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Transseptal Porcupine Quill Penetration of the Canine Heart: CT, Echocardiographic Diagnosis, and Intraoperative Extraction

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ABSTRACT

The porcupine is a nocturnal rodent covered with sharp quills, widespread throughout Italy. When confronted by danger, it raises its spines, shakes its tail, and charges either backward or sideways toward attackers. Once contact occurs, the quills detach and can penetrate into muscles or body cavities because of the downward-facing serrated cuticle near their base, which acts like a harpoon. In rare cases, these quills have been found inside the heart of dogs, producing serious clinical symptoms. This paper reports a case involving a single Hystrix cristata (HC) quill that migrated into a dog's heart and explains how several imaging techniques were used for its identification and surgical removal. A 4-year-old, 25-kg, mixed-breed female dog was referred with recurrent episodes of fever. Echocardiography revealed a bright, linear foreign body crossing the interventricular septum from the cardiac base to the apex. Computed tomography and transesophageal echocardiography confirmed a quill-like object, while esophageal endoscopy ruled out structural or mucosal abnormalities. Through a median sternotomy and ultrasound-guided localization, the quill was successfully extracted. The dog recovered uneventfully without notable cardiac damage from the embedded quill. To the authors' awareness, this represents the first documented removal of an intracardiac Hystrix cristata quill identified via ultrasound and CT imaging.

Keywords: CT scan, Cardiac injury, Hystrix cristata, Migrating foreign body, Porcupine spine, Thoracic operation

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Introduction

The crested porcupine (Hystrix cristata) is a familiar species inhabiting most parts of Italy, especially forested and scrub-covered areas. Its defense mechanisms are quite unique: the animal typically rattles its tail to deter predators, but when threatened directly, it may move backward or sideways to strike [1]. Contrary to the common myth, porcupines do not shoot their quills. Instead, they contract the skin muscles to erect them, and because the quills are loosely fixed, they detach upon impact and lodge in the predator's skin [1]. The quills of HC are cylindrical for roughly two-thirds of their length and flatten near the tip. They can grow to 380–400 mm long and about 2 mm thick, with as many as 12 grooves corresponding to internal septa dividing the medullary core [2]. These differ from those of the North American porcupine (Erethizon dorsatum), which are shorter (≈85 mm), smoother, only slightly curved, and somewhat flattened. The latter's tips carry tiny backward-facing barbs, while their medulla lacks thick internal partitions [2, 3]. In Hystrix species, the tip is smooth and sharp, without barbs, but the base has reversed scales facing the shaft, functioning like a harpoon [2]. This configuration—along with the barbs in Erethizon quills—enhances their ability to penetrate and prevents easy withdrawal once embedded [1–3]. Because they may carry bacterial contamination, these spines can induce tissue infection and inflammatory reactions [4].

