biowet Sp. z o.o., Poland), sedimentation, Baerman method and direct smear was performed.

Qualitative detection of *Dirofilaria immitis* antigen and antibodies against *Ehrlichia canis*, *Borrelia burgdorferi and Anaplasma phagocytophilum/Anaplasma platys* was performed using the serum of the wolf as recommended by the manufacturer (CaniVec-4, Vet Expert, Poland).

Moreover, qualitative detection of Canine Parvovirus (CPV), Canine Coronavirus (CCV), Canine Distemper Virus (CDV), and *Giardia* was performed using a fecal sample as instructed by the manufacturer (Vet Expert CPV/CCV/Giardia Ag test).

The animal was heavily infested with *Toxocara* sp. and had iron deficiency anemia confirmed in biochemical examination and a blood smear cytology. Rapid tests results were all negative except *A. phagocytophilum/ A. platys* (Table 1).

Table 1
Vet Expert CPV/CCV/*Giardia* Ag and CaniVec-4 rapid tests results

Pathogen	**Test result**
CPV	Negative
CCV	Negative
CDV	Negative
Giardia	Negative
A. phagocytophilum/A. platys	Positive
B. burgdorferi	Negative
E. canis	Negative
D. immitis	Negative

Primary treatment included deworming (Drontal junior, Vetoquinol S.A., France; Advantix, Elanco Animal Health GmbH, Germany), iron supplementation (Ferroloxan, Nutrifarm Sp. z o.o. Vebiot, Poland), probiotic (Petbiom, Anibiom, Poland), and nutraceutical (Colaid, Fenixvet, Poland) support for the gastrointestinal tract was provided. Dosages of used products were calculated according to the recommendations of the manufacturer for dogs. The pup was also vaccinated against CPV and CDV (Versican Plus DP, Zoetis, Poland).

The animal has been eating eagerly and has constantly gained weight. After a week, it began walking in circles and appeared to be losing vision on one side – the pup started running into obstacles occasionally. The loss of appetite was noted, as well as the abdominal tension in the palpation. Due to suspicion of hydrocephalus, the CT scan was performed.

Computed Tomography

CT examination of the head was performed in a private veterinary practice in Ostrowiec Świętokrzyski, Poland. The animal underwent an anesthetic protocol, which included an intramuscular injection with 0.04mg/kg medetomidine (Sedator 1 mg/ml, Eurovet Animal Health BV, Netherlands) and 0.4mg/kg butorphanol (Torphadine vet 10mg/ml, Le Vet. Beheer BV, Netherlands). Induction was performed with intravenous infusion of 5mg/kg of propofol (Propomitor 10mg/ml, Orion Corporation, Finland). The animal was intubated and the anesthesia was maintained with boluses of propofol to effect when needed.

The patient's head was imaged using a 32-slice MDCT scanner (Siemens Somatom go.Now, Forchheim, Germany) with the following parameters: 130 kVp, 96 mA, 0.6 mm slice thickness, and a spiral pitch of 0.8. The scan data were reconstructed using high- and low-frequency reconstruction algorithms (Hr64 and Hr44). Iodinated contrast medium (Ultravist 370, Bayer AG Berlin, Germany, dosage 1.5ml/kg) was injected as a single bolus by hand, and post-contrast images were acquired 60 seconds after injection. The post-contrast series was reconstructed with a low-frequency reconstruction algorithm (Hr44).

The CT images revealed a dome-shaped skull with open fontanelles. The lateral ventricles were severely dilated and asymmetrical, with the right being slightly larger than the left. Their margins were rounded with an undulating outline. Extending along the dorsal margins of the lateral ventricles towards the periventricular white matter were a few finger-shaped, fluid-attenuating regions. The volume of grey and white matter of the cerebral hemispheres was severely reduced. The third ventricle and diencephalon were compressed. Subjectively, the osseous tentorium cerebelli was displaced ventrally, and the volume of the caudal fossa was reduced. The lumen of the rostral portion of the mesencephalic aqueduct was not visible. The fourth ventricle was considered normal in size (Fig. 2).

The CT findings were most consistent with severe internal obstructive intraventricular hydrocephalus with secondary brain atrophy and formation of periventricular diverticula. Congenital/developmental stenosis or obstruction of the mesencephalic aqueduct was suspected as the underlying cause.

