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“Journal of Applied Animal Science” (JAAS)

Scope of the Journal

The philosophy of the Faculty of Veterinary Science, Mahidol University, is “*One Health*”, i.e., to interweave the disciplines of veterinary sciences with medical sciences for extreme advantages to human, animals and environment. The *Journal of Applied Animal Science (JAAS)*, is a peered review journal which published 2 numbers (January-June, July-December) a year by Faculty of Veterinary Science, Mahidol University, accepts manuscripts presenting information for publication with this philosophy in mind. Articles published in *JAAS* include a broad range of research topics in veterinary science, animal science, animal husbandry, animal production and fundamental aspects of genetics, nutrition, physiology, and preparation and utilization of animal products. Articles typically report research with cattle, companion animals, goats, horses, pigs, and sheep; however, studies involving other farm animals, aquatic and wildlife species, and laboratory animal species that address fundamental questions related to livestock and companion animal biology will be considered for publication.

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“Journal of Applied Animal Science” (JAAS)

สารจากคณบดี

เรียน ท่านผู้อ่านและผู้สนใจทุกท่าน

ขอถือโอกาสนี้ขอขอบคุณท่านผู้อ่านทุกท่านที่ให้ความสนใจและติดตามวารสาร Journal of Applied Animal Science (JAAS) มาอย่างต่อเนื่อง ฉบับนี้ (Vol.17 No.2 (2024): กรกฎาคม-ธันวาคม) ถือเป็นฉบับพิเศษ เนื่องจากเป็นฉบับสุดท้ายของวารสารที่ได้รับการจัดให้อยู่ในกลุ่ม Tier 3 จากฐานข้อมูล TCI (Thai Journal Citation Index Centre) และฉบับต่อไปจะเป็นการจัดให้อยู่ในกลุ่ม Tier 1 จากฐานข้อมูล TCI ซึ่งถือเป็นก้าวสำคัญในการพัฒนาวารสารให้มีคุณภาพและมาตรฐานสากล

ในฉบับนี้ วารสาร JAAS ได้รวบรวมบทความที่น่าสนใจและมีคุณค่าทางวิชาการ โดยเฉพาะอย่างยิ่ง กรณีศึกษา จำนวน 3 เรื่อง ที่มีความหลากหลายและครอบคลุมประเด็นทางสัตวแพทย์และวิทยาศาสตร์การสัตว์ ดังนี้

1. A Case Report of an Eyelid Amelanotic Malignant Melanoma in Ferret (*Mustela putorius furo*) บทความนี้นำเสนอกรณีศึกษาของมะเร็งผิวหนังชนิด amelanotic malignant melanoma ในบริเวณเปลือกตาของเฟอร์เรต ซึ่งเป็นสัตว์เลี้ยงที่ได้รับความนิยมมากขึ้นในปัจจุบัน กรณีศึกษานี้ไม่เพียงแต่ให้ข้อมูลเชิงลึกเกี่ยวกับการวินิจฉัยและรักษาโรค แต่ยังช่วยเพิ่มความตระหนักเกี่ยวกับโรคมะเร็งในสัตว์เลี้ยงชนิดนี้

2. Case Report: Surgical Repair and Pericardial Drainage in a Scottish Fold Cat with Congenital Peritoneopericardial Diaphragmatic Hernia กรณีศึกษานี้กล่าวถึงการผ่าตัดรักษาและการระบายของเหลวในช่องเยื่อหุ้มหัวใจในแมวพันธุ์ Scottish Fold ที่มีภาวะไส้เลื่อนกะบังลมแต่กำเนิด บทความนี้เน้นถึงเทคนิคการผ่าตัดที่ทันสมัยและการจัดการหลังการผ่าตัด ซึ่งเป็นประโยชน์ต่อสัตวแพทย์และผู้ที่ทำงานด้านสุขภาพสัตว์

3. Application of Sutures for Skull Stabilization: A Novel Technique for Cranioplasty in Fennec Fox (*Vulpes zerda*) บทความนี้นำเสนอเทคนิคใหม่ในการรักษากระดูกกะโหลกของเฟนเนคฟ็อกซ์ โดยใช้การเย็บเพื่อสร้างความมั่นคงให้กับกะโหลกศีรษะ เทคนิคนี้ไม่เพียงแต่ช่วยให้การรักษามีประสิทธิภาพมากขึ้น แต่ยังเป็นแนวทางใหม่ในการผ่าตัดสัตว์ป่าและสัตว์เลี้ยงชนิดพิเศษ

ดิฉันขอขอบคุณผู้เขียนทุกท่านที่ส่งบทความที่มีคุณภาพมาตีพิมพ์ในวารสารฉบับนี้ รวมถึงผู้ทรงคุณวุฒิที่ให้ความเห็นและข้อเสนอแนะเพื่อพัฒนาบทความให้มีคุณภาพสูงสุด และขอขอบคุณทีมบรรณาธิการและผู้สนับสนุนทุกท่านที่ทุ่มเทแรงกายแรงใจในการจัดทำวารสารฉบับนี้ให้สำเร็จลุล่วง

วารสาร JAAS จะยังคงมุ่งมั่นในการเผยแพร่ความรู้และงานวิจัยที่ทันสมัย เพื่อสนับสนุนการพัฒนาด้านสัตวแพทย์และวิทยาศาสตร์การสัตว์ต่อไปในอนาคต และหวังเป็นอย่างยิ่งว่าท่านผู้อ่านจะได้รับประโยชน์จากบทความในวารสารฉบับนี้ และขอเชิญชวนทุกท่านร่วมส่งบทความที่มีคุณภาพเพื่อตีพิมพ์ในวารสารฉบับต่อๆ ไป

รองศาสตราจารย์ ดร.สัตวแพทย์หญิงวลาสินี ศักดิ์คำดวง
คณบดีคณะสัตวแพทยศาสตร์
มหาวิทยาลัยมหิดล

“Journal of Applied Animal Science” (JAAS)

ปีที่ 17 ฉบับที่ 2 กรกฎาคม-ธันวาคม 2567 Vol. 17 No. 2 July-December 2024

สารบัญ

คำแนะนำสำหรับผู้แต่ง

"Journal of Applied Animal Science" (JAAS)

วารสารสัตวศาสตร์ประยุกต์เป็นวารสารวิชาการราย 6 เดือน (2 ฉบับต่อปี เดือนมกราคม-มิถุนายน และเดือนกรกฎาคม-ธันวาคม) ของคณะสัตวแพทยศาสตร์ มหาวิทยาลัยมหิดล เผยแพร่ผลงานวิจัยครอบคลุมสหสาขาวิชาทั้งสัตวแพทยศาสตร์ และสัตวศาสตร์ ตั้งแต่พื้นฐานถึงระดับโมเลกุล รวมถึงรายงานทางคลินิก บทความที่ได้รับการตีพิมพ์ในวารสารต้องผ่านการประเมินโดยผู้ทรงคุณวุฒิอย่างน้อย 3 ท่าน ในรูปแบบ double-blind peer review

ผู้สนใจส่งบทความเพื่อตีพิมพ์ในวารสารสัตวศาสตร์ประยุกต์กรุณาปฏิบัติตามข้อแนะนำและส่งพร้อมจดหมายนำ

1. ประเภทบทความ ที่รับพิจารณาได้แก่ รายงานการวิจัย รายงานฉบับย่อ บทความปริทัศน์และรายงานทางคลินิกเขียนด้วยภาษาไทยหรือภาษาอังกฤษ แต่บทคัดย่อต้องมีทั้งภาษาไทยและภาษาอังกฤษ

2. การส่ง ส่งต้นฉบับพร้อมสำเนา 4 ชุด และไฟล์ดิจิตอลทางไปรษณีย์ ไฟล์ดิจิตอลต้องสร้างด้วยโปรแกรม MS-Word หรือซอฟต์แวร์ที่ใช้แทนกันได้ อาจส่งต้นฉบับผ่านอีเมลโดยไม่มีสำเนาได้

3. รูปแบบ ขนาดกระดาษเอ 4 พิมพ์หน้าเดียว เว้นระยะ 1 บรรทัด ขอบกระดาษ 2.54 ซม. (1 นิ้ว) ฟอนต์ Angsana New หรือ TH SarabunPSK 16 พอยต์

4. ส่วนประกอบ รายงานการวิจัยต้องประกอบด้วยหน้าแรก (ได้แก่ ชื่อเรื่อง ชื่อผู้แต่ง สถานที่ทำงานและที่อยู่ ชื่อผู้แต่งหลักพร้อมที่อยู่ที่ติดต่อได้และอีเมล พิมพ์ทั้งภาษาไทยและภาษาอังกฤษ) บทคัดย่อ (สั้นกระชับได้ใจความและคำสำคัญ 3-4 คำ) บทนำ อุปกรณ์และวิธีการ ผลการวิจัย วิจารณ์ กิตติกรรมประกาศและเอกสารอ้างอิง

ก. รายงานฉบับย่อและรายงานทางคลินิก อาจเขียนโดยไม่แยกหัวข้อ หรืออาจรวมส่วนผลการวิจัยและวิจารณ์เป็นหัวข้อเดียว

ข. บทความปริทัศน์ ควรเริ่มด้วยบทนำ แล้วบรรยายโดยแยกตามหัวข้อที่ต้องการนำเสนอ พร้อมบทสรุป

5. ตาราง-รูปภาพ ตารางและรูปภาพให้แทรกไว้ท้ายสุดของบทความ คำบรรยายตารางพิมพ์ด้านบน คำบรรยายรูปภาพพิมพ์ใต้ภาพ และมีหมายเลขอารบิกกำกับตามลำดับการอ้างถึง ตารางควรเข้าใจได้ง่าย ให้ส่งรูปภาพความละเอียดสูงแยกต่างหากมาพร้อมด้วย

6. การอ้างอิง ผู้แต่งต้องปฏิบัติตามรูปแบบการอ้างอิงของวารสาร การอ้างอิงในเนื้อหาใช้ระบบนาม-ปี เช่น (คัมภีร์ กอธีระกุล และคณะ 2530) หรือ คัมภีร์ กอธีระกุล และคณะ (2530) การเขียนรายการเอกสารอ้างอิงให้เขียนไว้หลังกิตติกรรมประกาศ โดยพิมพ์เอกสารภาษาไทยก่อนแล้วตามด้วยเอกสารภาษาอังกฤษ สำหรับการเขียนเอกสารอ้างอิงภาษาอังกฤษให้ดูจากส่วนแนะนำภาษาอังกฤษ

คัมภีร์ กอธีระกุล, เทิด เทศประทีป, วรา พานิชเกรียงไกร, โสมทัต วงศ์สว่าง, วราภรณ์ แซ่ลี้, สมศักดิ์ ภัดีศิริภรณ์. การสำรวจพบเชื้อ *อี.โคไล* ซีโรไทป์ K88 จากลูกสุกรวัยดูดนมและหลังหย่านม. เวชชสารสัตวแพทย์. 2530; 17(1): 21-7.

7. ชื่อวิทยาศาสตร์ ให้พิมพ์เป็นภาษาอังกฤษตามประมวลนามศัพท์สากลและทำให้เด่นแตกต่างจากเนื้อหา

8. การถอดคำไทยเป็นภาษาอังกฤษ ใช้หลักเกณฑ์การถอดอักษรไทยเป็นอักษรโรมันแบบถ่ายเสียงของราชบัณฑิตยสถาน

9. อักษรย่อและสัญลักษณ์ หากเป็นที่รับรู้โดยทั่วกันอนุโลมให้ใช้ได้โดยไม่ต้องพิมพ์ตัวเต็มก่อน

สำหรับรายละเอียดเพิ่มเติมและแม่แบบต้นฉบับ ให้ไปที่เว็บไซต์ของวารสาร https://he02.tci-thaijo.org/index.php/jaas_muvs

อีเมลบรรณาธิการวารสาร editor.jaas2020@gmail.com

ที่อยู่ คณะสัตวแพทยศาสตร์ มหาวิทยาลัยมหิดล 999 ถนนพุทธมณฑล สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170

Instructions to Authors

"Journal of Applied Animal Science" (JAAS)

Journal of Applied Animal Science is a peer-review journal (2 issues/year; January-June and July-December) which publishes papers that report on original research covering broadly interdisciplinary of veterinary and animal sciences with results of more than local regard. *JAAS* invite and welcome submissions on existing new research from basic to molecular. Articles published under our journal are double-blind peer reviewed by at least 3 reviewers.

The author should follow the instructions below for manuscript preparation and submit with covering letter.

1. Categories: *JAAS* accepts varieties of article, including research articles, short communications, reviews and also clinical reports.

2. Language: English articles are preferable; however, both Thai and English manuscripts are acceptable, with Thai and English abstracts.

3. Submission: Submission via email is our most preferable way. However, submission of the manuscript is acceptable by either paper (4 copies) or digital format (email). Finally, digital format must be submitted. The submission file is in MS-Word format or compatible software.

4. Format: The manuscript should be used A4 size with margin of 2.54 cm (1 in), double spacing and indentions by using tabs. Times New Roman font 12 points is favored for English and Angsana New or TH SarabunPSK 16 points is desirous for Thai.

5. Components: The research manuscripts should have sequential components as title page, abstract and 3-4 keywords, introduction, materials and methods, results, discussion, conclusion, acknowledgements and references. Title page, in both Thai and English, includes title, author(s) and affiliation(s) for each author. Corresponding author must provide full contact address and email.

a. Short communications or clinical reports: These could be written as no sections, combination of results and discussion or introduction and followed by several presentation sections.

b. Reviews: The manuscript should start with introduction and followed by demonstration sections and conclusion.

6. Tables-Figures: Tables and figures must be numbered by using Arabic numbers. The caption must be written on the top of table or the bottom of figure. Tables and figures should be put at the end of article. All tables should be understandable by itself. All figures with high quality should be prepared in black and white as separate files.

7. References: Authors must be careful for the reference formats of both in-text citations and bibliography. In-text citations use author(s)-year in parentheses, the proper format is (Smith 2008; Kennedy and Smith 2009; John et al., 2010a, 2010b) or Smith (2008).Two authors use "and" in between. Using "et al.," when there are more than 2 authors. Multiple citations in a sentence must be in chronological order first, then alphabetical order. Bibliography should be in the last part of article and arranged alphabetically by authors or title. List first 6 authors and followed by "et al." when there are more than 6 authors. The title is followed the last author. Abbreviated journals are according to the conventional ISO abbreviations used by PubMed. One-word journal title must be spelled out. Year of publication, volume, issue in parentheses, and begin and end pages. These are examples of bibliography.

Barker K. At the Bench: A laboratory navigator. New York: Cold Spring Harbor Laboratory Press; 1998.

Fairbrother JM, Gyles CL. Escherichiacoliinfections. In: Straw BE, Zimmerman JJ, D'Allaire S, Taylor DJ, editors. Diseases of swine. 9th ed. Iowa: Blackwell Publishing; 2006. p. 639-74.

Laohasinnarong D, Kaeoket K, Prasitphon B. Estrus synchronization in gilts with altrenogest by different given time. Proceedings of the 19th IPVS Congress. Copenhagen, Denmark: Narayana Press; 2006. p. 118.

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WHO media centre. African trypanosomiasis (sleeping sickness) [Internet]. WHO. 2010 [cited 2011 Oct 29]. Available from: http://www.who.int/mediacentre/factsheets/fs259/en/.

8. Scientific terms should use the update and follow the International Code of Nomenclature, written by emphasis.

9. Standard abbreviations and symbols are acceptable without definition.

Please visit *JAAS* website for more information and manuscript template, https://he02.tci-thaijo.org/index.php/jaas_muvs

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Editor Note

สวัสดีครับท่านผู้อ่านและสมาชิกวารสาร Journal of Applied Animal Science (JAAS) ทุกท่าน วารสารฉบับนี้ถือเป็นฉบับส่งท้ายของปี พ.ศ. 2567 และเป็นฉบับสุดท้ายของวารสารที่ได้รับการจัดให้อยู่ใน Tier 3 จากฐานข้อมูล TCI (Thai Journal Citation Index Centre) ซึ่งได้รับการรับรองระหว่างปี พ.ศ. 2563-2567 สำหรับเนื้อหาของวารสารฉบับนี้ประกอบด้วยรายงานสัตว์ป่วยที่น่าสนใจ 3 เรื่อง ได้แก่

1. **รายงานสัตว์ป่วยมะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีที่บริเวณเปลือกตาในเฟอเรท (*Mustela putorius furo*)**
2. **รายงานสัตว์ป่วย: การผ่าตัดแก้ไขโรคไส้เลื่อนกะบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจแต่กำเนิดในแมวสกอตติช โฟลด์**
3. **การประยุกต์ใช้ไหมเย็บในการเชื่อมกะโหลก: เทคนิคใหม่สำหรับการผ่าตัดกะโหลกสุนัขจิ้งจอกเฟนเนก**

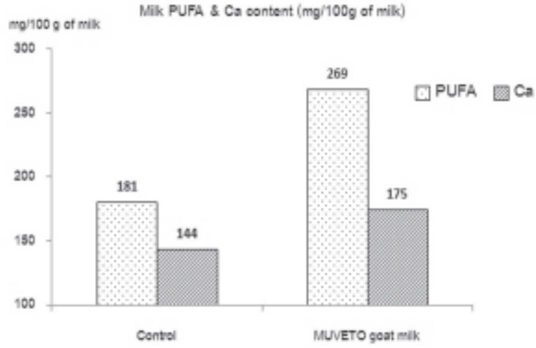
นอกจากนี้ ทางกองบรรณาธิการขอถือโอกาสแจ้งให้ทุกท่านทราบว่าในฉบับถัดไป ปี พ.ศ. 2568 ทางวารสารได้รับการรับรองคุณภาพจากศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI) ให้เป็น "**วารสารกลุ่มที่ 1 หรือ Tier 1**" และจะได้รับการรับรองคุณภาพวารสารกลุ่มที่ 1 เป็นระยะเวลา 5 ปี ระหว่าง พ.ศ. 2568-2572 ซึ่งเป็นการการันตีว่าทางวารสารของเรามีการพัฒนาคุณภาพอย่างต่อเนื่อง