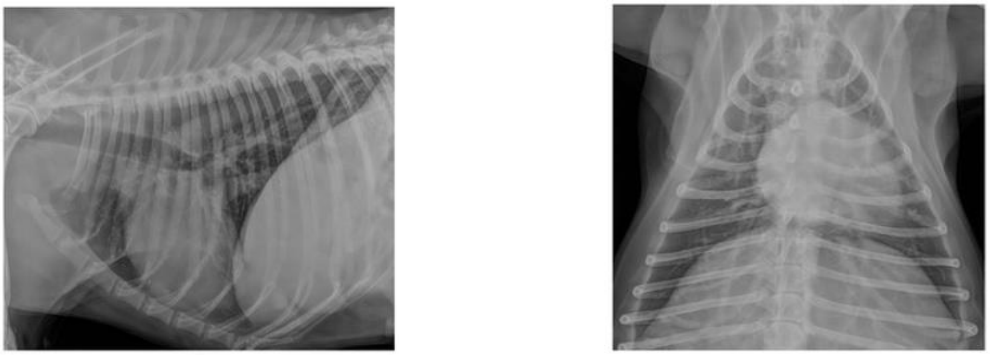
In veterinary practice, porcupine quills are a frequent foreign object retrieved from dogs, most often lodged in the head, cervical area, or chest [5–13]. Both Hystrix and Erethizon quills tend to break close to the skin, which complicates detection during the initial examination [9]. Early recognition and total extraction are crucial for a positive prognosis [8]. If not removed promptly, the spines can migrate deeper, affecting vital organs or cavities. Migration to the thoracic cavity may result in pneumothorax or pleural effusion [8]; penetration of the eye can cause irreversible blindness [6, 12]; entry into joints may trigger septic arthritis or even lead to endocarditis [7]. In some cases, quills have been found to travel to the spine or brain, leading to progressive neurological symptoms and death [11, 14, 15]. Although migration of quills within canine tissues is fairly common, their entry into the heart remains extremely rare [9, 16]. Penetration may occur directly through the thoracic wall or secondarily after migration from the neck region [8]. The extent of cardiac trauma determines how soon symptoms appear and influences the treatment approach. Rapid movement of a quill through the chest can produce serious complications such as hemothorax, cardiac tamponade, or pneumothorax [13]. Hence, accurate imaging plays a critical role in pinpointing the foreign body's location, predicting complications, and ensuring full retrieval.

This paper reports a rare case of an intracardiac porcupine quill in a dog with repeated fever episodes and describes how combined imaging modalities were applied to confirm the diagnosis and enable successful ultrasound-assisted surgery.

Case presentation

Case description and clinical investigations

A 4-year-old, 25-kg, female mixed-breed dog was referred to the Veterinary Teaching Hospital at the University of Perugia for repeated fevers. Four months earlier, the referring veterinarian had treated swelling and pain in the lower neck—initially suspected as a snake bite—with antibiotics and corticosteroids. Since that time, the animal had experienced three febrile episodes, each resolving after antimicrobial therapy. No other abnormalities were noticed. On admission, the dog was lethargic, febrile (40.4 °C), and mildly tachypneic (28 breaths/min). A complete blood count and serum biochemistry profile were obtained. The results showed neutrophilic leukocytosis ($19.43 \times 10^3/\mu L$; reference $6–12 \times 10^3/\mu L$), mild nonregenerative anemia (RBC $4.05 \times 10^6/\mu L$; reference $5.5–8.21 \times 10^6/\mu L$; Hb 10.1 g/dL; reference 12–18 g/dL; Hct 29.2%; reference 37–55%; MCV 72.1 fL; reference 60–72 fL; MCH 24.9 pg; reference 20–25 pg; MCHC 34.6%; reference 32–39%; RDW 15.2%; reference 12–16%) and increased alkaline phosphatase levels (198 U/L; reference 10–100 U/L). Thoracic radiography **(Figure 1)** and abdominal ultrasound scans were unremarkable. Electrocardiography did not reveal any arrhythmia.



a) b)

Figure 1. Thoracic radiographs of the dog with an intracardiac porcupine quill. (a) Left lateral and (b) ventrodorsal projections display no notable radiologic lesions.

To eliminate the possibility of endocardial or myocardial infection, a cardiac ultrasound was performed using an imaging unit fitted with a phased-array probe (1–4 MHz, MyLab™ Eight, Esaote, Genova, Italy). A bright linear structure was observed crossing the interventricular septum, stretching from the cardiac base toward the apex. In longitudinal views, it appeared as two distinct, reflective, parallel lines accompanied by several faint parallel echoes **(Figure 2)**. Cross-sectional views depicted a circular, echogenic object producing acoustic shadowing **(Figure 2)**. Around the heart base, a low-echo zone was evident **(Figure 2)**. No further structural alterations were noted.