Cerebrospinal fluid examination

During general anaesthesia for CT examination CSF was collected from the pup and has been sent to the external laboratory for further examination. CSF sample was sent to two different laboratories (ALAB weterynaria, Warsaw, Poland; Laboklin, Warsaw, Poland) for a general examination, cytology, aerobic and anaerobic culture (ALAB weterynaria, Warsaw, Poland), PCR for *A. phagocytophilum*, *Neospora caninum*,

CDV, *Toxoplasma gondii*, Immunoglobulin A, FSME Immunoglobulin G, CRP, total protein and microalbumins (Laboklin, Warsaw) (Table 2).

Table 2
Results of the wolf's cup CSF laboratory tests (ALAB weterynaria(*), Warsaw, Poland; Laboklin, Warsaw, Poland)

Parameter of CSF/pathogen in CSF	**Test result**
Color	Colorless*
Clarity	Clear*
Clot	None*
Pleocytosis	5 cells/µl*
Pandy's test	Negative*
Nonne-Apelt test	Negative*
Glucose	81 mg/dl*
Total protein	21.5 mg/dl*
Cytology	Low-cell slides, well-stained cells, clear background, erythrocytes present in the background. In the slides, one field with accumulation of cells and erythrocytes. Predominantly erythrophages, small percentage of small lymphocytes. No atypical cells or infectious agents found. *
Immunoglobulin A (IgA)	0.02 mg/dl
FSME IgG	< 0.1 U/ml
Total protein	23 mg/dl
CRP	0.40 mg/l
Microalbumins	33.5 mg/l
Aerobic and anaerobic bacteriology culture	negative*
A. phagocytophilum (PCR test)	Negative
N. caninum (PCR test)	Negative
CDV (PCR test)	Negative
T. gondii (PCR test)	Negative
*ALAB weterynaria	
Necropsy	

Due to hydrocephalus diagnosis the official consent for euthanasia was granted by the RDOŚ. The animal was sedated with intramuscular injection of 0.04mg/kg medetomidine (Sedator 1 mg/ml, Eurovet Animal Health BV, Netherlands), 0.4mg/kg butorphanol (Torphadine vet 10mg/ml, Le Vet. Beheer BV, Netherlands) and afterwards intravenously injected with 0.5ml/kg pentobarbital (Morbital 133.3mg/ml + 26.7mg/ml Biowet Puławy, Puławy, Poland) and transferred to Warsaw University of Life Sciences for a necropsy and histopathological examination.

The necropsy was performed according to the standardized protocol previously applied in study of wild carnivores (Kliczkowska et al. 2026). After opening the skull, clear, straw-colored fluid spilled out. The brain tissue was collapsed, particularly in the right hemisphere, with a flaccid structure, weighing 98.6 g. The whole brain was fixed in 10% buffered formalin for detailed examination. Macroscopic examination of the brain revealed excessive dilation of the lateral ventricles with significant thinning of the brain tissue, particularly in the right ventricle (approximately 2 mm at the narrowest point, Fig. 3).

Histopathological examination

For histopathological examination, samples were embedded in paraffin wax, sectioned at 4 µm, and stained with hematoxylin and eosin (H&E). Histopathological slides were evaluated with light microscopy (OLYMPUS BX43F microscope).

Histopathological examination revealed haemorrhages with the presence of numerous macrophages laden with hemosiderin granules and erythrocytes (siderophages) in the brain tissue tangent to the ventricular lumen. Additionally, sparse inflammatory infiltrates of mononuclear cells, mainly small lymphocytes and plasma cells, were present, particularly around blood vessels (Fig. 4). Multifocally in the brain tissue, atrophy of neurons, neuronophagia (phagocytosis of damaged neurons by microglia), and massive oedema were found (Fig. 5).