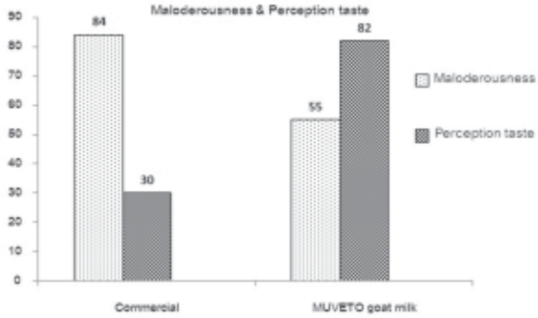
ในโอกาสนี้ ทางกองบรรณาธิการขอเชิญชวนผู้เชี่ยวชาญและนักวิจัยในสาขาสัตวแพทย์หรือสัตวศาสตร์ทุกท่านส่งบทความที่มีคุณภาพและน่าสนใจมาตีพิมพ์ในวารสารของเรา โดยทุกบทความจะได้รับการตรวจสอบคุณภาพอย่างเข้มงวดจากผู้ทรงคุณวุฒิที่มีความเชี่ยวชาญในสาขานั้น ๆ และบทความที่ได้รับการตีพิมพ์จะช่วยเสริมสร้างองค์ความรู้ทางวิชาการ ซึ่งเป็นประโยชน์ต่อการพัฒนาวิชาการทั้งในระดับชาติและนานาชาติ

สุดท้ายนี้ ในนามของหัวหน้ากองบรรณาธิการ ขอขอบพระคุณผู้นิพนธ์ทุกท่าน กองบรรณาธิการวารสาร และผู้ทรงคุณวุฒิที่ให้ความอนุเคราะห์ในการพิจารณาบทความและให้คำแนะนำอันเป็นประโยชน์ต่อการพัฒนาคุณภาพของบทความสู่วงการวิชาการ โดยทางกองบรรณาธิการหวังเป็นอย่างยิ่งว่าจะได้รับการสนับสนุนจากทุกท่านอีกในปีถัดไป

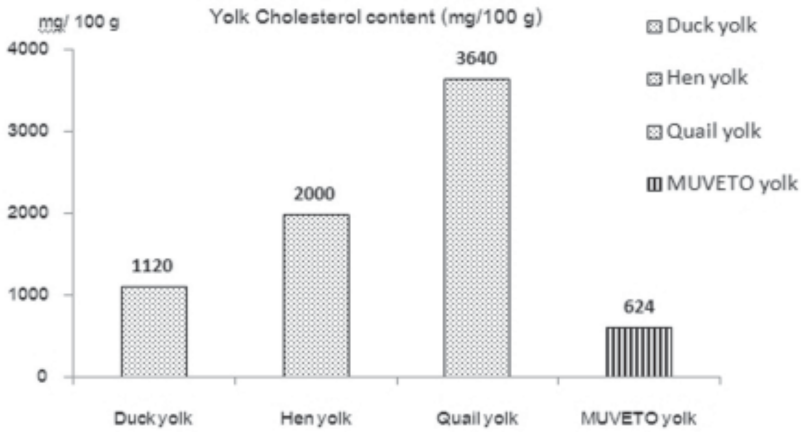
รองศาสตราจารย์ ดร.นายสัตวแพทย์ธนศักดิ์ ช่างบรรจง

บรรณาธิการ (Editor-in-Chief)





Functional goat milk: Naturally high PUFA,Ca and maloderousness



Functional egg: Low cholesterol

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Case Report

A Case Report of an Eyelid Amelanotic Malignant Melanoma in Ferret (*Mustela putorius furo*)

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Abstract

Amelanotic malignant melanoma is a rare subtype of melanoma that can occur in any part of the body, presenting in various forms and associated with a poor prognosis. Due to the absence of the pigment melanin, clinical diagnosis is challenging, often leading to delays in treatment. The primary treatment is early surgical intervention, which can be combined with radiotherapy, cryotherapy, and chemotherapy if necessary. To the best of the autho's knowledge, this is the first report of an eyelid amelanotic malignant melanoma in a ferret (*Mustela putorius furo*). A 5-year-old male ferret was presented with a small, irregular, protruding pinkish firm mass located in the medial of the left lower eyelid, extending to the palpebral conjunctiva of the left eye. The mass did not respond to medical treatment. Thoracic and abdominal radiographs revealed no abnormalities. Hematology and serum biochemistry results were within normal limits. The left eyelid mass was surgically removed using the H-plasty technique for biopsy. Histopathological examination and immunohistochemistry labeling with Melan-A confirmed a diagnosis of amelanotic malignant melanoma. A recurrent mass was observed 14 weeks after the initial surgery. Pre-operative computed tomography (CT) revealed that the left eyelid mass had extended into the left retrobulbar region, causing left ocular compression and exophthalmos. A second surgical excision and enucleation were performed. Histopathological evaluation confirmed the diagnosis of amelanotic malignant melanoma. Approximately 5 weeks after the second surgery, the tumor recurred and invaded the oral cavity, with bone lysis at the zygomatic arch and maxilla. The ferret was found dead at home approximately 8 months after the diagnosis. Amelanotic malignant melanoma appears to be a highly aggressive type of tumor in ferrets, and surgical removal alone is not effective in preventing metastasis or prolonging survival. Although uncommon, amelanotic malignant melanoma should be considered in the differential diagnosis of eyelid neoplasms in ferrets.

Keywords: Amelanotic malignant melanoma, Cancer, Eyelid, Ferret

รายงานสัตว์ป่วยมะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีที่บริเวณเปลือกตาในเฟอเรท (*Mustela putorius furo*)

ปณิชา สิงห์เสนา[1*] ธาเนศ อนุศักดิ์เสถียร[2] เชาวพันธ์ ยินหาญมิ่งมงคล[1]

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บทคัดย่อ

มะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีเป็นมะเร็งที่พบได้น้อยแต่มีความรุนแรงมาก สามารถเกิดขึ้นได้กับทุกส่วนของร่างกายในหลากหลายรูปแบบ เนื่องจากเป็นมะเร็งที่ไม่ผลิตเม็ดสี จึงยากต่อการวินิจฉัยหรืออาจวินิจฉัยผิดพลาดส่งผลให้เกิดการรักษาที่ล่าช้า การผ่าตัดเป็นวิธีการรักษาที่เป็นมาตรฐานโดยสามารถทำร่วมกับการให้รังสีบำบัด การบำบัดด้วยความเย็น และการให้ยาเคมีบำบัด รายงานสัตว์ป่วยนี้เป็นรายงานแรกของการเกิดมะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีที่บริเวณเปลือกตาในเฟอเรท เฟอเรทเพศผู้ อายุ 5 ปี ตรวจพบก้อนเนื้อสีชมพูขนาดเล็ก รูปร่างไม่สม่ำเสมอ บริเวณกลางเปลือกตาล่างจนถึงเยื่อบุตาขาวด้านในของเปลือกตาล่างซ้ายและไม่ตอบสนองต่อการรักษาทางยา ผลการตรวจเลือดและรังสีวินิจฉัยไม่พบความผิดปกติใดใด จึงพิจารณาผ่าตัดเอาก้อนเนื้อออกทั้งหมดและตัดเก็บชิ้นเนื้อเพื่อส่งตรวจทางพยาธิวิทยาด้วยวิธีเฮช พลาสที (H-plasty technique) ลักษณะเซลล์ที่พบทางพยาธิวิทยาและผลการตรวจทางอิมมูนฮิสโตเคมีวินิจฉัยได้ว่าเป็นมะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีที่บริเวณเปลือกตา หลังผ่าตัด 14 สัปดาห์พบว่ามีการกลับมาเป็นซ้ำ และก้อนเนื้อขนาดใหญ่ขึ้น เฟอเรทได้รับการตรวจเอกซเรย์คอมพิวเตอร์พบว่าก้อนเนื้อที่เปลือกตาซ้ายขยายเข้าไปในบริเวณหลังตาซ้ายส่งผลให้ตาซ้ายถูกดันออกจากเบ้าตา จึงทำการผ่าตัดก้อนเนื้อและควักตา ผลการตรวจทางพยาธิวิทยายืนยันว่าเป็นมะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีที่บริเวณเปลือกตา ประมาณ 5 สัปดาห์หลังจากการผ่าตัดครั้งที่ 2 พบการกลับมาเป็นซ้ำของมะเร็งและลุกลามไปบริเวณช่องปากส่งผลให้เกิดภาวะการสลายตัวของกระดูกโหนกแก้มและกระดูกขากรรไกรบน เฟอเรทเสียชีวิต ประมาณ 8 เดือนหลังจากได้รับการวินิจฉัย การศึกษาพบว่ามะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีเป็นมะเร็งชนิดร้ายแรงในเฟอเรท การรักษาด้วยการผ่าตัดเพียงอย่างเดียวไม่สามารถป้องกันการแพร่กระจายตัวของมะเร็งหรือเพิ่มอัตราการรอดชีวิตในเฟอเรทได้ ถึงแม้จะเป็นมะเร็งที่พบได้น้อย แต่ควรพิจารณามะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสีในการวินิจฉัยแยกโรคเนื้องอกที่เปลือกตาของเฟอเรท

คำสำคัญ : มะเร็งเมลาโนมาชนิดไม่สร้างเม็ดสี มะเร็ง เปลือกตา เฟอเรท

Introduction

Neoplastic diseases are commonly diagnosed in domestic ferrets (*Mustela putorius furo*) (Williams and Wyre 2020). Ferrets can develop the same types of neoplasms that occur in other species. The age distribution with the highest tumor incidence is between 4 and 6 years (Williams and Wyre 2020). In ferrets, adrenocortical tumor is the most common, followed by lymphoma and pancreatic islet cell tumor (Shiga et al., 2021). Melanoma in ferrets has been reported in a limited number of cases over the years. Tunev and Wells documented a case of spontaneous cutaneous melanoma in a 4-year-old spayed female ferret in 2002. Additionally, d'Ovidio et al. (2016) described an oral malignant melanoma in a 3-year-old intact male ferret.

Melanocytic tumors are one of the most common neoplasms of the integumentary system in dogs but are rare in other domesticated species (Smedley et al., 2022; Abbate et al., 2023; Polton et al., 2024). Melanoma is a melanocytic tumor that arises from melanocytes in the skin, mucosa, and indigenous melanocytes of various internal organs (Long et al., 2023). Malignant melanoma accounts for 70% of all melanin-producing tumors and 7% of all malignant tumors (Polton et al., 2024). Amelanotic malignant melanoma is a rare subtype that constitutes approximately 2% to 20% of all melanomas in humans, that has little or no melanin pigment and can occur in any part of the body, presenting various manifestations related to the affected structure (Osama et al., 2023). Amelanotic malignant melanoma has a poor prognosis due to the absence of melanin pigment, which makes clinical diagnosis difficult, often leading to misdiagnosis and delayed treatment (Polton et al., 2024). Diagnosis of malignant melanoma with melanin pigment is straightforward, but the amelanotic form is much more challenging (Polton et al., 2024). Histopathological diagnosis may be difficult if the tumor does not contain melanin; therefore, immunohistochemistry is important for diagnosing amelanotic malignant melanoma (Mathewos et al., 2020; Pérez-Santana et al., 2024). Surgical resection with wide margins remains the primary treatment for local control of melanomas and is often supplemented by radiotherapy, immunotherapy, and chemotherapy, if necessary (Williams and Wyre 2020; Long et al., 2023; Kaminsky et al., 2023; Abbate et al., 2023). A limited number of melanoma cases in ferrets have been reported. Tunev and Wells (2002) documented a case of spontaneous cutaneous melanoma in a 4-year-old spayed female ferret. Additionally, d'Ovidio et al. (2016) described an oral malignant melanoma in a 3-year-old intact male ferret.

The aim of the present study was to describe the clinical manifestations and histological appearance of malignant amelanotic melanoma in ferrets. To date, there has been no documented evidence of amelanotic melanoma in ferrets (Mustela putorius furo) in the veterinary literature. This is the first published description of a clinical case and the histopathological findings of amelanotic malignant melanoma of the eyelid in this species.

Case description

A 5-year-old male ferret was presented to the Animal Space Pet Hospital with a history of left eye inflammation and ocular discharge for 2 weeks. Physical examination revealed a small, irregular, protruding pinkish firm mass located in the median area of the left lower eyelid, extending to the palpebral conjunctiva of the left eye (Figure 1). The remainder of the physical examination was unremarkable.

Ophthalmic examination showed that the dazzle reflex, menace response, palpebral reflex, and pupillary light reflexes (both direct and consensual) were present in both eyes. The intraocular pressure (IOP) in both eyes was within the reference range, and both eyes were negative for corneal fluorescein staining. Nuclear sclerosis was present bilaterally. There was mild conjunctivitis in the left eye. A protruding, solitary, well-defined, firm, pinkish mass measuring 0.5 x 0.3 x 0.2 cm in the palpebral conjunctiva and lower eyelid region of the left eye was noted. The ferret was started on topical eye ointment (MAXITROL® Ophthalmic Suspension, Novartis Pharma AG, Basel, Switzerland) in a 0.5 cm strip, applied to the left eye (OS) every 8 hours, marbofloxacin at 5 mg/kg orally (PO) every 24 hours, and prednisolone at 0.5 mg/kg PO every 12 hours for 2 weeks. The ferret did not respond to the treatment.

A presurgical clinical assessment of the patient's health status was performed for an excisional surgical biopsy. While anesthetized, blood was collected from the cranial vena cava, and full-body radiographs were performed. The complete blood count and serum biochemical profile were unremarkable. Radiographic evaluation did not reveal any evidence of distant metastasis.

The ferret was premedicated with ketamine at 7 mg/kg intramuscularly (IM), midazolam at 0.5 mg/kg IM, and atropine at 0.04 mg/kg IM. An endotracheal tube was placed and maintained with isoflurane gas. Reconstructive surgery was performed using the H-Plasty technique, which involves an "H"-shaped incision to reconstruct tissue. This approach successfully removed the mass from the lower palpebral conjunctiva and eyelid margin (Figure 2). Monofilament suture material (7-0) was used for intradermal closure. The mass was fixed in 10% neutral buffered formalin for histological examination at Vet Central Lab. The tissue was embedded in paraffin, sectioned into 3 μm thick slice, and stained with hematoxylin and eosin (H&E). Additionally, immunostaining was performed using antibodies specific to Melan-A proteins to immunohistochemical evaluation.

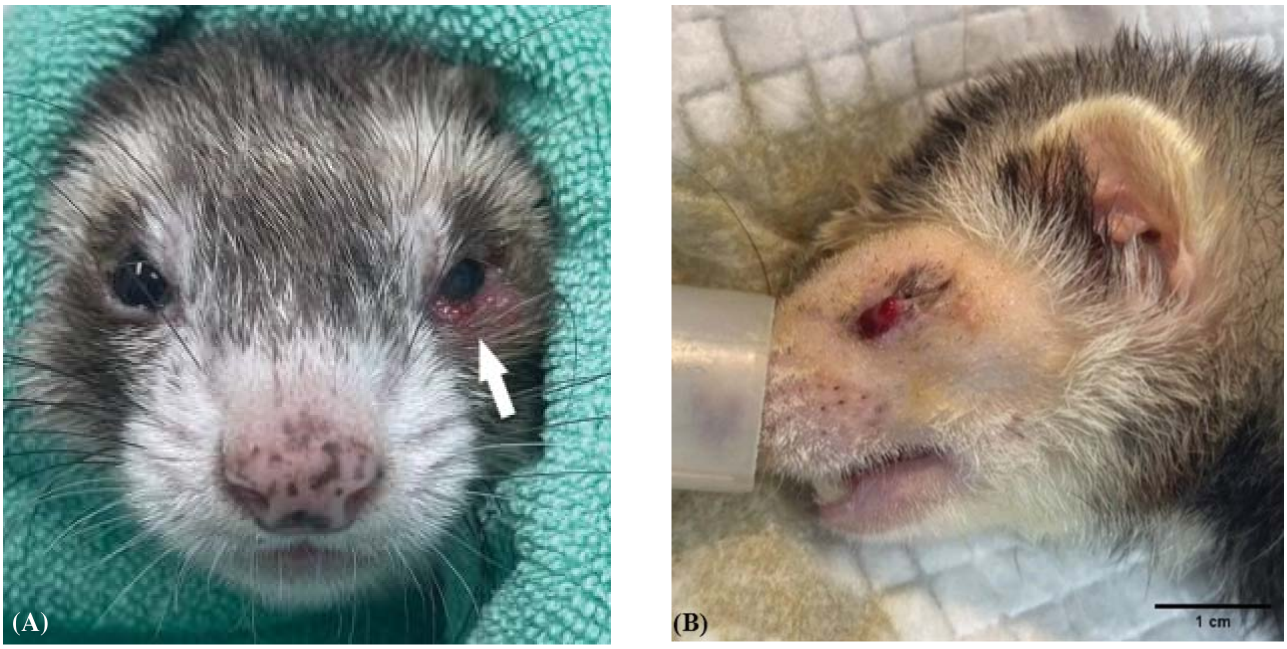

Figure 1. A 5-year-old male ferret was presented with a small, irregular, protruded pinkish firm mass located in the median left lower eyelid area to the palpebral conjunctiva of the left eye (arrow) (A). The same mass in lateral view. Bar = 1 cm (B).

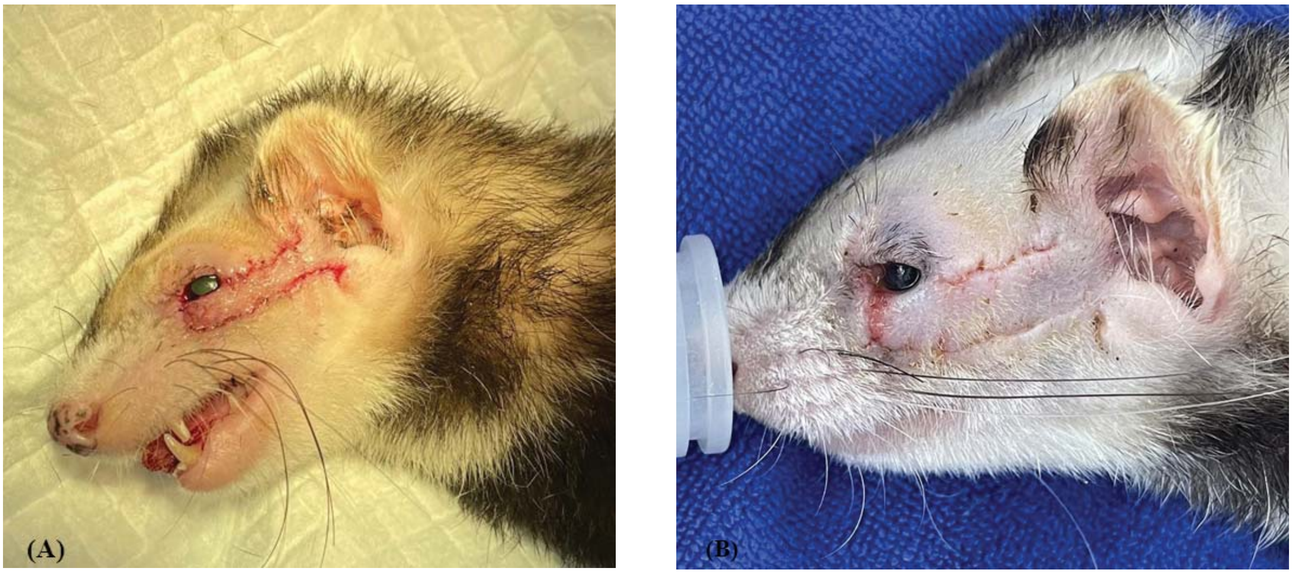

Figure 2. The H-plasty reconstructive surgery was performed to completely remove the mass in lower palpebral conjunctiva and eyelid margin of the ferret (A). Seven days after surgery, the sutures were removed (B).