Computed tomography (CT) of the thoracic region was then performed with a 16-slice helical scanner (Fujifilm FCT Speedia, Fujifilm Italia S.p.A., Milan, Italy), acquiring images before and after intravenous contrast injection. Parameters were: 120 kV, 100 mAs, pitch 1, tube rotation 0.75 s, and slice thickness 2.5 mm with 1.25 mm overlap during reformatting. Soft tissue reconstruction was used to assess axial and multiplanar images. Three-dimensional renderings allowed precise evaluation of the foreign object's trajectory and dimensions. In the axial sequence, a roughly circular, slightly hyperdense focus—brighter than the adjacent myocardium—was identified, visible continuously from the cardiac base to the left side of the apex through the septum. Multiplanar reconstructions aligned to the object's long axis revealed its shape and size, measuring about 80 mm in length and 5 mm in width **(Figure 3)**. The structure appeared elongated and triangular with dense margins and a less dense inner core. Volumetric imaging confirmed a tapered, conical object consistent with a quill.

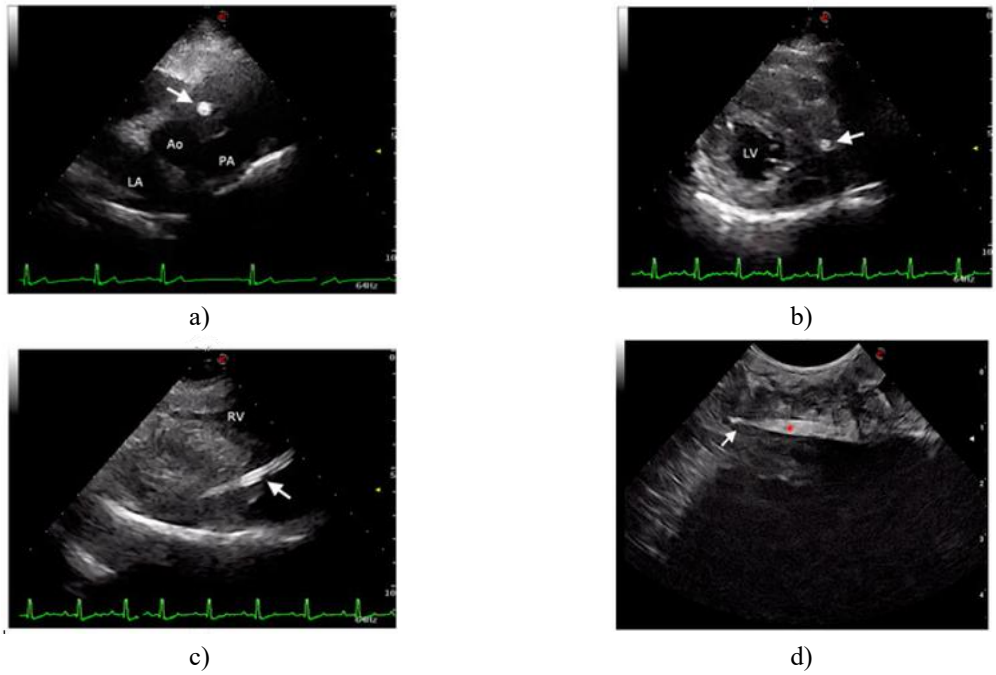


Figure 2. Ultrasonographic detection of the quill within myocardial tissue. (a) Right parasternal short-axis image at the heart base showing a circular bright focus (arrow). (b) Right parasternal short-axis image at the left ventricle showing a similar bright circular form (arrow) with distal shadowing. (c) Modified right parasternal long-axis view optimized to follow the object along its full length (arrow). (d) Intraoperative ultrasound illustrating the quill tip (arrow) and the red asterisk marking its location. Ao, aorta; PA, pulmonary artery; LA, left atrium; LV, left ventricle; RV, right ventricle; e, orientation symbol.