Genetic testing

To exclude hybridization, genetic confirmation of the puppy's species identity was performed. A blood sample was collected from the juvenile wolf during veterinary procedures, stored on an FTA card (QIAGEN), and kept dry at room temperature until further processing. DNA was extracted from the blood sample using the SherlockAX kit (A&A Biotechnology) in a dedicated genetic laboratory. We then amplified (1) a fragment of the mtDNA control region containing a 230-bp segment rich in parsimony-informative sites that is widely used in wolf phylogeographic studies (e.g. Pilot et al. 2010), and (2) 13 unlinked autosomal microsatellite markers previously used to study wolf population genetics (e.g. Szewczyk et al. 2019; Jarausch et al. 2021). All procedures were performed as previously described (Szewczyk et al. 2019). The amplified mtDNA fragment was sequenced using an ABI 3730xl Genetic Analyzer (Applied Biosystems). The resulting sequence was compared with known wolf mtDNA haplotypes reported by Pilot et al. (2010) and with sequences deposited in the NCBI database. Microsatellite amplicons were separated using an ABI 3730xl Genetic Analyzer with the GeneScan™ 600 LIZ® internal size standard (Applied Biosystems). Allele sizes were determined and binned using

PeakScanner 1.0 software. The microsatellite genotype of the studied individual was compared with reference genotypes of wolves selected from the dataset of Szewczyk et al. (2019), representing three wolf populations inhabiting Poland: Baltic, Carpathian, and Central European Lowland (30 genotypes per population), as well as with reference dog genotypes. Population assignment analysis was performed using STRUCTURE v2.3.4 to assess the individual's membership in the predefined population clusters. The studied wolf' pup carried the w6 mtDNA haplotype, the most common haplotype in the Carpathian population (Pilot et al. 2010; Hulva et al. 2018; Szewczyk et al. 2019). Microsatellite analyses indicated that the juvenile was a purebred wolf from the local population, with 98% assignment to the Carpathian wolf cluster and 0% assignment to the dog cluster, providing no evidence of recent dog ancestry (Supplement 1).

Discussion and conclusions

This report describes a case of hydrocephalus in a free-living grey wolf pup and outlines the diagnostic approach undertaken. To the authors' knowledge, this is the first documented case of hydrocephalus in a free-living wolf pup. Earlier reports in the scientific literature concerning hydrocephalus in wolves date back to the 1980s (Packard et al. 1985). Packard and co-authors documented this disease in a captive pup, which was one of the reasons for reproductive failure in a wolf pack after offspring copulated with their parents and with siblings.

Hydrocephalus in wild canids may arise from congenital malformations, infectious processes (particularly CDV), trauma, or, less commonly, neoplastic or inflammatory conditions, and its underlying causes are considered similar to those described in domestic dogs (Dewey and da Costa, 2016; Thomas, 2010). In free-living populations, congenital and infectious causes are considered the most relevant, although the condition is likely underreported due to limited diagnostic opportunities and low survival of affected individuals.

In the present case, CSF analysis did not reveal any abnormalities suggestive of inflammatory or infectious central nervous system disease. Cell count and protein concentration were within normal limits, and no infectious agents were detected by PCR or culture. Nevertheless, the pup tested positive for *A. phagocytophilum/A. platys* antibodies in rapid test. Anaplasmosis is a zoonotic, tick-borne pathogen commonly reported in wild canids, including wolves, where infections are often subclinical or associated with non-specific signs such as fever, lethargy, thrombocytopenia and musculoskeletal signs such as stiffness or lameness, while less frequently gastrointestinal signs or mild neurological abnormalities may be observed (Remesar et al., 2025; Hodžić et al., 2020; Dzięgiel et al., 2015; Leschnik et al., 2012). In this animal, the infection may have contributed to non-specific clinical findings, including loss of appetite and abdominal discomfort. However, the progressive neurological signs (circling, visual impairment) and cranial abnormalities (dome-shaped skull, strabismus) are not typical of anaplasmosis and are more consistent with structural intracranial pathology. These clinical findings and test results indicate exposure to this pathogen rather than an active infection. Therefore, although co-infection with *A. phagocytophilum* may have contributed to the overall clinical condition of the animal, it cannot

account for the development of hydrocephalus. The detected infection should be considered an incidental or concurrent finding rather than active infection primarily causing the observed neurological deficits.

These findings support a non-inflammatory etiology of hydrocephalus and, in combination with CT imaging, are most consistent with congenital obstructive hydrocephalus, likely due to stenosis of the mesencephalic aqueduct. No infectious agents, traumatic or environmental factors that could have contributed to the development of the disease were identified during the diagnostic process. The neurological deficits observed in the pup were most probably the cause of delayed development and abnormal behaviour, including separation from the pack and repeated proximity to human settlements. Cases of hydrocephalus of probable congenital etiology were also noted in foxes and bears (Ferguson et al., 2016; Silva et al., 2023).