The ferret was discharged with chloramphenicol eye ointment (1%) in a 0.5 cm strip OS every 12 hours, marbofloxacin at 5 mg/kg PO every 24 hours, and meloxicam at 0.5 mg/kg PO every 24 hours. The sutures were removed 2 weeks after surgery, with no complications noted at the surgical site. Approximately 14 weeks after surgery, the ferret was presented with a recurrent raised, ulcerated, reddish, irregular, firm mass measuring 1 x 1 x 0.5 cm displacing the left eye laterally (Figure 3). Pre-operative computed tomography (CT) was recommended for surgical planning of the invasive mass. Skull CT showed the left eyelid mass extended into the left retrobulbar region, causing left ocular compression and exophthalmos. The left eye was smaller compared to the right. No evidence of bone reaction or destruction was detected. Mild swelling of the left medial retropharyngeal lymph node was present; the approximated size is 4.4 x 3.3 mm. (figure 4). Thoracic CT revealed an unremarkable tracheal diameter and alignment, with no evidence of airway collapse. The pulmonary parenchyma and vasculature were also unremarkable.

An extended enucleation of the left eye globe was performed and submitted for histopathologic evaluation. However, the protruding pinkish, firm tumor measuring 2 x 2 x 2.5 cm recurred 5 weeks after enucleation and invaded the oral cavity (Figure 5). Radiographs of the skull revealed a large soft tissue opacity on the left side of the head, resulting in the loss of the left zygomatic arch and bone lysis in the body of the mandible (Figure 6). The owner requested palliative care, and the ferret was found dead at home approximately 8 months after the diagnosis.

Figure 3. The ferret was presented with the recurrence mass displacing the left eye laterally approximately 14 weeks after surgery. Bar = 1 cm.

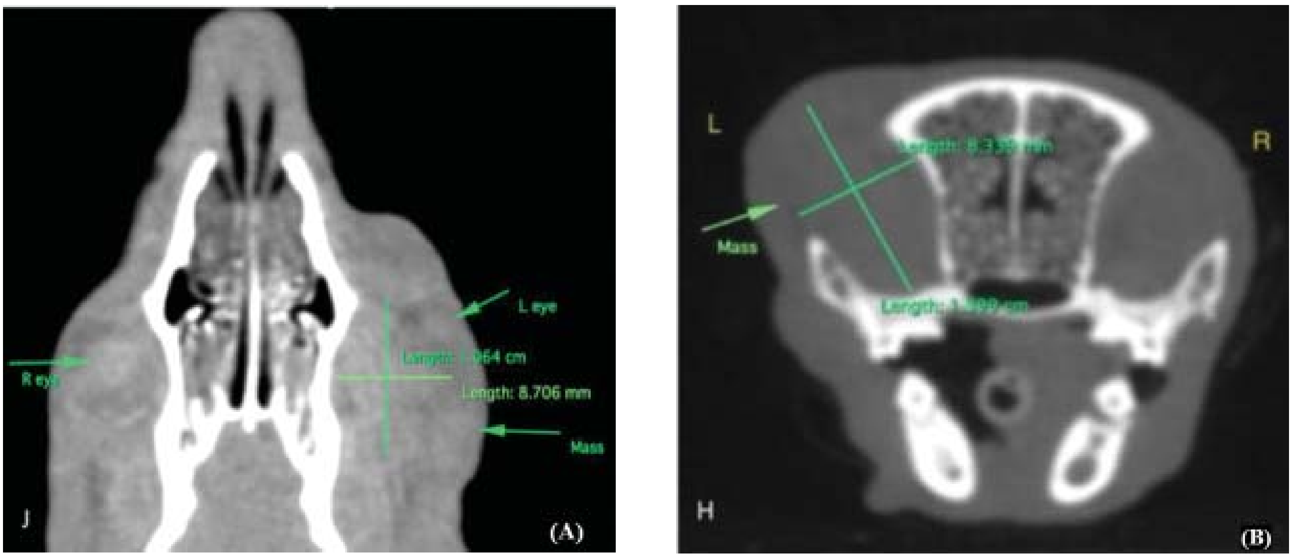

Figure 4. Soft tissue window of dorsal view skull CT scan showed left eyelid mass extended into the left retro bulbar region caused the left ocular compression and exophthalmos. Small size of left ocular (smaller compared to the right ocular). No evidence of bone reaction and bone destruction was detected. Mild reactive of left medial retropharyngeal lymph node (regional lymph node) (A). The same mass in transverse view skull CT scan (B).

Figure 5. The tumor was recurrent at 5 weeks after enucleation and invaded the oral cavity. Bar = 1 cm.

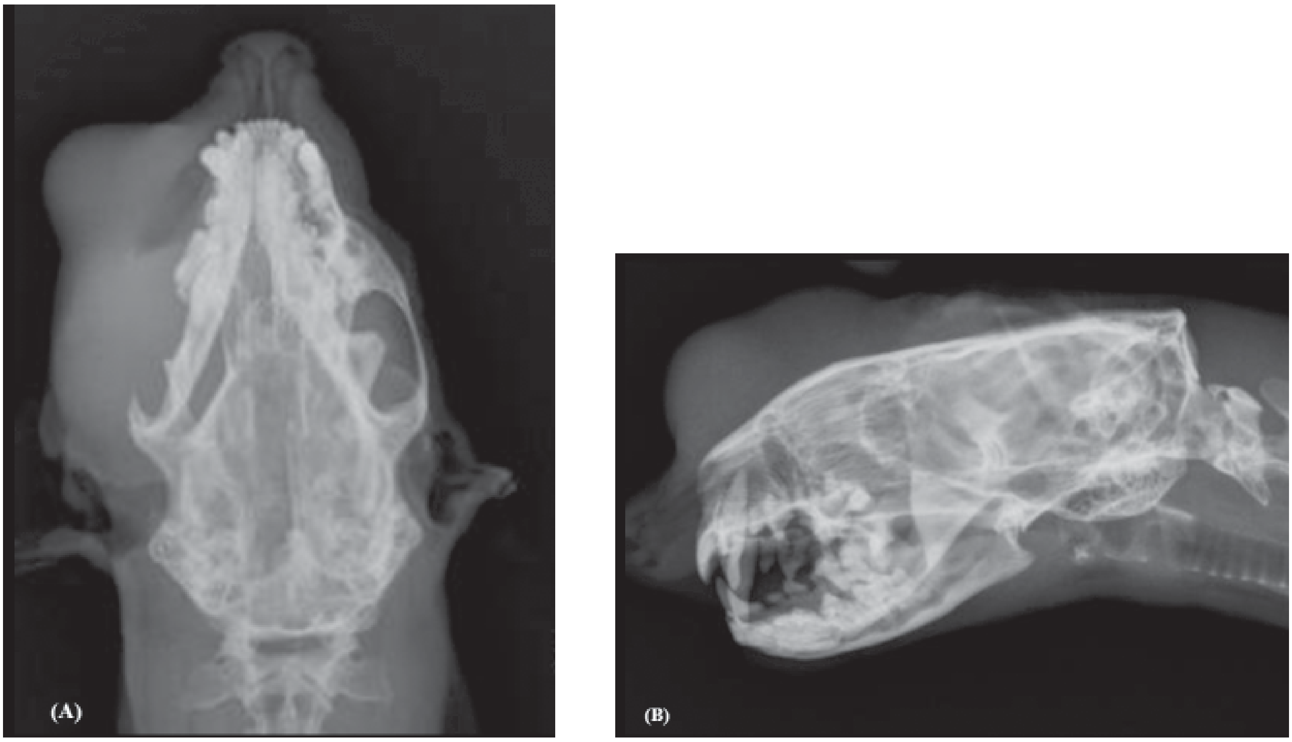

Figure 6. Radiographic examination of the skull dorsoventral view showing a large soft tissue opacity mass at left side of head affected to loss of left zygomatic arch (A). Right lateral view showing a soft tissue opacity mass at the rostro dorsal area with a bone lysis at rostal part of mandibular (B).

Results

The surgically removed mass was fixed in 10% neutral-buffered formalin and sent to Vet Central Lab, the standard laboratory procedures, for histopathological examination. The tissue sections were stained with Hematoxylin and Eosin (H&E). Histopathological examination revealed a section measuring 1 cm in size, with a soft consistency and pink coloration, from the left eyelid mass. It exhibited a well-demarcated, unencapsulated melanocytic neoplasm within the upper and deep dermis, dense palisading pattern of the epithelioid cell type of melanocytic tumor cells supported by a fibrovascular stroma. The neoplastic cells were pleomorphic, spindle and epithelioid shaped to ovoid, with variably distinct cell borders and moderate volume of pale basophilic cytoplasm. Some neoplastic cells contained scant brown pigment (melanin). The nuclei exhibited moderate anisokaryosis and large pleomorphic ovoid nuclei with prominent nucleoli. The histopathological diagnosis was amelanotic malignant melanoma of the left eyelid mass (Figure 7a). Immunohistochemistry was recommended to confirm the tentative diagnosis. Immunopositivity for Melan-A was characterized by brown coloured staining in the cytoplasm of neoplastic cells (Subapriya 2021). Immunohistochemical labeling with Melan-A revealed that all tumor cells exhibited mild light brown cytoplasmic expression of Melan-A. The failure to demonstrate strong immunoreactivity of Melan-A was caused by incompatibility of epitope antigen of ferret species (Figure 7b).

Histopathological examination of the second surgical mass showed the section of measuring 1-2 cm in size, firm consistency, oval shape, pink to red in color, lower eyelid mass with a suppurative lesion revealed a nonencapsulated, dense palisading pattern of the epithelioid cell type of melanocytic tumor cells supported by a fibrovascular stroma. The neoplastic cells were pleomorphic, spindle and epithelioid shaped to ovoid, with variably distinct cell borders and moderate volume of pale basophilic cytoplasm. A few neoplastic cells contained brown pigment (melanin). Nuclei were large pleomorphic ovoid with prominent nucleoli. Pathological diagnosis was amelanotic malignant melanoma of the lower eyelid mass (Figure 7c).

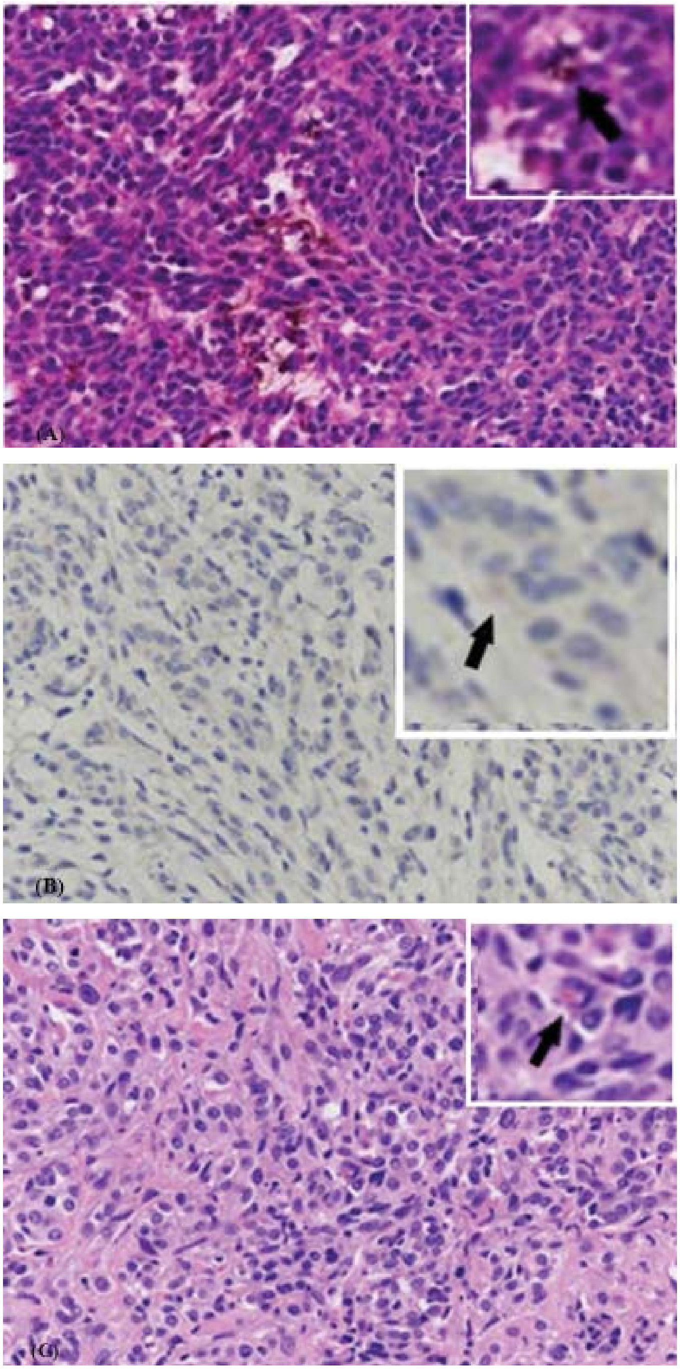

Figure 7. The eyelid; ferret. Amelanotic malignant melamona. The dense palisading pattern of the epithelioid cell type of melanocytic tumor cells supported by a fibrovascular stroma. The neoplastic cells were pleomorphic, spindle cell and epithelioid shaped to ovoid, with variably distinct cell border and moderate volume of pale basophilic cytoplasm. A few neoplastic cells contained brown pigment (melanin) (Arrow). Nuclei were large pleomorphic ovoid with prominent nucleoli (H&E stain, 40x) (A). All of tumor cells showed mild light brown cytoplasmic expression of Melan-A (Arrow) (IHC Melan-A stain 40x) (B). The second surgical mass showed a dense palisading pattern of the epithelioid cell type of melanocytic tumor cells supported by a fibrovascular stroma. The neoplastic cells were pleomorphic, spindle and epithelioid shaped to ovoid, with variably distinct cell borders and moderate volume of pale basophilic cytoplasm; some neoplastic cells contained scantly brown pigment (Arrow). The nuclei exhibited moderate anisokaryosis and large pleomorphic ovoid nuclei with prominent nucleoli (H&E stain, 40x) (C).

Discussion

Amelanotic malignant melanomas have been described in various animals, including dogs (Oliveira Júnior et al., 2022), cats (Jajou 2020), rabbits (Brandão et al., 2015), guinea pigs (Allnoch et al., 2020), and goats (Patel et al., 2020). However, melanomas are uncommon in ferrets and eyelid amelanotic melanoma is extremely rare. A few cases of melanoma in ferrets have been reported. Tunev and Wells (2002) documented a case of spontaneous cutaneous melanoma in a 4-year-old spayed female ferret. d'Ovidio et al. (2016) described an oral malignant melanoma in a 3-year-old intact male ferret. In dogs, malignant melanoma of the eyelid margin is reported in less than 1% of cases (Grahn 2023). In horse, eyelid melanomas are less commonly affected than other typical sites such as the perineum, ventral tail, and prepuce (Rose and Mair 2023). A survey of the literature found no documented evidence of amelanotic melanoma in ferrets. This is the first published case of amelanotic malignant melanoma of the eyelid in this species.

Neoplasia is commonly diagnosed in middle-aged to older ferrets, between 4 and 6 years old, with the average age of affected ferrets being 4.6 years (Otrocka-Domagala et al., 2022). Similarly, in this report the ferret was 5 years old. Clinical signs of eyelid margin neoplasia can lead to ocular complications including ocular pain, ocular discharge, conjunctivitis, and even corneal ulceration. As the size of the mass increases, clinical symptoms may be apparent including eyelid movement may be affected, making blinking difficult and leading to discomfort (Ahn et al., 2023). In this case, the eyelid tumor showed mild conjunctivitis and a protruding pinkish mass in the palpebral conjunctiva and lower eyelid region; however, clinical symptoms were not apparent.

Diagnosis is based on detailed ophthalmological exams and supported by pathological evaluation. The differential diagnosis is neoplasms and inflammatory skin diseases. Biopsy of the eyelid mass revealed the potential utility of the diagnostic method in differentiating diagnosis (Shiga et al., 2021; Long et al., 2023; Polton et al., 2024). Due to the location and size of the mass in this case, complete surgical removal with H-plasty for eyelid reconstruction was the procedure of choice for both diagnostic and therapeutic purposes. In this case, the left medial retropharyngeal lymph node (regional lymph node) showed mild reactivity; however, a lymph node biopsy was not performed due to the deep location and the small size of the retropharyngeal lymph node, which complicates access and increase the risk of damaging surrounding structures, such as blood vessels, nerves, and the trachea during the procedure (Evans and An 2014).

Differential diagnosis for non-pigmented or minimally pigmented neoplasms can be challenging. In this case, histopathological investigation of the excised mass confirmed the diagnosis of eyelid amelanotic malignant melanoma. A study on canine cytology showed a sensitivity and specificity of 100% for diagnosing pigmented melanocytic neoplasms; however, both sensitivity and specificity decrease for amelanotic melanocytic neoplasms (Smedley et al., 2022). Immunohistochemistry is recommended for poorly differentiated tumors and positive staining for melanocytic markers such as S-100, tyrosinase and Melan-A can help distinguish melanoma from other neoplasms (Smedley et al., 2022; Polton et al., 2024). In canine studies, immuno-cytochemistry for Melan-A may be useful in differentiating between non-melanocytic tumors and diagnosing amelanotic melanocytic neoplasms; Melan-A has been demonstrated in more than 80% of primary or metastatic canine oral melanomas (Smedley et al., 2011). Immunohistochemical staining with Melan-A was used in the presented case to confirm the diagnosis of amelanotic malignant melanoma.