Reports of hydrocephalus in wild carnivores are rare. Most available data concern foxes (Lacitignola et al., 2021; Silva et al., 2023), bears (Sorjonen et al., 1982; Kübber-Heiss et al., 2009; Ferguson et al., 2016) and raccoons (Lee et al., 2021). Most existing knowledge on hydrocephalus is derived from studies in domestic dogs, where the condition is well recognized, particularly in toy and brachycephalic breeds, and associated with variable prognosis depending on severity and treatment (Thomas, 2010; Dewey and da Costa, 2016).

Treatment of hydrocephalus in dogs can be based on pharmacological reduction of CSF production (acetazolamide, furosemide, glucocorticoids), but it provides mainly temporary or palliative effects. Definitive treatment involves surgical placement of a ventriculoperitoneal shunt, which allows controlled drainage of CSF from the ventricular system to the peritoneal cavity. Although surgical management can lead to significant clinical improvement, it is associated with possible complications, including shunt obstruction or dislocation, infection, or mechanical failure (Przyborowska et al., 2013; Estey, 2016). Conservative treatment has been reported in a captive adult fox with congenital hydrocephalus and resulted in partial long-term clinical improvement during a 16-month follow-up period (Raposo et al., 2022). Ventriculoperitoneal shunt placement was performed in a 2-year-old red fox with hydrocephalus and despite the postoperative complications surgical treatment increased the life expectancy and improved quality of life of the patient. Pizzi et al. describe a case of surgical treatment of hydrocephalus in a zoo bear. The animal's condition improved for approximately 4 years. However, in their conclusion, the authors state that in such cases, euthanasia should rather be considered (Pizzi et al., 2017).

To date, peer-reviewed reports describing hydrocephalus in wolves remain extremely limited. However, a single case of surgical management of hydrocephalus in a captive gray wolf has been described in non-scientific media sources, although detailed clinical data are not available and the case cannot be critically evaluated (KTVQ News, 2023). While such reports cannot be considered equivalent to scientific evidence, they may indicate that this condition can occur sporadically in this species. The present report, therefore, contributes novel data to the limited literature on neurological disorders in large free-living carnivores and highlights the need for further documentation of such conditions in wildlife species.

The described case illustrates the importance of comprehensive diagnostic evaluation of wild animals admitted to wildlife rehabilitation centers. Establishing a reliable diagnosis based on clinical, imaging, and laboratory findings is essential for evidence-based decision-making to ensure the best possible animal welfare. The availability of imaging diagnostics is a highly beneficial and necessary tool in making decisions regarding the treatment, rehabilitation, or euthanasia of wild animals. A similar observation was made in the diagnosis of foxes (Lacitignola et al., 2021; Neagu et al., 2025).

In the present case, euthanasia was the most appropriate choice based on welfare considerations and prognosis. The severity of the neurological impairment, its presumed congenital nature, and the lack of curative treatment options compatible with survival in the wild indicated a poor long-term outcome. Given these factors, successful reintroduction into a free-living wolf population was considered impossible, and prolonged captivity would not have met acceptable welfare standards for this species.

The most important limitation of this study is that it describes a single clinical case, which inherently limits the ability to generalize the findings to the broader population of free-living wolves. In addition, as is common in wildlife cases, there was no access to a detailed medical or developmental history of the animal, preventing assessment of potential genetic, environmental, or perinatal factors. Although extensive diagnostics were performed, some etiological factors, particularly subtle infectious or developmental influences, cannot be entirely excluded. In particular, subtle infectious, toxic, or developmental influences may remain undetected despite negative laboratory results. The interpretation of findings is also limited by the lack of comparative data for this species, as most current knowledge on hydrocephalus is derived from domestic dogs rather than wild canids. Despite these limitations, the case provides valuable insight into a rare neurological condition in a free-living wolf and contributes to the limited body of literature available for this species.

Abbreviations

CCV - Canine Coronavirus

CDV - Canine Distemper Virus

CPV - Canine Parvovirus

CSF - Cerebrospinal Fluid

CT - Computed Tomography

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the Knowledge Base of University of Gdańsk repository, https://repozytorium.bg.ug.edu.pl/info/researchdata/UOG6de6bda538574648b22067b91379b0d0/.

Consent for publication

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Contributions

WW: performed analyses, conceptualization, methodology, revision of the manuscript

KK: performed necropsy and the histopathological examination, writing and edition of the manuscript

BO: performed necropsy, conceptualization, writing, editing and revision of the manuscript

ES: CT scan analyses, edition of the manuscript

AD: revision of the manuscript

MS: genetic analysis

SN: genetic analysis

KA: revision of the manuscript

MG: data curation, writing the original draft, review and editing of the manuscript, conceptualization, supervision

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Ethics declarations

Conflict of interest

The authors of this work declare that they have no conflicts of interest.

Ethical approval

The official consent for treatment and euthanasia was granted by the Regional Directorate for Environmental Protection (RDOŚ) in Poland.

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Figures

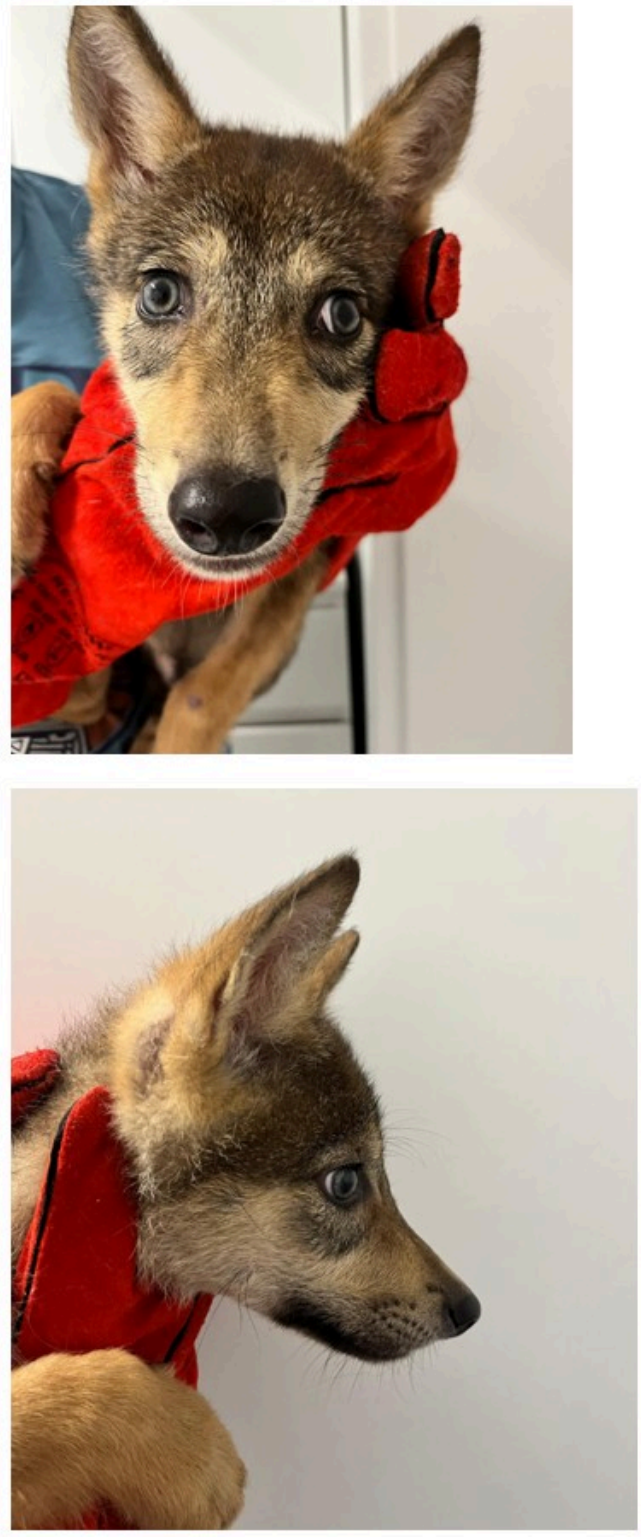


Figure 1

a,b. Pictures of the wolf pup’s dome-shaped skull and mild strabismus.



Figure 2

Transverse post-contrast CT image of the head at the level of the caudal fossa. Please note the severe asymmetrical dilation of the lateral ventricles and finger-shaped fluid-attenuating regions (white arrows) associated with the dorsal margin of the lateral ventricles. The rostral portion of the mesencephalic aqueduct is not visible.