Melan-A is a specific marker for melanocytes that targets a cytoplasmic protein of melanosomal differentiation recognized by cytotoxic T-cells (Ohsie et al., 2008). In canine studies, immunocytochemistry for Melan-A may be useful in differentiating between non-melanocytic tumors and diagnosing amelanotic melanocytic neoplasms; Melan-A has been demonstrated in more than 80% of primary or metastatic canine oral melanomas (Smedley et al., 2011). Additionally, the use of Melan-A markers to confirm the amelanotic melanocytic origin in felines has also been reported (Pittaway et al., 2019). Therefore, Immuno-histochemical staining with Melan-A was used in the presented case to confirm the diagnosis of amelanotic malignant melanoma in this study.

Tunev and Wells (2002) reported on cutaneous melanoma in a ferret, the mass was characterized by closely packed large, atypical cells that were polygonal to spindle-shaped, arranged in sheets, poorly formed nests, and short bundles. Some cells contained varying amounts of granular, brown to black intracytoplasmic pigment. Nuclei were large, round to oval, and with a vesicular pattern of chromatin dispersion. Most nuclei contained one and rarely two large and round magenta nucleoli. The atypical cells of the mass stained negatively Melan-A. In the case of amelanotic melanoma in the rabbit, the cells exhibited densely cellular neoplasm with cells arranged in sheets and nests supported by a fine, fibrovascular stroma, a round epithelioid morphology, characterized by abundant, homogeneous, amphophilic cytoplasm. The nuclei were round to oval, finely stippled, and centrally located, with one to two prominent nucleoli. The neoplastic cells in this case stained strongly positive for Melan-A (Brandão et al., 2015). In this study, the neoplastic cells were arranged in a palisading pattern, while other reports described them as being organized in nests. The neoplastic cells exhibited pleomorphism, varying from spindle to epithelioid shapes and ovoid forms, with variably distinct cell borders and a moderate volume of pale basophilic cytoplasm. The nuclei demonstrated moderate anisokaryosis and large pleomorphic ovoid nuclei with prominent nucleoli, resembling findings in the amelanotic melanoma of the rabbit, although the neoplastic cells stained only mildly positive for Melan-A. The lack of strong immunoreactivity for Melan-A may be attributed to the incompatibility of the epitope antigen specific to the ferret species.

A melanocyte containing melanin can be distinguished from a melanophage by the latter's distinctive solitary distribution around the papillary dermal capillaries. Melanophages are typically larger than melanocytes and have a bright, granular cytoplasm with a coarser texture, whereas melanocytes tend to have a more uniform appearance and are smaller in size (Busam et al., 2001).

In veterinary medicine, there are no established clinical guidelines for treating amelanotic malignant melanoma of the eyelid. Therapeutic plans are based on the clinician's judgment, the patient's health, and the owner's financial considerations (Guerra Guimarães et al., 2021). In this case, due to local recurrence after surgical excision, it was concluded that eyelid amelanotic malignant melanoma may have a high risk of recurrence and distant metastasis. Consultation with an oncologist for adjunctive therapies such as cryotherapy, radiotherapy, or laser therapy was recommended. However, the owner declined due to the long distance to the university clinic. Therefore, enucleation was considered following the first recurrence of the neoplasm for invasive tumors, with frequent monitoring for further recurrence. A poor prognosis was given.

Conclusion

This report describes a case of eyelid amelanotic malignant melanoma in a 5-year-old ferret presenting with a rapidly growing mass on the eyelid. The case presentation describes the clinical and histopathological features of an eyelid amelanotic malignant melanoma in a ferret. A presumptive clinical diagnosis of an eyelid tumor was formulated based on history and clinical signs, but a definitive diagnosis was confirmed through histopathological and immunohistochemical examination of the mass after surgical excision. A study indicated that surgical removal alone in ferrets with eyelid amelanotic malignant melanoma is not effective in preventing metastasis or prolonging survival. Although uncommon, amelanotic malignant melanoma should be considered in the differential diagnosis of eyelid neoplasms in ferrets.

Acknowledgments

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Case Report

Case Report: Surgical Repair and Pericardial Drainage in a Scottish Fold Cat with Congenital Peritoneopericardial Diaphragmatic Hernia

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Abstract

Peritoneopericardial diaphragmatic hernia (PPDH) is the most frequently encountered congenital defect affecting the diaphragm and pericardium in cats. This report aimed to present the case of a 4-month-old intact male Scottish Fold cat that was diagnosed with PPDH, focusing on the surgical technique for pericardial drain insertion and the long-term outcome. The patient had a history of acute vomiting. Physical examination revealed abdominal breathing and mild abdominal discomfort upon palpation, with no history of dyspnea or cyanosis. Thoracic radiography confirmed the diagnosis of diaphragmatic hernia, while abdominal ultrasonography revealed displacement of parts of the liver and gallbladder into the pericardial space, along with thickening of the intestinal wall. Based on this investigation, congenital PPDH was diagnosed. Surgical repair of the PPDH was performed, and the hernial contents included the liver and gallbladder in the pericardial sac. The PPDH was closed with nylon No.3-0 using a simple continuous suture pattern. Air was aspirated from the pericardial sac to establish negative pressure by a pericardial tube. One year post-surgery, the cat exhibited normal breathing and regained overall health.

Keywords: Cat, Pericardial tube, Peritoneopericardial diaphragm hernia, Surgical treatment

รายงานสัตว์ป่วย: การผ่าตัดแก้ไขและการระบายเยื่อหุ้มหัวใจ โรคไส้เลื่อนกะบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจแต่กำเนิด ในแมวสกอตติช โฟลด์

รุจธร มณีวรรณ วิจิตร สุทธิประภา วุฒิธิ บรรเจิดสุวรรณ ชัยกร ฐิติญาณพร*

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บทคัดย่อ

โรคไส้เลื่อนกะบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจ (Peritoneopericardial diaphragmatic hernia: PPDH) เป็นความผิดปกติตั้งแต่กำเนิดที่ส่งผลกระทบต่อกะบังลมและเยื่อหุ้มหัวใจ พบได้บ่อยในแมว รายงานนี้มีวัตถุประสงค์เพื่อนำเสนอกรณีศึกษาของแมวสายพันธุ์สกอตติช โฟลด์ อายุ 4 เดือน เพศผู้ ยังไม่ทำหมันซึ่งได้รับการวินิจฉัยว่าเป็นโรค PPDH โดยเน้นที่เทคนิคการผ่าตัดที่มีการใส่สายสวนระบายเยื่อหุ้มหัวใจและผลลัพธ์ระยะยาว โดยสัตว์ป่วยมาด้วยอาการอาเจียนเฉียบพลัน โดยจากการตรวจร่างกายพบว่าสัตว์ป่วยมีการหายใจโดยใช้ช่องท้องและรู้สึกไม่สบายเล็กน้อยเมื่อมีการคลำบริเวณช่องท้อง และไม่พบประวัติของอาการหายใจลำบากและลักษณะเขียวคล้ำของเยื่อเมือกมาก่อน โดยจากการถ่ายภาพรังสีช่องอกช่วยยืนยันการพบภาวะไส้เลื่อนกะบังลมและจากภาพอัลตร้าซาวด์ช่องท้องพบการเคลื่อนของตับและถุงน้ำดีเข้าสู่ช่องเยื่อหุ้มหัวใจ พร้อมกับพบการหนาตัวของผนังลำไส้ จากผลการตรวจข้างต้นสัตว์ป่วยจึงถูกวินิจฉัยว่าเป็นโรค PPDH แต่กำเนิด และได้มีการผ่าตัดแก้ไขโรค PPDH โดยพบว่าอวัยวะที่เข้าไปอยู่ในเยื่อหุ้มหัวใจคือตับและถุงน้ำดี จากนั้นจึงได้ทำการเย็บปิด PPDH โดยใช้ไนลอนเบอร์ 3-0 โดยใช้เทคนิคการเย็บแบบต่อเนื่องจากนั้นมีการดูดอากาศออกจากเยื่อหุ้มหัวใจผ่านทางสายสวนระบายเพื่อสร้างแรงดันลบ หลังการผ่าตัด 1 ปี พบว่าแมวมีการหายใจเป็นปกติและมีสุขภาพโดยรวมที่ดี

คำสำคัญ : แมว สายสวนระบายเยื่อหุ้มหัวใจ โรคไส้เลื่อนกระบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจ การรักษาโดยการศัลยกรรม

Introduction

Peritoneopericardial diaphragmatic hernia (PPDH) occurs when there is an abnormal connection between the pericardial sac and the abdominal cavity (Nikiphorou et al., 2016). In both cats and dogs, PPDH is linked exclusively to congenital defects (Banz and Gottfried 2010). It is hypothesized that incomplete midline fusion during embryonic development or prenatal trauma may contribute to the formation of PPDH (Margolis et al., 2018). As a result of this formation, abdominal organs can move into the pericardial space. The liver, gallbladder, and small intestines are the most commonly herniated organs (Lohinger et al., 2022). A thoracic radiograph is a common diagnostic tool for identifying this condition. Additional imaging techniques, such as positive contrast radiography using oral barium, ultrasonography, echocardiography, and computed tomography (CT), can also be used for diagnosis (Campanile et al., 2024).

PPDH is typically discovered incidentally in cats, often without specific clinical signs. In such cases, the absence of symptoms makes it challenging to justify surgical intervention (Linton et al., 2016). Surgical intervention is recommended for patients showing clinical signs and typically involves closing the congenital defect. During surgery, a tear in the pericardium leading to communication with the pleural cavity may result in postoperative pneumothorax (Hunt 2012). Additionally, the size of the diaphragmatic defect can affect the amount of air that accumulates in the pericardial sac, potentially causing postoperative pneumopericardium (Papazoglou et al., 2015). However, Pneumopericardium associated with PPDH repair has not been reported in the veterinary literature (Papazoglou et al., 2015). A thoracostomy tube is inserted when the pleural cavity is accessed and is typically removed either shortly after the patient recovers from anesthesia or within 12 hours after surgery (Banz and Gottfried 2010). Management of pneumopericardium is typically unnecessary unless the cardiopulmonary function is compromised due to significant air accumulation within the pericardial sac (Papazoglou et al., 2015).

PPDH in Scottish Fold Cats is uncommon. Normally, PPDH in cats is presented in long-haired breeds, including Persians, Himalayans, Maine Coons, and domestic long hairs (Margolis et al., 2018). In this case report, the surgical technique showed the success of PPDH management in cats using pericardial drain surgery. This case report describes clinical presentations, preoperative management, surgical technique, postoperative care, long-term follow-up, and outcome.

Case descriptions

A 4-month-old intact male Scottish Fold cat presented to the Kasetsart University Veterinary Teaching Hospital (KUVTH), Faculty of Veterinary Medicine, Kasetsart University, exhibiting acute vomiting. Physical examination revealed abdominal breathing and mild abdominal discomfort upon palpation, with no history of dyspnea or cyanosis. The cat had a complete vaccination history and lived in a closed-system environment. Hematology examinations showed mild anemia and leukocytosis. Blood chemistry showed increased alanine aminotransferase. Thoracic radiographs revealed an enlarged cardiac silhouette (Figure 1), while abdominal ultrasound showed a discontinuous diaphragmatic line, with both the liver and gallbladder located within the pericardial sac (Figure 2), leading to the suspicion of PPDH. Supportive treatment was administered continuously, including an omeprazole dose of 0.7 mg/kg was administered intravenously once daily, while a maropitant citrate dose of 1 mg/kg was administered subcutaneously once daily (Cerenia®, Zoetis), and an amoxicillin-clavulanic acid dose 20 mg/kg was administered intravenously every 8 hours (Cavumox®, Siam Bheasach). After two weeks of supportive treatment, a repeat of hematology and blood chemistry examinations showed improvement (Table 1). However, signs of abdominal breathing persisted. From this problem, the surgical correction of PPDH was recommended to the owner.

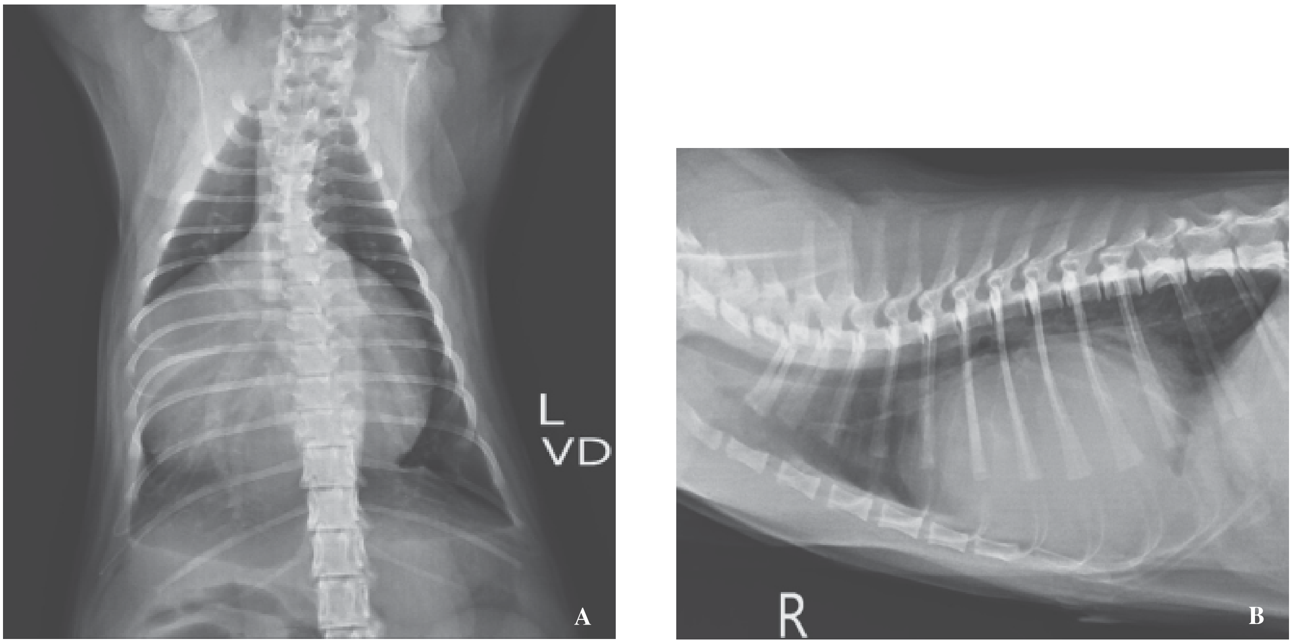

Figure 1. Thoracic radiographs of ventrodorsal (A) and lateral (B) views showing a severely enlarged cardiac silhouette with discontinuing of the ventral diaphragmatic line at the ventral region concurrent with small hepatic volume at the cranial abdomen.

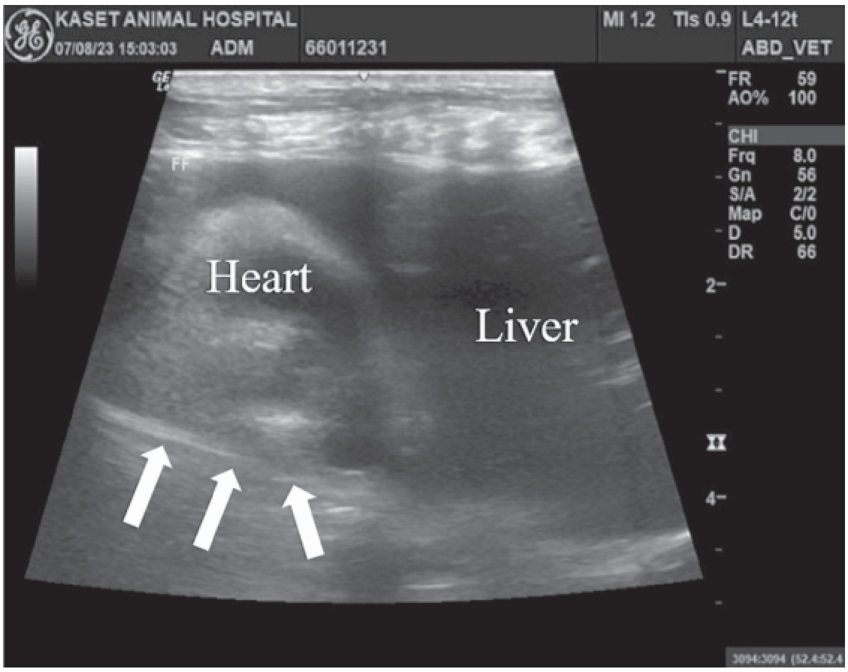

Figure 2. Thorax and abdominal ultrasound revealed a part of the liver displaced into the pericardial sac. The white arrows indicated the boundary of the pericardial sac.

Table 1. Complete Blood Count and Serum Biochemistry results before and after supportive treatment.

Parameter	Before supportive treatment	After supportive treatment	Reference range*
Hemoglobin	9.1	11.5	9.8-15.4gm%
Hematocrit	24	34	30-45%
RBC	6.61	8.66	5-10fL
WBC	13.77	21.65	5.5-19 x 10^3/μL
SEGS	49	30	2.5-12.5 10^3/μL
LYMPH	38	63	1.5-7 10^3/μL
RETICS	0.18	0.19	0-0.6%
Platelets	64	477	200-500 x 10^3/μL
Plasma protein	7.0	7.0	5.8-7.8 gm%
BUN	22	30	15-34 mg/dL
Creatinine	1.1	1.01	0.5-1.8 mg/dL
ALT	574	74	28-80 U/L
Albumin	3.1	3.3	2.3-4 gm%
Total protein	6.3	6.3	5.8-7.8 gm%

*Reference ranges used at the Laboratory of Veterinary Diagnostic Unit, Faculty of Veterinary Medicine, Kasetsart University, Thailand; RETICS = Reticulocyte; RBC = Red blood cell; WBC = White blood cells; SEGS = Segmented neutrophils; LYMPH = Lymphocytes.

*Reference ranges of serum parameters analyzed by IDEXX VetTest Chemistry Analyzer, BUN = Blood urea nitrogen; ALT = alanine aminotransferase.

Preoxygenation and electrocardiogram (ECG) monitoring were performed. ECG revealed a normal electrocardiographic pattern. For anesthetic induction, propofol was administered intravenously at a dose of 8 mg/kg. Maintenance of anesthesia was achieved using sevoflurane at 1.3-1.5% of the minimum alveolar concentration (MAC = 2.6) via inhalation. Pain management included morphine at a dose of 0.3 mg/kg intramuscularly, followed by an intravenous loading dose of fentanyl at 2 mcg/kg. Continuous rate infusion (CRI) of fentanyl was administered intravenously at a rate of 10 mcg/kg/hr. The cat was positioned in dorsal recumbency for the preparation of the surgical site, which included hair clipping and scrubbing routinely with a 2% chlorhexidine scrub and 70% isopropyl alcohol.