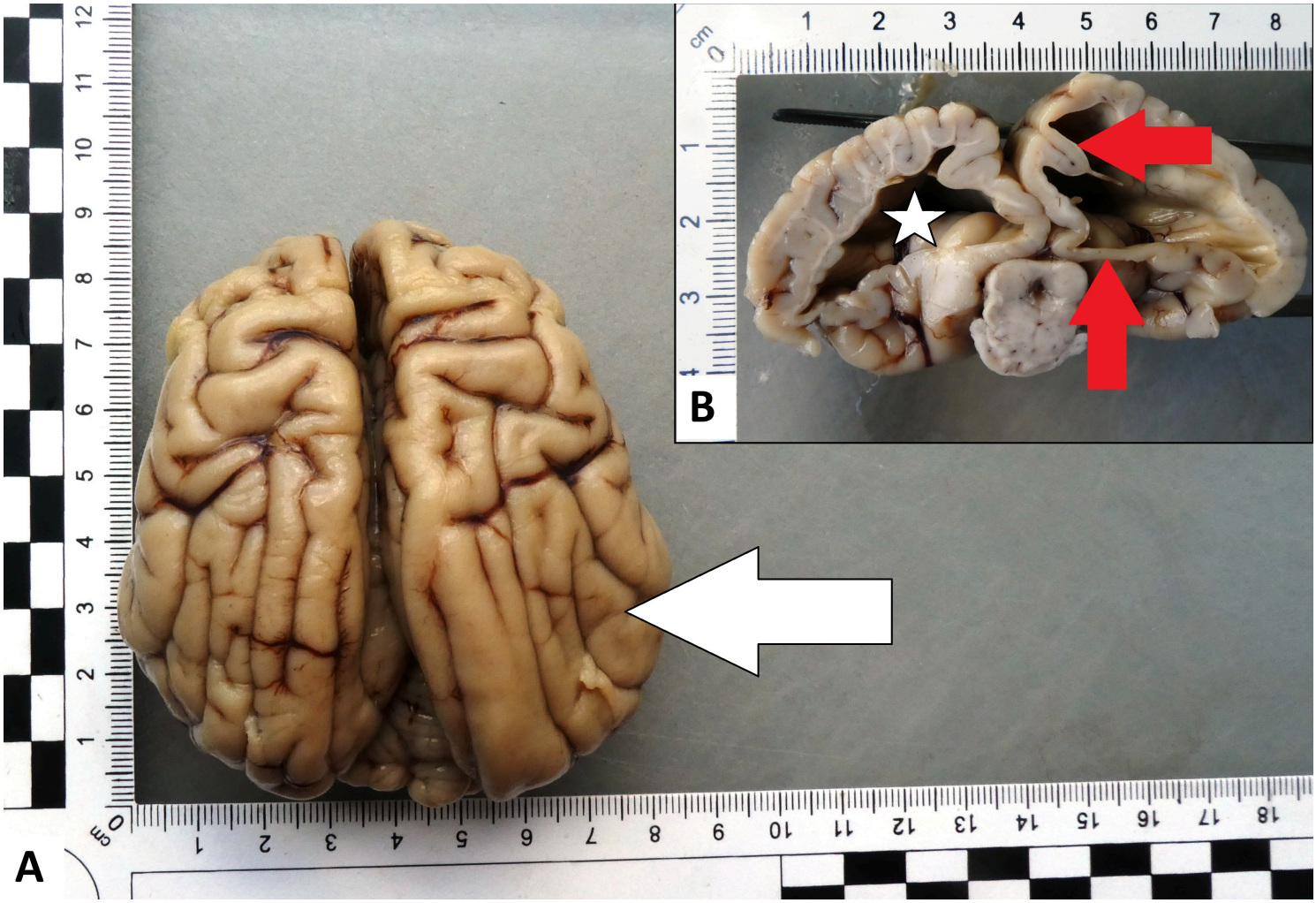


Figure 3

Macroscopic picture of the brain after fixation. A. Expanded outline of the cerebral hemispheres, particularly the right hemisphere, resulting from dilated ventricular lumen. The right hemisphere is markedly collapsed (arrow). B. Brain in cross-section. Dilated lumen of the lateral ventricles (asterisk) with significant thinning of the brain tissue (arrows).

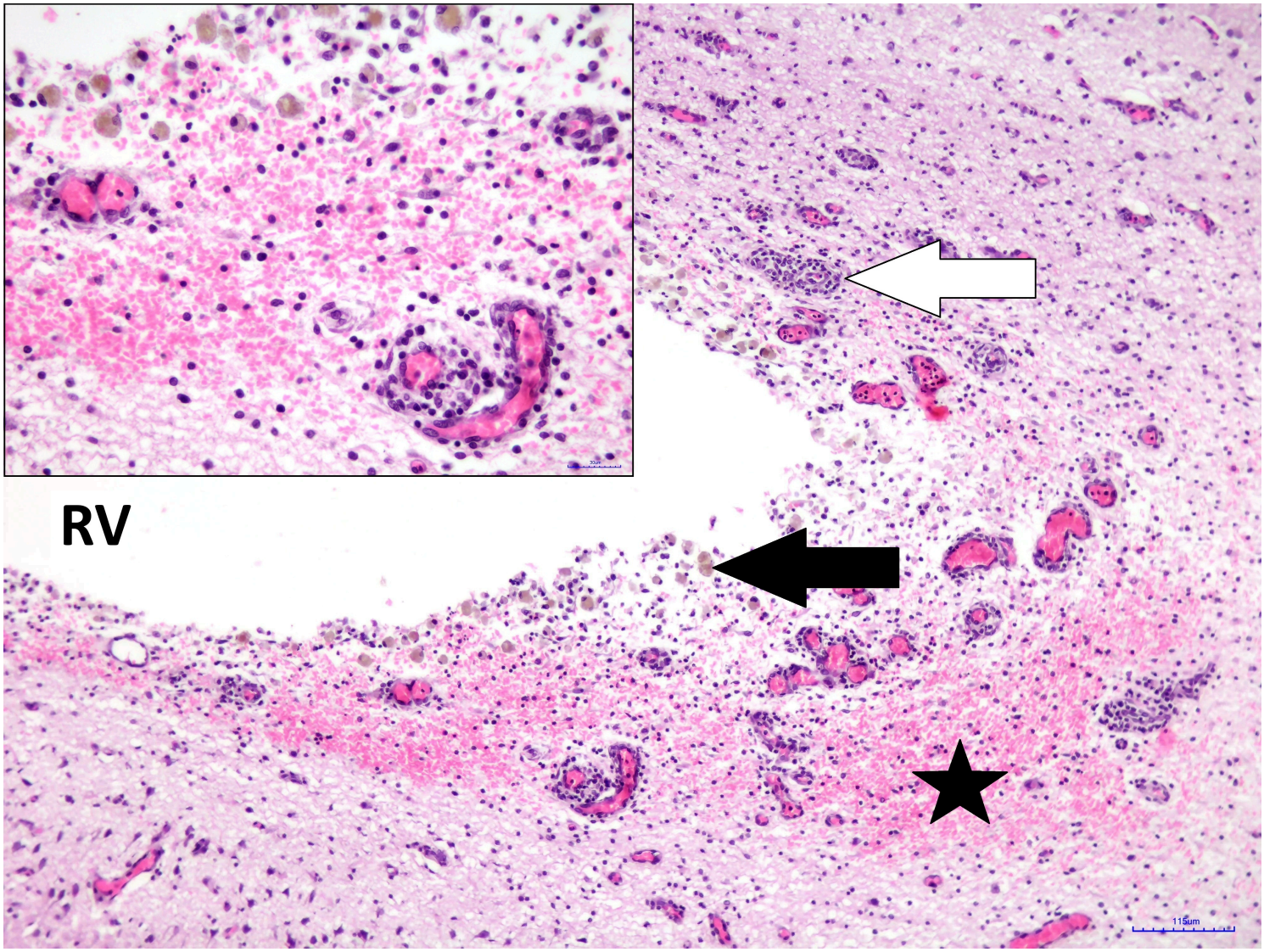


Figure 4

Histopathological picture of the brain in the area tangent to the right lateral ventricle. RV – right lateral ventricle. Haemorrhages (asterisk) with numerous siderophages (black arrow) were found probably as a result of increased tension. Perivascular inflammatory infiltrates composed of mononuclear cells (mainly small lymphocytes) were also found (white arrow). H&E, magn. 100x. Frame - higher magnification of the same area. H&E, magn. 400x .