A laparotomy was performed by a longitudinal incision along the cranial midline of the abdomen from the xiphoid cartilage to the umbilicus. The peritoneum was dissected away from the muscular part of the diaphragm using Metzenbaum scissors (Figure 3). The gallbladder, right lateral, and right medial liver lobes were found in the pericardial sac as hernial contents and passed through the opening of the ventral third of the diaphragm. The visceral organs and pericardial sac showed no adhesion. The herniated organs were returned to their original positions, and herniorrhaphy was performed using a simple continuous suture pattern with a monofilament, non-absorbable suture (Dafilon® 3-0, B Braun, Spain).

After suturing, a pericardial drainage tube (silicone oval-shaped DEK eyes, open-ended tube, non-toxic and medical-grade materials, size 6 French; manufactured by K.F. Medical Co., Ltd., Thailand) was placed into the pericardium, passed through the ventrally of the herniorrhaphy site, and exited externally through the abdominal wall at the left paramedian (Figure 4). The abdominal cavity was closed using a simple continuous suture pattern with monofilament, absorbable sutures (PDS™II 3-0, Ethicon®, USA). Air from the pericardial sac was aspirated to achieve negative pressure. The drainage tube was left in place to enable postoperative air and fluid removal. The skin was closed with a monofilament, non-absorbable suture, and cross mattress pattern (Dafilon® 3-0, B Braun, Spain). Postoperative radiographs of the thorax in the ventrodorsal view and lateral view showed no evidence of pneumopericardium and pneumothorax (Figure 5). The pericardial drainage tube was removed immediately after the thoracic radiograph. ECG monitoring in the recovery room after tube removal showed no abnormalities.

The cat was admitted to the critical care unit to observe the clinical signs of respiration. Oxygenation was provided continuously after recovery. The oxygen support was discontinued for 48 hours postoperatively. Amoxicillin-clavulanic acid dose of 20 mg/kg was administered intravenously every 8 hours (Cavumox®, Siam Bheasach) for infection control. This treatment was continued for 1 week following a 2-week course of supportive treatment. For pain control, a morphine dose of 0.2 mg/kg was administered subcutaneously every 8 hours, and a gabapentin dose of 7 mg/kg was administered by peroral route every 8 hours for 1 week. The cat was discharged from the hospital 1 week after surgery. A month after surgery, the cat showed normal vital signs and maintained a good appetite. However, thoracic radiographs revealed that the heart shadow remained enlarged, with a vertebral heart scale (VHS) of 9.5. As a result, a transthoracic echocardiographic examination was performed using a phased array probe of Mindray M9 ultrasound system with 12 MHz frequency to examine cardiac function. Measurement was performed in parasternal long and short-axis views with the patient positioned in lateral recumbency and without the administration of sedation. The echocardiographic examination result is described in Table 2. The left ventricular wall structure and function were evaluated using two-dimensional and M-mode echocardiographic measurements, which revealed a normal left ventricular size and overall heart function. At the six-month follow-up appointment, no complications were noted, and the cat was living a normal life without any signs related to the digestive or respiratory systems.

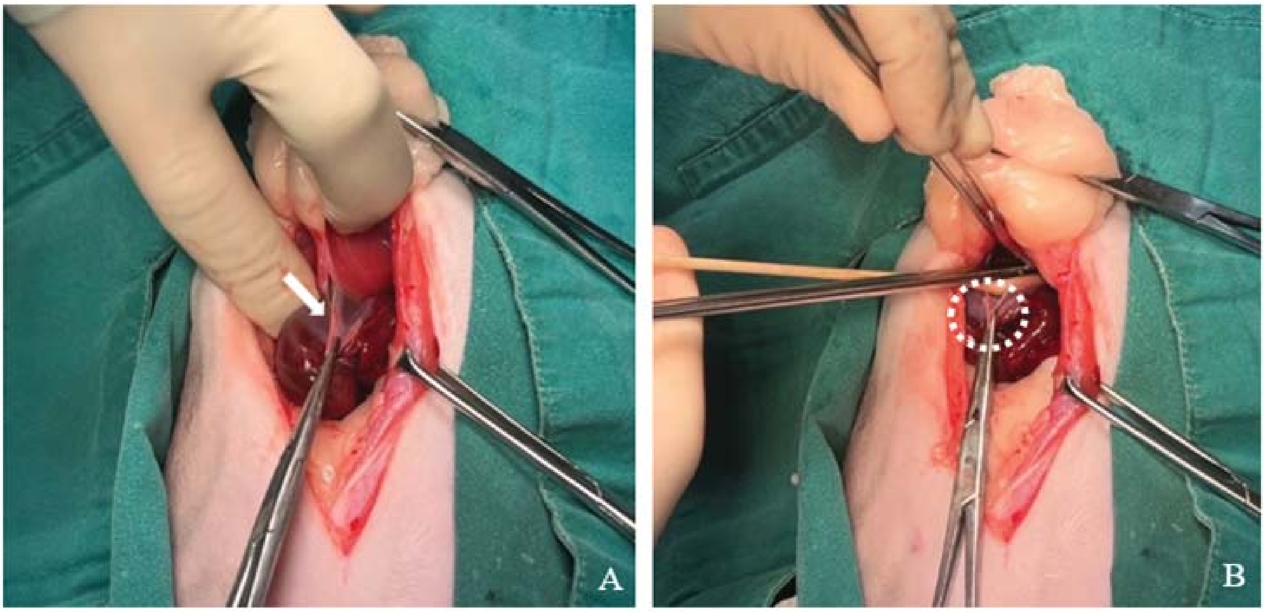

Figure 3. The white arrow highlights the adhesion between the peritoneum and the muscular part of the diaphragm (A), and Metzenbaum scissors were used to cut and separate the adhesion (B; white circle).

Figure 4. The distal end of the pericardial tube exits through the abdominal wall at the left paramedian position (Black arrow).

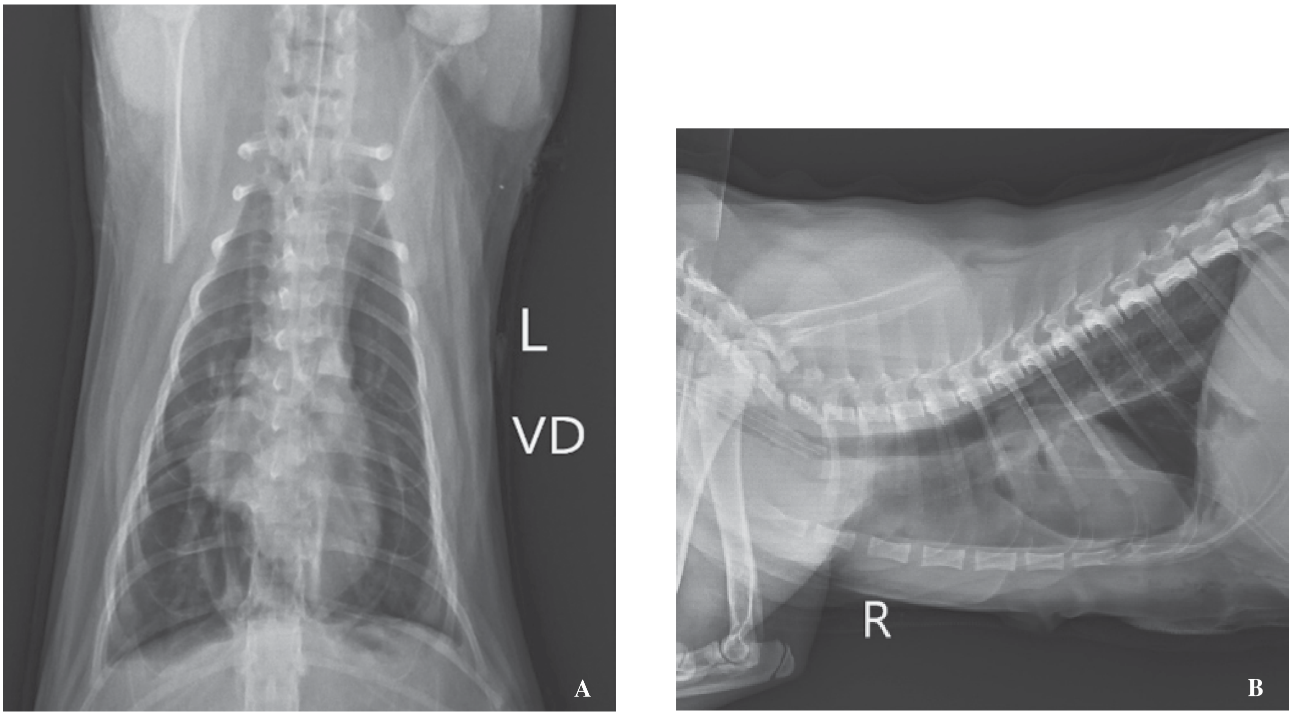

Figure 5. Postoperative thoracic radiographs of ventrodorsal (A) and lateral (B) views showed no evidence of pneumopericardium.

Table 2. Echocardiography parameters after surgical repair of PPDH in a Scottish Fold cat.

Echocardiography Parameter	Value	Reference range
IVSs (mm)	7.5 mm	4.4-8.7 mm
IVSd (mm)	5.1 mm	2.9-5.1 mm
LVIDs (mm)	7.7 mm	5.7-13 mm
LVIDd (mm)	15.3 mm	12.7-19.8 mm
LVFWs (mm)	6.7 mm	5.4-8.1 mm
LVFWd (mm)	3.9 mm	2.2-4.4 mm
FS	49.51%	28-62 %
LA:Ao	1.22	0.88-1.43
LA	10.8 mm	8.2-14.5 mm
Ao	8.9 mm	7.5-11.9 mm

*Reference ranges used at the Cardiovascular center, Faculty of Veterinary Medicine, Kasetsart University, Thailand.

IVSs, interventricular septum systole; IVSd, interventricular septum diastole; LVIDs, left ventricular internal diameter systole; LVIDd, left ventricular internal diameter diastole; LVFWs, left ventricular free wall systole; LVFWd, left ventricular free wall diastole; FS%, fractional shortening; LA:Ao, left atrial to aortic ratio; LA, left atrial diameter; and Ao, aortic diameter.

Discussion

PPDH is one of the congenital defects that present in cats over 2 years old. The prevalence of PPDH in cats (0.062%) is significantly higher (P = 0.04) compared to dogs (0.015%). More than 100 cases have been reported in domestic cats, with approximately 50% being found incidentally (Burns et al., 2013). A previous study reported that Persians and other long-haired breeds (domestic long-hair and Himalayans) have a higher predisposition to PPDH (Reimer et al., 2004). Similar to a report in 2004, the prevalence of PPDH was high in long-haired cats, particularly Maine Coon, and Persians when compared to domestic cats (prevalence = 0.062-0.59%) (Margolis et al., 2018). However, PPDH in short-haired cats such as Scottish Fold cats has rarely been reported in the last decade (Burns et al., 2013). Clinical signs of PPDH in short-haired and long-haired cats are similar signs. The commonly reported clinical signs include asymptomatic cases, muffled heart sounds, respiratory distress, and gastrointestinal symptoms like regurgitation, anorexia, or vomiting (Margolis et al., 2018). In this case, the cat exhibited clinical signs including abdominal breathing and gastrointestinal symptoms.

The liver is the most commonly herniated organ in PPDH cases (Sicoe et al., 2019). When the liver becomes trapped within the pericardial sac, it can lead to inflammation, which may result in elevated liver enzyme levels in blood tests (Linton et al., 2016). Additionally, other organs such as the stomach, small intestine, and pancreas can also herniate. Inflammation of these organs may cause conditions such as leukocytosis and anemia (Lee and Kim 2014). However, patients with PPDH do not consistently exhibit anemia, leukocytosis, or elevated liver enzymes. Blood test changes often depend on the specific pathological conditions present at the time. In this case, the elevated liver enzyme levels are likely due to inflammation caused by the liver's displacement into the pericardial sac. As for the anemia and leukocytosis, they may be related to concurrent gastroenteritis or other underlying conditions occurring simultaneously.

The treatment approach for PPDH can be either surgical or conservative, with both options offering good long-term survival rates (Morgan et al., 2020). Conservative treatment is usually performed in asymptomatic cases, while surgical intervention is recommended for symptomatic patients. Surgical correction is generally recommended for the treatment of PPDH and should be performed as early as possible in young animals (Fossum 2018). In this case, the surgery was conducted at 4 months old, which likely contributed to the absence of adhesions.

In terms of the PPDH surgical technique, the cranial midline celiotomy approach is the most popular. In addition, caudal median sternotomy can be performed when adhesions are present between the liver or intestines and the pericardium (Burns et al., 2013). In the final step of the procedure, the air should be evacuated from the pericardial cavity using a drainage tube to prevent the limited expansion of the lung (Lohinger et al., 2022).

The incidence of pneumopericardium after surgical correction of PPDH is not frequently reported in veterinary literature. However, complications such as pneumothorax or pneumopericardium may occur due to the surgical procedure's invasive nature and manipulation of thoracic and pericardial structures (Less et al., 2000). During surgery, accidental tearing of the pericardium may occur, potentially leading to pneumothorax. Therefore, placing a pericardial drainage tube can help ensure that no air remains in the pleural cavity postoperatively and confirm the integrity of the pericardium. This technique is simple, requires minimal equipment, and has relatively low complication rates. Potential complications include malposition, tube blockage, and subcutaneous air leakage (Heier et al., 2022). In this case, a pericardial drainage tube was inserted into the pericardium, with the distal end routed through the abdominal wall. The tube placement was intended to be temporary, with the drain removed once postoperative chest radiographs confirmed the absence of pneumopericardium and pneumothorax. Exiting the tube through the abdominal wall facilitated easier removal and minimized trauma compared to routing the tube through the intercostal muscles.

Severe injuries and significant intrathoracic trauma during surgery can lead to delayed recovery from anesthesia in animals (Imazio and Hoit 2013). These injuries can increase the risk of postoperative complications and contribute to higher mortality rates, ultimately resulting in prolonged hospitalization (Legallet et al., 2017). In the current case, no tears in the pericardium extending into the thoracic cavity were observed during surgery. The surgeon placed a pericardial drainage tube to remove the air from the pericardial sac and maintained drainage until a postoperative thoracic radiograph confirmed the absence of pneumopericardium and pneumothorax (Figure 5). This procedure can contribute to a shorter postoperative hospitalization and a favorable long-term outcome.

In this case, one month after surgery, thoracic radiographs revealed a persistently enlarged cardiac silhouette. However, echocardiogram findings indicated that the size of the cardiac muscle was within normal limits. It might be because, after PPDH surgery, there might be a shift of internal organs or residual tissue from the healing process, which could create a silhouette resembling cardiomegaly on radiographs without reflecting the actual cardiac size (Fossum 2018). Additionally, thoracic radiographs only provide a two-dimensional view, which may not show the heart's structure as clearly as echocardiography, which gives a three-dimensional view of its function and anatomy (Häggström et al., 2016).

Long-term follow-ups of cats that underwent surgical treatment indicated that owners were generally satisfied with the outcomes of the procedure (Reimer et al., 2004). Prognoses following surgical repair of PPDH are typically favorable, with survival rates ranging from 86% to 97% (Burns et al., 2013). Most cats receiving surgical intervention for PPDH displayed prominent clinical signs, such as respiratory difficulties or other abnormalities, which improved significantly after surgery (Reimer et al., 2004). In this case, a year follow-up revealed that the cat showed no respiratory or gastrointestinal symptoms and maintained a quality of life comparable to that of a healthy cat.

In conclusion, the current case details the successful surgical repair of a congenital peritoneopericardial diaphragmatic hernia (PPDH) in a Scottish Fold cat, utilizing a pericardial drain to prevent postoperative pneumopericardium and verifying the integrity of the pericardium. Using a pericardial drain technique ensured the immediate evacuation of air from the pericardial space, minimizing potential complications such as cardiac tamponade. The surgical outcome was favorable, with no respiratory or gastrointestinal symptoms observed during the long-term follow-up. This case shows the importance of careful postoperative management in PPDH cases and demonstrates that the use of a pericardial drain may improve recovery and prevent complications. Moreover, this report adds to the limited information on PPDH in Scottish Fold cats and provides evidence for the successful long-term prognosis following surgical treatment.

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Case Report

Application of Sutures for Skull Stabilization: A Novel Technique for Cranioplasty in Fennec Fox (*Vulpes zerda*)

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Abstract

Skull fractures in fennec foxes (*Vulpes zerda*) are a serious issue that demands urgent intervention because of the species' fragile cranial structure. Compressed fractures can cause brain injury, bleeding within the skull, and neurological disability. Failure to promptly manage these complications can be fatal. A 1-month-old, 0.29 kg female fennec fox suffered a traumatic bite wound to its head from a skunk. Panalai Veterinary Hospital received a referral for the fennec fox, which showed signs of lethargy, ataxia, and left circling. The heart rate, respiratory rate, capillary refill time (CRT), and rectal temperature were within normal range. Diagnostic imaging, including a computed tomography (CT) scan, revealed collapse of the frontal and parietal bones, invading the left parietal-temporal lobe of the brain, and a fracture of the vertical ramus of the left mandible. Surgical interventions were performed with frontal and parietal bone decompression, as well as suturing the fractured skull using a tapered needle and a 4-0 polydioxanone suture in a simple interrupted pattern, without the use of skull mesh. Postoperative care included intensive monitoring, hyperbaric oxygen therapy, and acupuncture to promote brain healing, wound recovery, and neurological improvement. The fox was administered amoxicillin-clavulanic acid, followed by a switch to cefovecin sodium for infection control; pregabalin for neuropathic pain; meloxicam for inflammation management; vitamin B complex and Aktivait dog® for nerve function support; and dimenhydrinate to alleviate vestibular signs. The wound, appetite, ataxia, and left circling were gradually improving. The fox fully recovered within two months and returned to a normal daily life, although it continued to exhibit mild circling before eating. This case highlights the importance of prompt and comprehensive treatment for skull fractures in fragile species. The successful application of straightforward surgical techniques demonstrates their practicality and adaptability for managing complex cranial injuries in small animals. These methods could serve as a valuable reference for addressing similar challenges in other small exotic mammals with delicate skull structures.