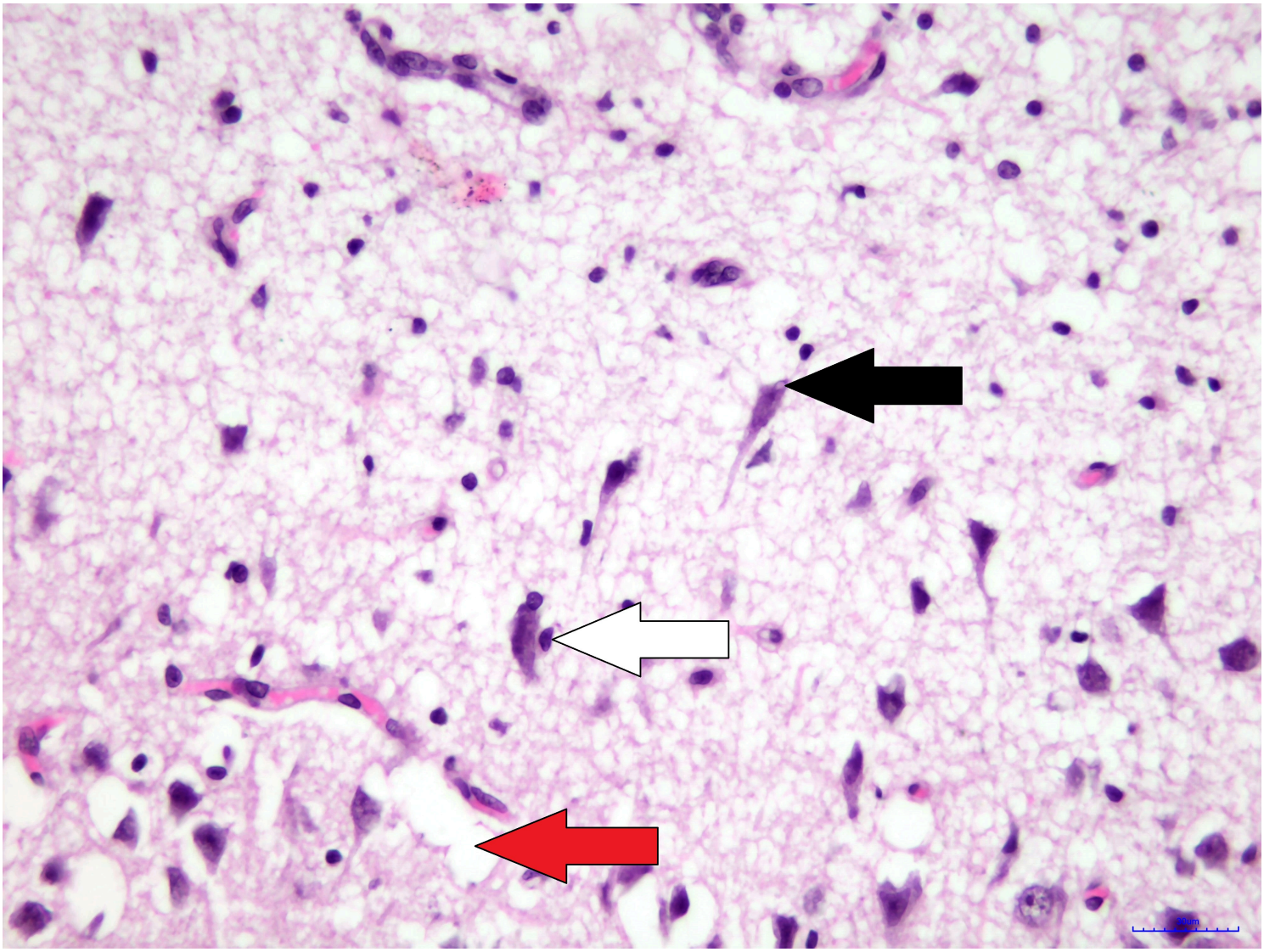


Figure 5

Histopathological picture of the atrophic areas of the brain. Multifocal atrophy of neurons were found (black arrow) with neuronophagy (white arrow). White spaces around cells and vessel (red arrow) represent massive oedema of the brain. H&E, magn. 400x.

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