Keywords: CT scan, Skull, Suturing, Treatment, Surgery

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การประยุกต์ใช้ไหมเย็บในการเชื่อมกะโหลก: เทคนิคใหม่สำหรับการผ่าตัดกะโหลกสุนัขจิ้งจอกเฟนเนก

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บทคัดย่อ

กะโหลกศีรษะแตกในสุนัขจิ้งจอกเฟนเนก (***Vulpes zerda***) นับเป็นปัญหารุนแรง ที่ควรได้รับการรักษา ให้ทันท่วงที เนื่องจากโครงสร้างกะโหลกศีรษะของสัตว์ชนิดนี้มีความเปราะบาง หากกะโหลกยุบตัวลงจะก่อให้เกิด ความเสียหายและการบาดเจ็บของสมอง รวมไปถึงเลือดออกในกะโหลกศีรษะ และทำให้เกิดความบกพร่องทาง ระบบประสาทหากไม่ได้รับการรักษาอย่างทันท่วงทีอาจส่งผลให้ถึงแก่ชีวิตได้ สุนัขจิ้งจอกเฟนเนกเพศเมียอายุ 1 เดือน น้ำหนัก 0.29 กิโลกรัม ได้รับบาดเจ็บที่ศีรษะจากการถูกกัดจากสกังก์อย่างรุนแรง ถูกส่งมาที่โรงพยาบาลสัตว์พนาลัย โดยสุนัขแสดง อาการเซื่องซึม เดินเซ และหมุนซ้ายเป็นวง อัตราการเต้นของหัวใจ อัตราการหายใจ การเติมเลือดฝอย และอุณหภูมิทางทวารหนักอยู่ในเกณฑ์ปกติ การตรวจวินิจฉัยด้วยเอกซเรย์คอมพิวเตอร์ (CT-scan) พบว่ากระดูกส่วนหน้าผาก (Frontal bone) และกระดูกขม่อม (Parietal bone) ยุบตัวเข้าไปในสมองบริเวณกลีบขม่อมซ้าย รวมถึงพบกิ่งตั้งของกระดูกขากรรไกรหัก (Vertical ramus of the mandible) หลังจากการวินิจฉัยสุนัขจิ้งจอกเฟนเนกจึง เข้ารับการผ่าตัดโดยยกกระดูกส่วนที่แตกแล้วกด เนื้อสมองออก เพื่อลดแรงที่กระทำต่อเนื้อสมองที่บริเวณกระดูกหน้าผากและขม่อม หลังจากนั้นจึงทำการเย็บกะโหลกศีรษะที่แตกด้วยเข็มเย็บปลายเรียวและไหมเย็บชนิด 4-0 โพลีไดออกซาโนนในลักษณะการเย็บแบบธรรมดาปมเดี่ยว โดยไม่ใช้ตาข่ายกะโหลกศีรษะเทียม การดูแลหลังผ่าตัดประกอบด้วยการติดตามอาการเรื่องระบบประสาท บาดแผล การกินอาหาร และสัญญาณชีพอื่นๆ โดยสุนัขจิ้งจอกเฟนเน็กได้รับยาอะม็อก-ซิซิลลิน-คลาวูลานิกแอซิด (Amoxicillin-clavulanic acid) และเปลี่ยนเป็น เซโฟเวซิน โซเดียม (Cefovecin sodium) เพื่อควบคุมการติดเชื้อ พรีกาบาลิน (Pregabalin) สำหรับบรรเทาอาการปวดจากเส้นประสาท เมล็อกซิแคม (Meloxicam) เพื่อลดการอักเสบ วิตามินบีคอมเพล็กซ์ (Vitamin B complex) และ Aktivait Dog® เพื่อส่งเสริมการทำงานของเส้นประสาท และ ไดเมนไฮดริเนต (Dimenhydrinate) เพื่อลดอาการเวียนศีรษะจากความผิดปกติของระบบทรงตัว รวมไปถึงการบำบัดด้วยเครื่องบำบัดด้วยออกซิเจนแรงดันสูง (Hyperbaric oxygen therapy) และการฝังเข็ม เพื่อฟื้นฟูสมอง รักษาบาดแผล และกระตุ้นการหายของระบบประสาท เมื่อเวลาผ่านไปอาการทางระบบ ประสาทและแผล ดีขึ้นตามลำดับ และสุนัขจิ้งจอกเฟนเนกสามารถฟื้นตัวเต็มที่ภายในสองเดือน กลับมาใช้ชีวิตประจำวันได้ตามปกติ แต่ยังพบอาการทางระบบประสาทโดยมีการเดินเป็นวงกลมก่อนกินอาหาร ในรายงานกรณีศึกษานี้ได้ให้ความ สำคัญของการรักษาอย่างทันท่วงทีและเทคนิคการผ่าตัดที่เรียบง่าย แต่ให้ประสิทธิภาพสูงซึ่งเหมาะกับลักษณะ ของกะโหลก ที่บางในสัตว์ที่กะโหลกศีรษะบาง และสามารถปรับใช้เพื่อจัดการกับอาการบาดเจ็บที่ซับซ้อน ในสัตว์เลี้ยงลูกด้วยนมขนาดเล็กชนิดอื่นที่มีกะโหลกศีรษะที่บอบบางเช่นเดียวกัน

คำสำคัญ : การตรวจวินิจฉัยด้วยเอกซเรย์คอมพิวเตอร์ กะโหลก การเย็บ การรักษา การผ่าตัด

Introduction

The fennec fox (*Vulpes zerda*), the smallest member of the family Canidae, possesses a delicate and lightweight skull adapted for its desert habitat (Merritt 2010). The unique anatomy of the fennec fox presents several challenges in the treatment of skull fractures. The fennec fox's skull is characterised by its delicate and thin cranial bones (Kingdon 2013), which are more susceptible to fractures from even minor trauma and can suffer severe consequences from head injuries. Additionally, the small size of the fennec fox requires precise and delicate handling during both diagnostic imaging and surgical procedures.

Surgical intervention in human head trauma focuses on intracranial hemorrhage, midline shifts in computed tomography (CT) scan), and intracranial pressure (ICP) measurements, while it has traditionally been less common in veterinary cases due to the perceived rarity of significant hemorrhage. However, evidence suggests dogs and cats may benefit from surgery for manageable hemorrhages. With greater access to CT imaging, procedures like addressing skull fractures, removing contaminated fragments, and reducing ICP through craniotomy may gain importance in veterinary practice (Dewey and Da Costa 2015). Skull fractures and traumatic brain injury in dogs can range from mild to fatal. Understanding brain and meninges anatomy is crucial while working with the skull, especially the calvarium, dorsal section, paired frontal, and parietal bones. Cranial fractures can compress and harm the meninges' major venous sinuses and cerebral cortical functioning. Surgical techniques differ by skull fracture type and part.

In dogs, skull fractures are managed using a variety of advanced stabilization techniques. Titanium locking plates are commonly utilized due to their ability to provide strong and durable support for complex fractures, particularly in cases involving severe comminution (Illukka and Boudrieau 2014). Bioabsorbable implants offer an innovative alternative, reducing the need for secondary surgeries to remove implants and minimizing long-term foreign body reactions (Salmina et al., 2023). The titanium plates manufactured using 3D printing technology were used to close the skull in dogs. These titanium plates were custom designed for each patient to ensure a precise fit for the cranial structure after craniectomy to remove tumors; in addition, titanium mesh can also be used effectively in similar cases (Dierckx De Casterlé et al., 2017; James et al., 2020). If multiple linear fractures depress the brain, causing depression fractures, and the brain was depressed, surgery for calvarium elevation was required (Dewey and Da Costa 2015). Calvarium depressions should be lifted from underneath. Normally, elevating the lesion requires multiple large burr holes. Fragment edges can lacerate meninges, venous sinuses, and cerebral cortex. Surgeons should remove highly comminuted fracture pieces. Calvarial abnormalities might result from large comminuted areas. The temporalis muscle protects most animals, but some need rib or iliac crest onlay grafts (Nunamaker 1985).

Despite these advancements in canine skull fracture management, there is a significant gap in research regarding small mammals. Their unique anatomical and physiological characteristics present considerable challenges, as most existing surgical techniques and fixation devices are incompatible with their fragile skulls. In cases where rigid fixation is impractical, the simple interrupted suture method, widely used in soft tissue applications, offers controlled tension distribution, minimal disruption to vascular supply and maintains independent stabilization at each suture point compared to simple continuous suture method (Jarasviriyagul and Chanasriyotin 2023) maybe useful for this challenge. The suture method allows for precise adjustment at each suture point, reducing the risk of excessive compression or ischemia while ensuring adequate fixation. Additionally, its adaptability and minimal foreign body reaction make it a viable alternative when rigid fixation is impractical. Given the fragile skull of the fennec fox, this technique was applied as a stabilization method to assess its effectiveness in cranioplasty for such delicate structures.

Polydioxanone (PDS) suture is a monofilament, synthetic absorbable suture widely used in orthopedic and soft tissue surgeries. Its high tensile strength, prolonged absorption time; the maximum retention of original tensile strength after 28 days is 50%, and minimal tissue reactivity make it particularly useful in procedures requiring extended wound support. Unlike multifilament sutures, which may harbor bacteria and increase infection risk, PDS provides a smooth surface that reduces tissue drag and minimizes inflammation. Its degradation occurs through hydrolysis, ensuring a predictable absorption timeline without significant foreign body reactions (AlSarhan 2019; Anderson et al., 2020). Due to these properties, PDS was selected in this case to provide stable temporary cranial support, aligning with the skull healing timeline while minimizing the risk of excessive compression, inflammation, or foreign body reaction.

Case Description

A 1-month-old 0.29 kg female fennec fox was referred to Panalai Veterinary Hospital to perform the computerized tomography (CT-scan). The fennec fox was bitten by a skunk on his head five days ago before being presented at Panalai Veterinary Hospital. The previous physical examinations at another veterinary hospital were stupor, lateral recumbency, swollen head, and edema. After initial stabilization included intravenous fluid normal saline rate 2 ml/hr for resuscitation, mannitol 1 g/kg, slow intravenous (IV), q6h, transamin 10 mg/kg, IV, q8h, buprenorphine 0.02 mg/kg, intramuscular, q8h, amoxicillin-clavulanic acid 25 mg/kg, subcutaneous (SC), q24h, and meloxicam 0.3 mg/kg, SC, q24h. After treatment at previous veterinary hospital for 6 days, fennec fox's mental status and swollen head were gradually improved. Although she was responsive, she still had left circling and loss of balance. When the fennec fox presented at Panalai Veterinary Hospital, the further investigations were approached immediately. There was a puncture wound on the fennec fox's head, and the left side of the head appeared depressed compared to the right. Her vital signs were stable, with a heart rate of 120 bpm, respiratory rate of 30 bpm, rectal temperature of 100°F, and a capillary refill time of 2 seconds. She underwent a neurological re-evaluation, and the findings were summarized in the Tables 1-5. The pain score of the fennec fox was estimated to be grade 2-3/4. However, accurate pain assessment was challenging due to concurrent neurological impairment, which may have blunted the typical behavioral responses to pain. Hematological analysis showed mild anemia, suspected to result from blood loss due to the bite wound. As automated complete blood count (CBC) analysis lacked species-specific reference values for fennec foxes, a blood smear examination was performed for differential blood count assessment. The smear revealed leukocytosis as a response to trauma and hypochromic normocytic anemia due to blood loss. The blood biochemistry revealed hypoalbuminemia, likely due to trauma-induced inflammation; hyperglycemia, attributed to a stress response; and low BUN and low creatinine, resulting from young age and reduced protein intake (Tables 6-8). The CT scan revealed a skull fracture measuring approximately 1.39 cm x 2.29 cm in the frontal and parietal bones, with some displaced fragments compressing the left parietal-temporal lobe of the brain. The skull thickness was measured at 1.12 mm, highlighting its fragility. Additionally, a fracture of the vertical ramus of the left mandible was observed (Figures 1-5).

Table 1. Neurological examination of this patient: observation from Day 0 to Day 70.

Observation	Day 0	Day 7	Day 18	Day 28	Day 35	Day 63	Day 70
Mentation	Disorientation	Obtunded	BAR	BAR	BAR	BAR	BAR
Posture	Head turn left	Head turn left	Normal	Normal	Normal	Normal	Normal
Gait	Left circling	Left circling	Sometimes left circling	Sometimes left circling	Sometimes left circling	Sometimes left circling	Sometimes left circling

Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery.

BAR; Bright. alert and responsive.

Table 2. Neurological examination of this patient: postural reaction results from Day 0 to Day 70.

Postural reaction	Day 0	Day 7	Day 18	Day 28	Day 35	Day 63	Day 70
Proprioception							
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2
Lt HL	+1	+2	+2	+2	+2	+2	+2
Rt HL	+1	+2	+2	+2	+2	+2	+2
Hopping							
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2
Lt HL	+1	+2	+2	+2	+2	+2	+2
Rt HL	+1	+2	+2	+2	+2	+2	+2
Wheel barrowing							
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2
Ext.post.thrust							
Lt HL	+1	+2	+2	+2	+2	+2	+2
Rt HL	+1	+2	+2	+2	+2	+2	+2
Visual placing							
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2
Tactile placing							
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2
Lt FL	+1	+2	+2	+2	+2	+2	+2
Rt FL	+1	+2	+2	+2	+2	+2	+2

Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery.

Lt FL: Left forelimb, Rt FL: Right forelimb, Lt HL: Left hindlimb, Rt HL: Right hindlimb, Ext.post.thrust: Extensor postural thrust. Result: +1 = Decrease reflex, +2 = Normal reflex.

Table 3. Neurological examination of this patient: spinal reflex results from Day 0 to Day 70.

Spinal reflex	Day 0	Day 7	Day 18	Day 28	Day 35	Day 63	Day 70
Flexor reflex							
Lt FL	+2	+2	+2	+2	+2	+2	+2
Rt FL	+2	+2	+2	+2	+2	+2	+2
Lt FL	+2	+2	+2	+2	+2	+2	+2
Rt FL	+2	+2	+2	+2	+2	+2	+2
Ext.carp.radialis							
Lt FL	+2	+2	+2	+2	+2	+2	+2
Rt FL	+2	+2	+2	+2	+2	+2	+2
Patella reflex							
Lt FL	+2	+2	+2	+2	+2	+2	+2
Rt FL	+2	+2	+2	+2	+2	+2	+2
Perineal reflex							
Lt	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Rt	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Cross extensor							
Lt	-ve	-ve	-ve	-ve	-ve	-ve	-ve
Rt	-ve	-ve	-ve	-ve	-ve	-ve	-ve
Panniculus							
Lt	Present at T3-L3						
Rt	Present at T3-L3						

Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery.

Lt FL: Left forelimb, Rt FL: Right forelimb, Lt HL: Left hindlimb, Rt HL: Right hindlimb, Ext.post.thrust: Extensor postural thrust. Result: +2 = Normal reflex, +ve: Positive result, -ve: Negative result. T3 = 3rd thoracic spine, L3 = 3rd lumbar spine.

Table 4. Neurological examination of this patient: cranial nerve reflex results from Day 0 to Day 70.

Cranial nerve reflex	Day 0		Day 7		Day 18		Day 28		Day 35		Day 63		Day 70	
	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
Smell (l)	+ve		+ve		+ve		+ve		+ve		+ve		+ve	
Menace (ll/Vll)	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2
Pupil size (ll/lll/Sympathetic)	Symmetry		Symmetry		Symmetry		Symmetry		Symmetry		Symmetry		Symmetry	
Direct pupillary light reflex (ll/lll)	Normal		Normal		Normal		Normal		Normal		Normal		Normal	
Indirect pupillary light reflex (ll/lll)	Normal		Normal		Normal		Normal		Normal		Normal		Normal	
Oculocephalic reflex (lll/lV/Vl/Vlll)	Normal		Normal		Normal		Normal		Normal		Normal		Normal	
Nystagmus/Strabismus (lll/lV/Vl/Vlll)	Normal		Normal		Normal		Normal		Normal		Normal		Normal	
Cotton ball (ll/Vll)	-ve	-ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Dazzle (ll/Vll)	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Palpebral (V/Vll)	+1	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2
Corneal (V/Vl/Vll)	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2
Nostril sensation (V)	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2
Ear sensation (Vll)	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2	+2
Trigeminofacial reflex (V/Vll)	+1	+2	+1	+2	+1	+2	+2	+2	+2	+2	+2	+2	+2	+2
Gag reflex (lX/X)	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Tongue (Xll)	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Trapezius (Xl)	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve

Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery. Lt: Left, Rt: Right. Result: +1 = Decrease reflex, +2 = Normal reflex, +ve: Positive result, -ve: Negative result.

Table 5. Neurological examination of this patient: sensation result from Day 0 to Day 70.

Test	Result
Superficial pain at forelimb	Positive
Superficial pain at hindlimb	Positive
Deep pain at forelimb	Positive
Deep pain at hindlimb	Positive
Hyperesthesia	Negative
Self mutilation	Negative

Table 6. Complete blood count of the patient on Day 0.

Parameters	Results	Reference range*	Unit
White blood cell	10.20	5.0-14.1	10^9/L
% Lymphocyte	15.31	8-21	%
% Monocyte	3.12	2-10	%
% Neutrophil	79.22	58-85	%
% Eosinophil	1.85	0-9	%
% Basophil	0.44	0-1	%
Red blood cell	5.05	4.95-7.87	10^{12}/L
Hemoglobin	8.0	11.9-18.9	g/dL
Hematocrit	28.3	35-57	%
Mean corpuscular volume	56.2	66-77	fL
Mean corpuscular hemoglobin	15.8	21.0-26.2	pg
Mean corpuscular hemoglobin concentration	28.2	32.0-36.3	g/dL
Platelet	733		10^9/L

*Reference ranges in dog used at the Laboratory of Panalai Veterinary Hospital, Thailand.

*Reference ranges of automated complete blood count analyzed by URIT 5160 5-part diff hematology analyzer.

Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery

Table 7. CompleteDifferential blood count from blood smear on Day 0.

Parameters	Results	Reference range*	Unit
White blood cell estimates	10.0	5.96±2.33	10^9/L
Platelet counts	584.0+giant plt	471±222	10^9/L
% Band neutrophil	0		%
% Segment neutrophil	7.4	2.86±1.57	%
% Lymphocyte	2.3	2.40±1.43	%
% Monocyte	0.3	0.26±0.18	%
% Eosiophil	0		%
% Basophil	0		%
Red blood cell morphology		Hypochromic normocytic anemia	

*Reference ranges of blood biochemistry of fennec fox from International Species Information System (ISIS, March 2002). Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery

Table 8. Blood biochemistry of the patient on Day 0.

Parameters	Results	Reference range1*	Reference range2*	Unit
Albumin	1.8	2.5-4.4	3.0±0.5	g/dL
Alkaline phosphatase	81	20-150	54±55	U/L
Alanine transaminase	120	10-118	88±63	U/L
Amylase	134	200-1200	54.95±21.83	U/L
Total bilirubin	0.3	0.1-0.6	0.3±0.3	mg/dL
Blood urea nitrogen	16	7-25	78.54±28.56	mg/dL
Calcium	10.7	8.6-11.8		mg/dL
Phosphorus	8.0	2.9-6.6		mg/dL
Creatinine	0.2	0.3-1.4	0.7±0.18	mg/dL
Glucose	135	60-110	66.6±19.98	mg/dL
Sodium ion	155	138-160		mmol/L
Potassium ion	6.0	3.7-5.8		mmol/L
Total protein	4.7	5.4-8.2	5.6±6	g/dL
Globulin	2.9	2.3-5.2	2.5±0.6	g/dL

1*Reference ranges in dog used at the Laboratory of Panalai Veterinary Hospital, Thailand.

1*Reference ranges of blood biochemistry analyzed by VetScan VS2.

2*Reference ranges of blood biochemistry of fennec fox from International Species Information System (ISIS, March 2002). Day 0 is the 1st visit at Panalai Veterinary Hospital and before surgery

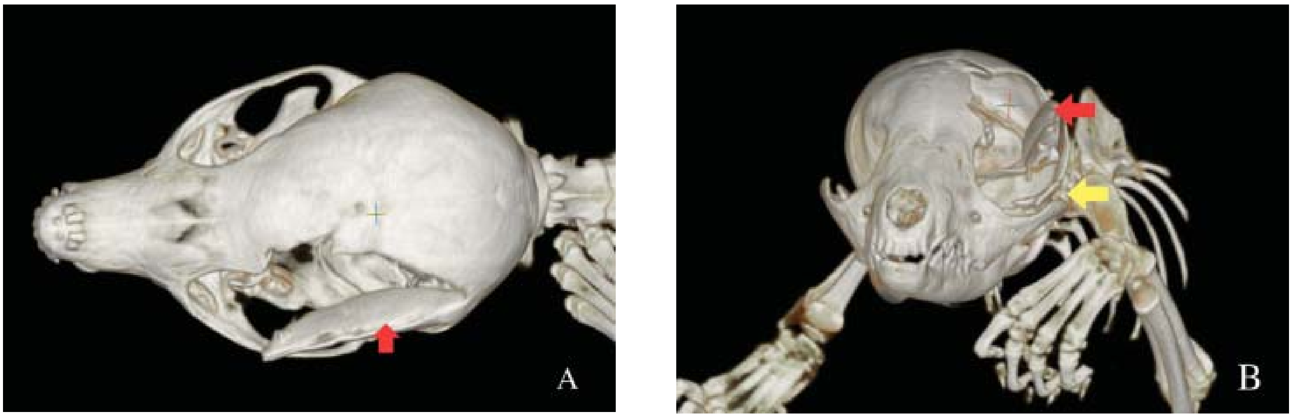


Figure 1. 3D volume rendering, dorsal view of skull, shows a fracture of frontal and parietal bones of the skull (A, B; red arrow) and the vertical ramus of the left mandible (B; yellow arrow).

Figure 2. The fracture, involving the frontal and parietal bones, measured approximately 1.39 cm x 2.29 cm.

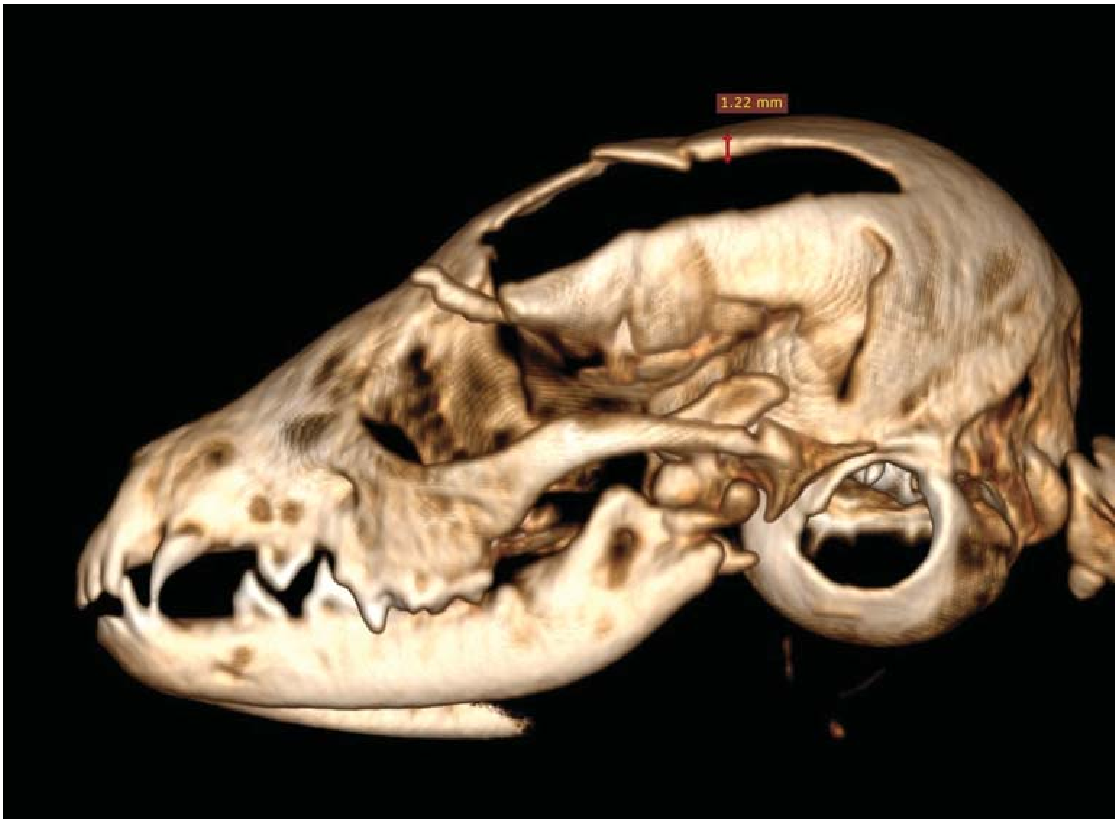


Figure 3. The skull thickness of this fennec fox measured approximately 1.12 mm.

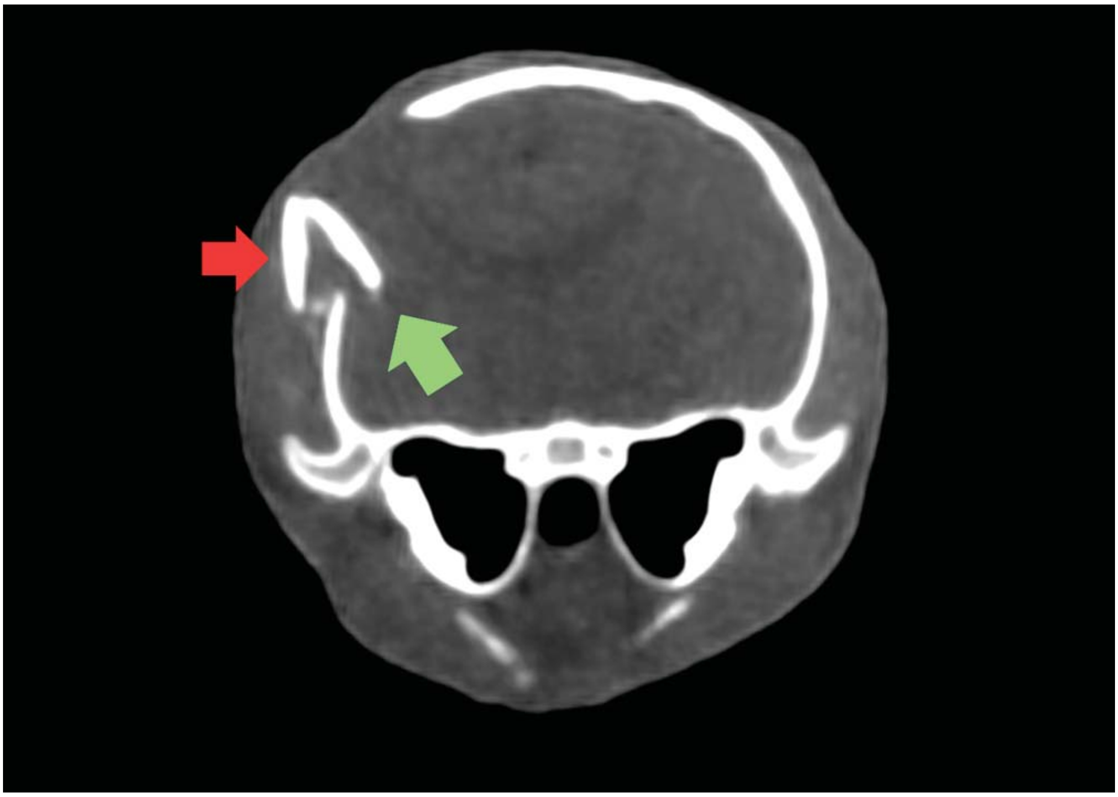


Figure 4. Soft tissue window CT: The transverse image shows no dilation of lateral ventricle, a fragmented piece of skull folded back (red arrow), and penetrated the left lobe of brain (green arrow).

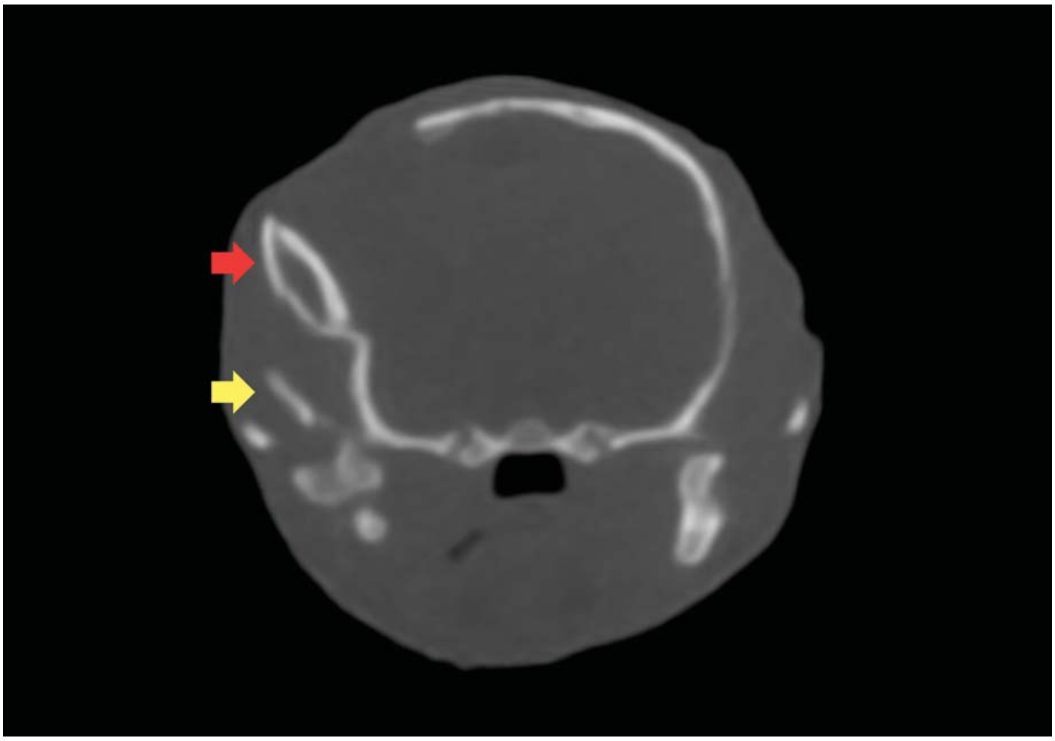


Figure 5. Bone window CT: The transverse image shows a fracture of the frontal and parietal bones of the skull (red arrow) and a fracture of the vertical ramus of the left mandible (yellow arrow).

Based on the compressed frontal-parietal lobe, surgical intervention was performed to elevate the fractured bone. The fennec fox was assessed as ASA (American Society of Anesthesiologists) score III, considering multiple factors including its young age, controlled seizure activity, responsiveness. The fennec fox was anesthetized using a combination of intramuscularly administered drugs for premedication and induction, consisting of medetomidine (Sedator®, Dechra, United Kingdom) at a dosage of 0.02 mg/kg, zolazepam-tiletamine (Zoletil®, VALDEPHARM, France) at 3.5 mg/kg, and butorphanol (Butodol®, NEON LABORATORIES LIMITED, India) at 0.1 mg/kg. Following anesthesia premedication and induction, an intravenous catheter was placed, and the animal was intubated using a 2.0-size endotracheal tube. Anesthesia was maintained with sevoflurane inhalation. The patient was positioned in sternal recumbency, and routine skin preparation was performed (Figure 6). The surgical procedure commenced with the decompression of the affected area, guided by palpation of the dented frontal bone. An elliptical incision on the skin affected area was made along the fracture line of the skull to expose the fractured skull, and careful blunt dissection was performed around the bone fragment and associated blood clots. A Lone Star® retractor system and elastic stay (CooperSurgical, USA) was employed to provide better visualization and access to the surgical site (Figure 7). The compressed bone fragment was gently elevated and repositioned (Figure 8), then sutured to the edge of the parietal bone using a tapered needle and polydioxanone, absorbable suture (MonoPlus® 4-0, B Braun, Spain), for 6 stitches with simple interrupted pattern suture (Figure 9). The subcutaneous tissue was subsequently closed with polydioxanone, absorbable suture (MonoPlus® 5-0, B Braun, Spain) with subcuticular pattern suture. The bacterial culture was performed around the wound. And the skin incision was sealed using tissue adhesive (Figure 10). The bacterial culture showed no bacterial growth at days 3 and 7.

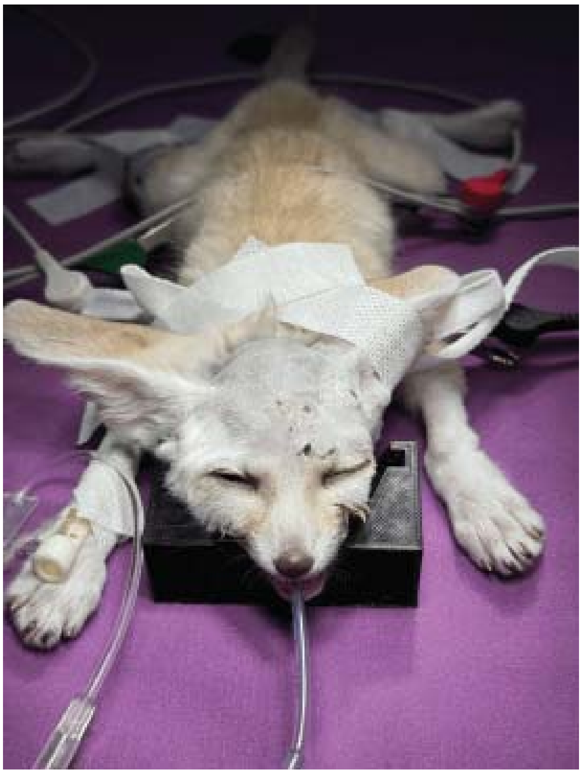


Figure 6. The patient was positioned in sternal recumbency, with preparation and monitoring prior to the operation.

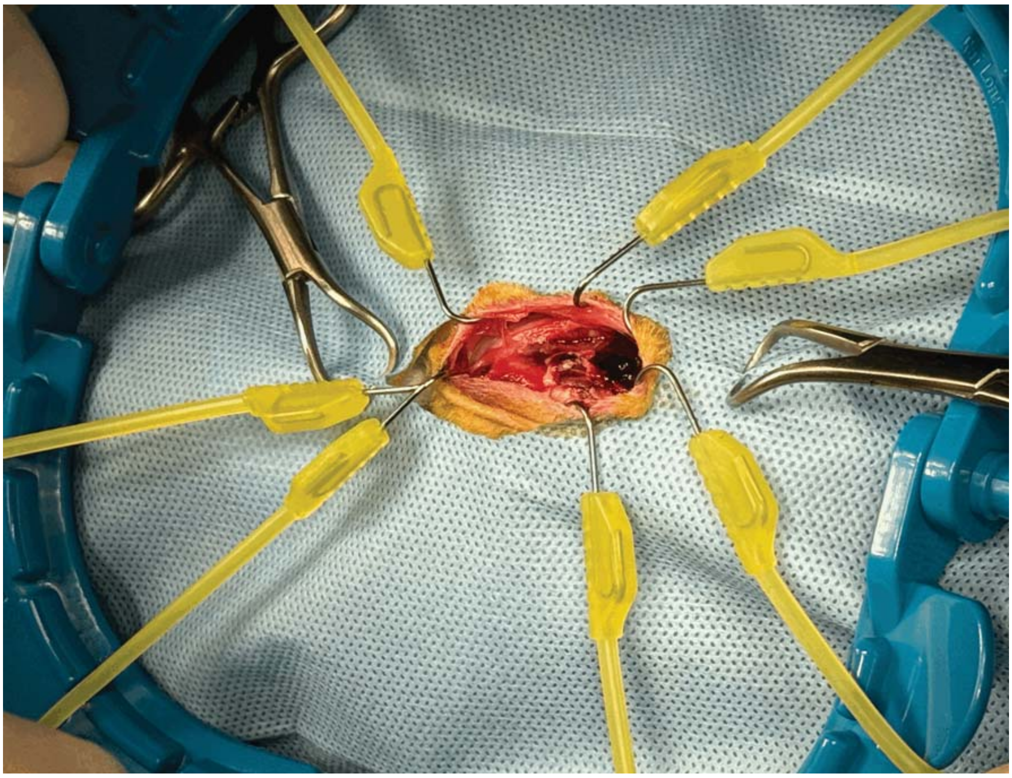
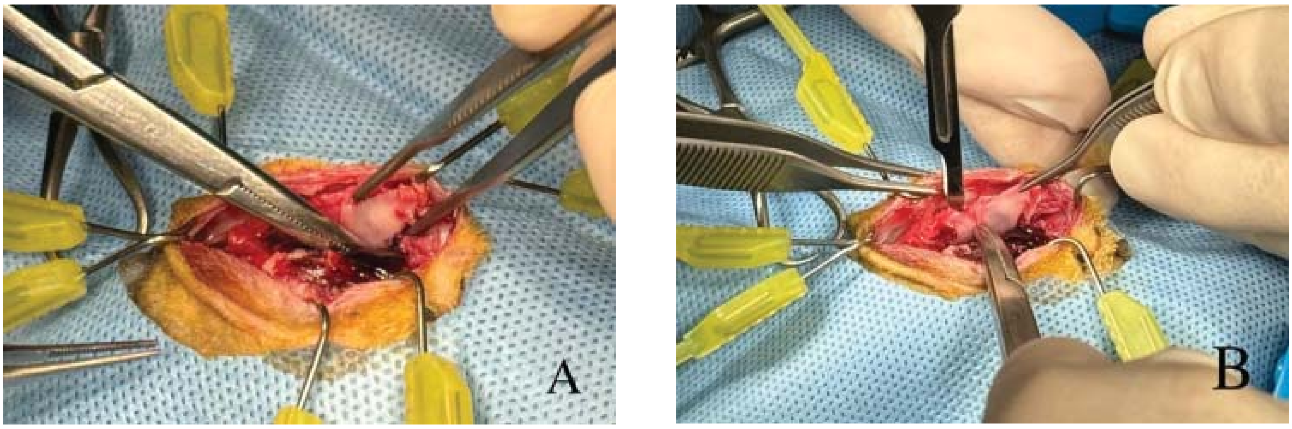


Figure 7. A Lone Star® retractor system and elastic stay were employed to provide better visualization and access to the surgical site.



Figures 8. The compressed bone fragment was gently elevated and repositioned (A, B).

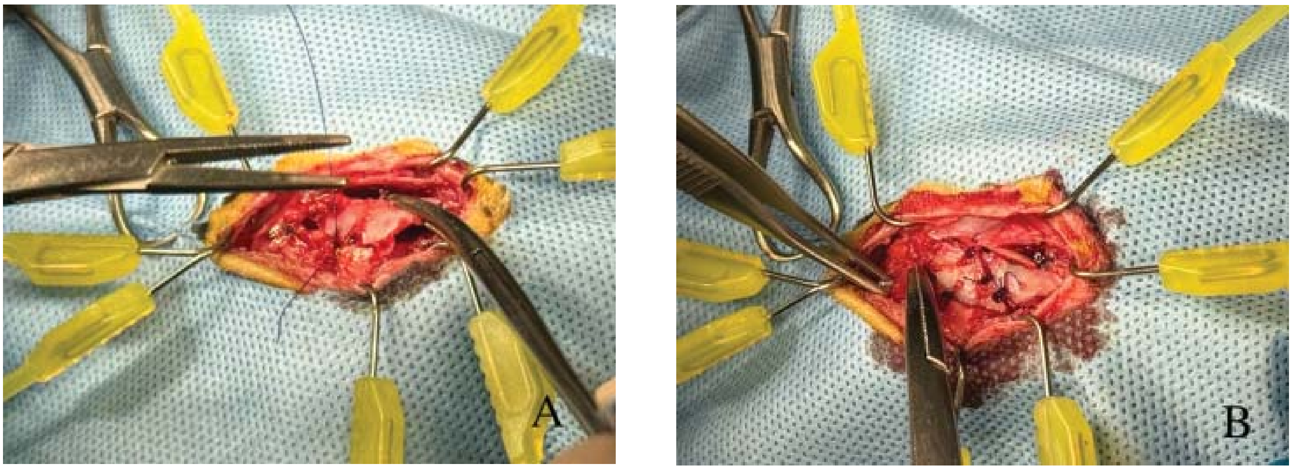


Figure 9. The fractured skull fragment was sutured to the edge of the parietal bone using a tapered needle and 4-0 polydioxanone suture material (A), then sutured along the fractured line (B).

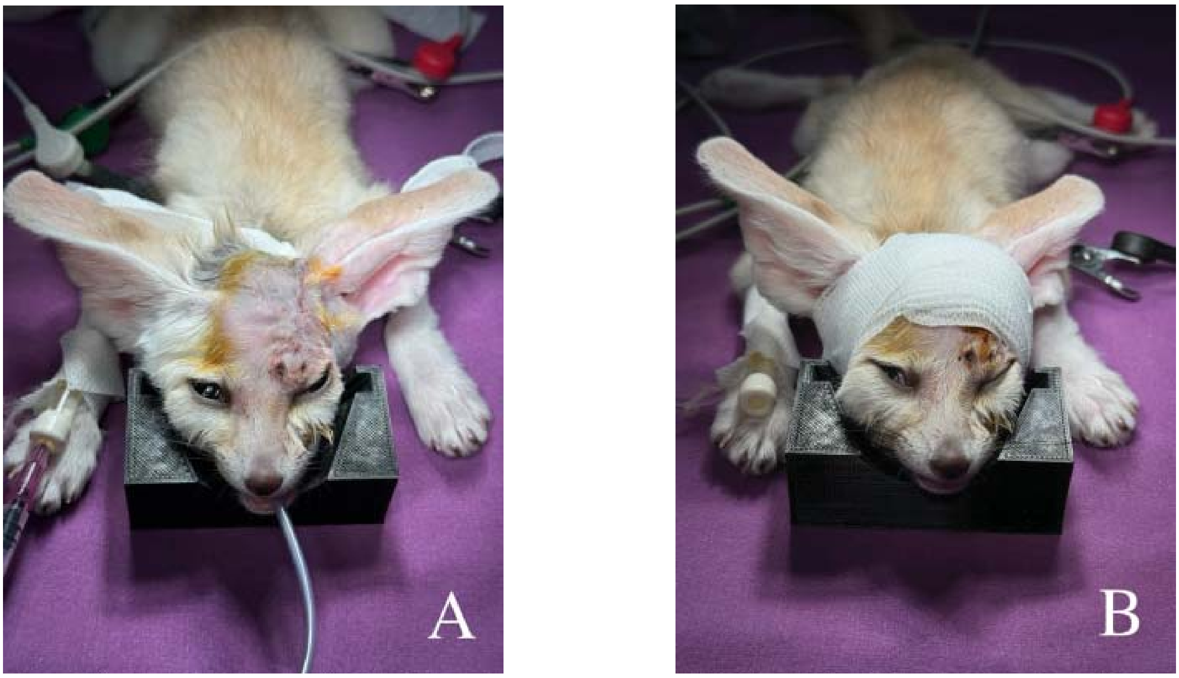


Figure 10. The patient skin incision was sealed using tissue adhesive (A) and then bandaged (B).

After the surgery, the fennec fox smoothly recovered. The medicines in post-postoperative care were Amoxicillin-clavulanic acid 25 mg/kg (Cavumox®, Siam Bheasach Co., Ltd., Thailand), intravenous twice a day for 2 days, then Amoxicillin-clavulanic acid 25 mg/kg (Synulox™, Haupt Pharma S.r.l.-Latina, Italy) subcutaneous, once a day for 8 days. However, as the fennec fox showed good clinical improvement but began resisting manual restraint for oral medication administration, the antibiotic was switched to cefovecin sodium (Convenia®, Zoetis Inc, USA) at 8 mg/kg, SC, once. This change aimed to reduce stress and handling time, minimizing the risk of increased intracranial pressure that these problems could affect the healing brain injury. Additional medications included pregabalin 4 mg/kg (Toprelin®, Buymed Siam Co., Ltd., Thailand) peroral twice a day, vitamin B complex (B1 100mg, B6 5mg, B12 50μg) (Bee Three®, Medicine Products Co., LTD., Thailand) 5 tab combined with co-dergocrine mesylate (1 mg) (Hydrine®, T.O.Chemicals (1979) LTD., Thaliand) 1 tab in multivitamin 10 ml give 0.3 ml twice a day, Aktivait dog® (VetPlus Ltd, United Kingdom) 0.45 ml peroral once a day, dimenhydrinate (H.K.Pharmaceutical Co., LTD., Thailand) 8 mg/kg per oral twice a day for 11 days. Additional post-operative care included providing sufficient nutrition with wet food, attended the hyperbaric oxygen therapy for 2 hours twice a day, and restricted area. Her mental status and neurological signs were gradually improving each day. She came back to bright alert and responsive on day 5 post-operative and expressed normal behavior like digging. At first, she was circling in a small circle, her circle was bigger consecutively (Tables 1-5). Her wound was good and no exudate in day 7 post-operative. Finally, the fox was discharged on day 11 post-operative, her clinical signs were circling in a big area. The 1 week recheck after discharging, she walked normally but circled in the big area. Then, she was performed the dry needle acupuncture once a week at GV-17, GV-20, GB-20, An-shen, Long-hui (Figure 11). After 4 sessions of acupuncture, the fennec fox did not continue an acupuncture due to the family condition. Two months later, the owner mentioned that she can live happily like a normal fennec fox though she rarely a little circling sign before eating.

Figure 11. The fennec fox was restrained to perform the acupuncture.

Discussion

The application of CT-scan in evaluating the skull fracture of this fennec fox underscores its versatility in veterinary medicine, extending beyond common species like dogs and cats. CT-scan imaging is essential for the precise identification of the extent and complexity of traumatic skull fractures in companion animals, which in turn informs treatment decisions (Amengual-Batle et al., 2020). This case illustrates that CT-scan can be effectively applied to exotic species, such as the fennec fox, where anatomical distinctions require precise preoperative imaging to plan surgical interventions. CT-scan provides veterinarians with the ability to customize surgical techniques, such as elevating and suturing cranial bones, to the patient's specific requirements by providing comprehensive visualisation of fracture configurations. Moreover, the timely decision to perform surgery to relieve brain compression significantly increases the chances of survival compared to relying on medical treatment alone.

Craniotomy is a routine procedure in human medicine, but its application in veterinary practice remains limited, particularly in small mammals like the fennec fox, where no prior case reports exist. The severity of this case, involving frontal and parietal bone fractures with significant depression compressing the brain, along with an infected wound from a skunk bite, made surgical intervention both challenging and necessary to improve survival. Given the lack of established guidelines for exotic species, the decision to proceed was based on human neurosurgical criteria for depressed cranial fractures, which recommend surgery in cases of severe skull depression, dural penetration, significant hematoma, frontal sinus involvement, infection, or pneumocephalus (Bullock et al., 2006). In this case, the fennec fox met multiple high-risk criteria, neurological signs, infection risk, and significant skull depression, surgical intervention was the most viable option to prevent worsening brain injury, secondary complications, and poor long-term prognosis.

The potential of minimalist approaches in species with delicate cranial structures is demonstrated by the effective use of decompression and suturing techniques in the repair of a fennec fox's fragile cranium. Unlike dogs and humans, the fennec fox's skull is exceptionally thin and lightweight, an evolutionary adaptation to its desert environment. Given the lack of species-specific fixation techniques for exotic mammals, a suture-based approach was chosen for stabilization. PDS suture was selected due to its high tensile strength, prolonged absorption period, and minimal tissue reactivity, making it well-suited for stabilizing delicate cranial fractures. Unlike rapidly degrading sutures, PDS maintains adequate tensile support for up to 6 weeks before gradual absorption, which aligns with the early phases of skull healing, providing structural support while minimizing foreign body reactions (Wolfs et al., 2022). In contrast, rigid fixation devices, such as titanium plates, bioresorbable implants, or mesh, are designed for larger species like dogs and humans, making them disproportionately large and heavy for a fennec fox's delicate skull. Their weight and stiffness could impose mechanical stress, increasing the risk of pressure-related complications and impaired healing (Dierckx De Casterlé et al., 2017; James et al., 2020; Salmina et al., 2023). Additionally, such implants require extensive soft tissue dissection and may not conform well to the thin, curved cranial anatomy of small exotic species. By using PDS in a simple interrupted suture pattern, the fractured cranial segments were secured with minimal additional weight and preserved vascular integrity, promoting natural osteosynthesis.

The medical management of skull fractures and traumatic brain injury (TBI) in fennec foxes remains largely uncharted due to the lack of species-specific guidelines. Given the absence of prior case reports, treatment in this case was adapted from established protocols in dog and human (Bullock et al., 2006; Dewey and Da Costa 2015). The primary focus of medical stabilization was intracranial pressure (ICP) management, utilizing osmotic therapy to mitigate cerebral edema, along with fluid therapy to maintain adequate cerebral perfusion. Pain control was prioritized using opioid analgesia, which is critical in TBI cases to prevent excessive sympathetic stimulation. Antibiotic therapy was administered prophylactically to prevent post-traumatic infections, particularly given the open wound and skull compression. In addition to standard TBI management, neuroprotective strategies were considered. These interventions were chosen based on their proven efficacy in canine patients with similar injuries.

In the postoperative treatment, there are articles demonstrating the safety and tolerability of hyperbaric oxygen therapy (HBOT) in dogs and cats with various conditions, including head trauma, showing its capability to enhance oxygen delivery, reduce inflammation, and improve healing (Birnie et al., 2018). Similarly, the acupuncture's efficacy in stimulating nerve regeneration and improving neurological outcomes in dogs with severe head injuries that were unresponsive to conventional treatments (Oraveerakul 2003). These therapies were effective in the recovery of neurological functions, including balance and mobility, in the case of a fennec fox, as they were in canine species. The treatment was enhanced by acupuncture, which promoted circulation and alleviated pain, while HBOT reduced inflammation and facilitated healing in the fox's delicate cranial tissues. These findings are consistent with the known advantages of these modalities in small companion animals, underscoring their adaptability and potential as essential components of a multimodal approach to head trauma rehabilitation.

This study presents several limitations due to the unique challenges of treating an unusual pet species. The lack of species-specific medical data for fennec foxes necessitated adapting treatment protocols, drug dosages, anesthetic management, and surgical approaches from studies in dogs. While this method provided a practical reference, physiological and anatomical differences between species may affect the direct applicability of these treatments. Additionally, assessing brain damage in skull fractures would ideally require MRI, which offers greater soft tissue contrast and more detailed visualization of intracranial structures. However, MRI was not feasible in this case due to limited equipment availability and the prolonged anesthesia time required, which could increase surgical risks in such a small exotic species. Although CT imaging provided essential structural details, it lacks the ability to fully assess soft tissue damage, hemorrhage, or subtle brain injuries compared to MRI.

Conclusion

This case emphasises the effective management of a skull fracture in a fennec fox by utilising a multidisciplinary approach that was specifically designed for the animal's unique anatomy. The precise decompression and suture-based stabilisation of the vulnerable cranial structure were made possible by CT imaging, which provided critical insights for surgical planning. Wound healing and neurological recovery were significantly enhanced by postoperative care, which encompassed hyperbaric oxygen therapy and acupuncture. The positive result shows the potential of integrating diagnostics, delicate surgical techniques, and comprehensive treatments to treat complex cranial injuries in fennec foxes. Notably, this is the first reported case of cranioplasty suturing in a fennec fox, paving the way for surgical decision-making in small exotic mammals to improve survival rates through timely and effective interventions.

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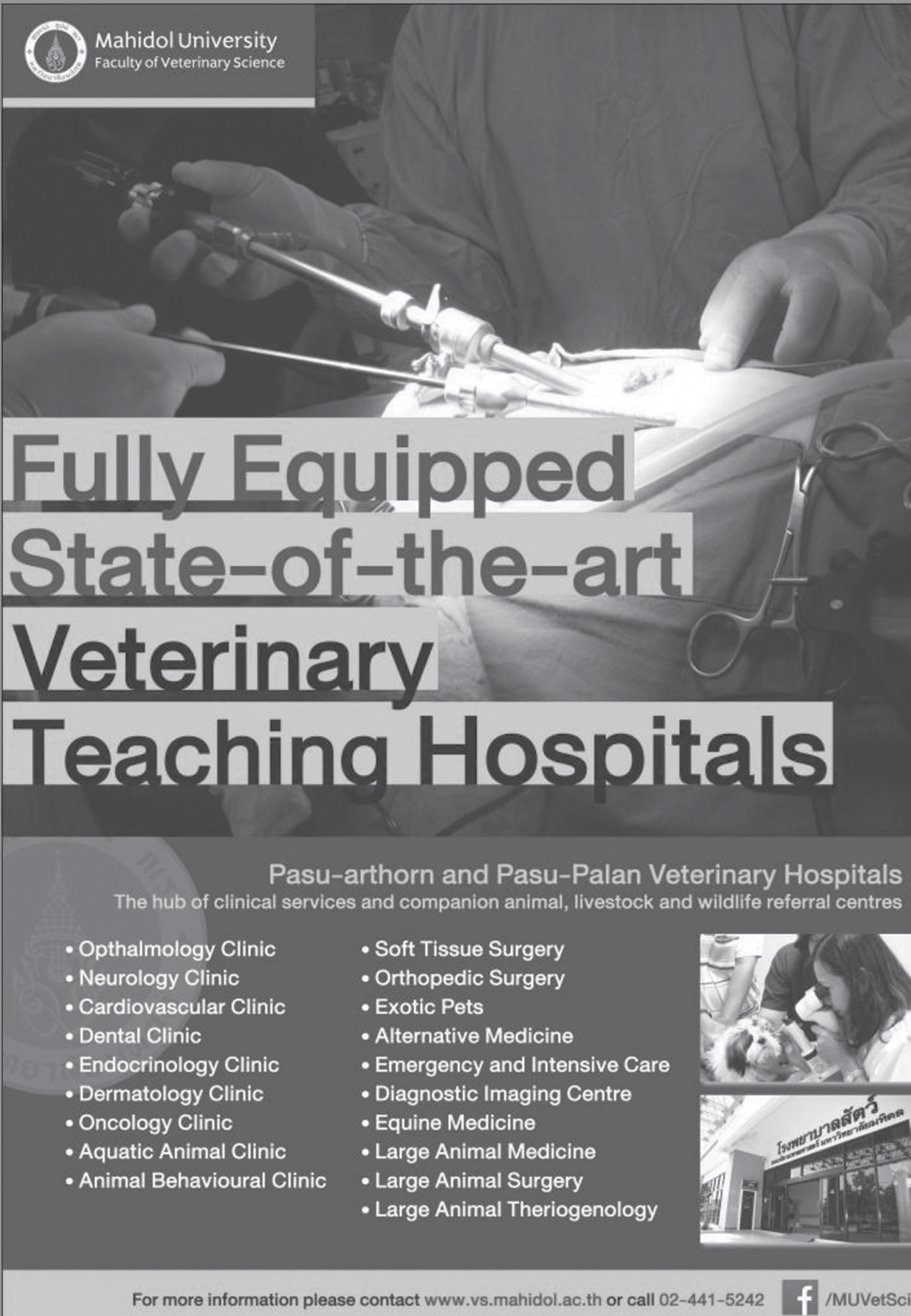

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