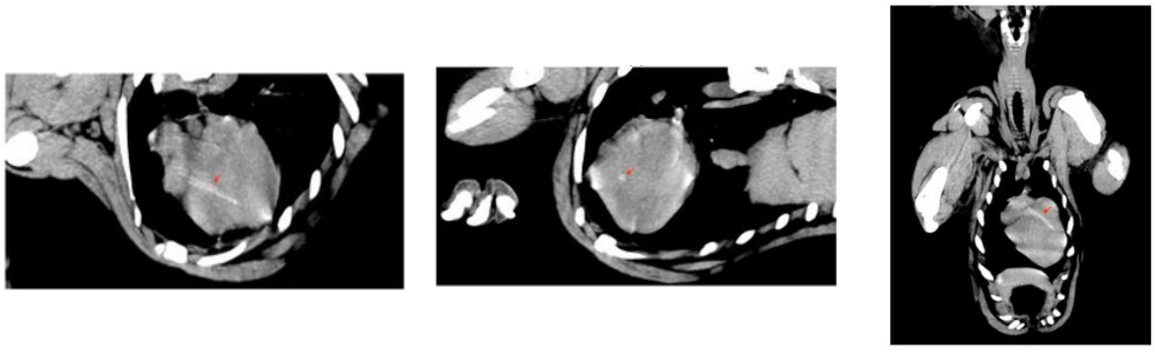


Figure 3. CT multiplanar reconstructions highlighting the elongated, tapered foreign body of moderate density inside the heart (red arrow). (a) Oblique cardiac reconstruction revealing the object's total length and its pointed end close to the outer cardiac surface. The three-layered appearance suggested a hollow medullary space, which was confirmed on the para-axial view (b) showing a ring-shaped profile. (c) Dorsal reconstruction localized the object across most of the interventricular septum's thickness.

An esophageal endoscopic inspection was conducted to check for internal migration. The mucosa and anatomic structures appeared completely normal. During anesthesia for the same procedure, transesophageal echocardiography verified the transthoracic findings **(Figure 4)**. Based on these results, an intracardiac foreign object—compatible with a migrating quill—was diagnosed, passing through the septum without breaching cardiac chambers. Surgical retrieval was therefore advised.

a) b)

Figure 4. Transesophageal echocardiographic visualization of the porcupine quill embedded in the heart. (a) Image of the cardiac base showing a circular bright lesion (arrow). (b) View including the left cardiac chambers and aorta, where the quill appears lengthwise (arrows). Ao, aorta; LA, left atrium; LV, left ventricle; e, orientation marker.

Surgical procedure and postoperative progress

Upon receiving written approval from the owner, the dog was anesthetized under a conventional clinical regimen. The animal was deprived of food for 12 hours but allowed unrestricted water intake. Sedation was initiated with methadone (0.2 mg/kg IV; Semfortan, Dechra Pharmaceutics, Northwich, UK). After approximately ten minutes, anesthesia induction was achieved using propofol (4 mg/kg IV; PropoVet, Zoetis Italia S.r.l., Rome, Italy) together with midazolam (0.2 mg/kg IV; Midazolam Accord Healthcare, Accord Healthcare Italia S.r.l., Milan, Italy) via a sterilely inserted cephalic catheter. Following intubation, the patient was connected to a rebreathing circuit with an oxygen flow rate of 50 mL/kg and maintained with isoflurane (1.2–2.0%; Isoflo, Zoetis Italia S.r.l., Rome, Italy) in 100% oxygen, with mechanical ventilation throughout the procedure. A constant infusion of lactated Ringer's solution (10 mL/kg/h) was provided during anesthesia.

Meloxicam (0.2 mg/kg SC; Metacam, Boehringer Ingelheim Italia S.p.a., Milan, Italy) and cefazolin (30 mg/kg IV; Cefazolina Teva, Teva Italia S.r.l., Assago, Italy) were administered at least two hours before incision. After aseptic preparation of the surgical site, a ventral midline sternotomy was carried out. Real-time echocardiographic imaging was used intraoperatively to locate and confirm the position of the intramyocardial object traversing the interventricular septum. The pericardial surface appeared unremarkable. A limited pericardiectomy (approximately 4 × 4 cm) was performed to improve visualization of the left ventricular area. A slightly raised, circular prominence was evident near the apex of the left ventricle, though the foreign object itself was not externally visible.

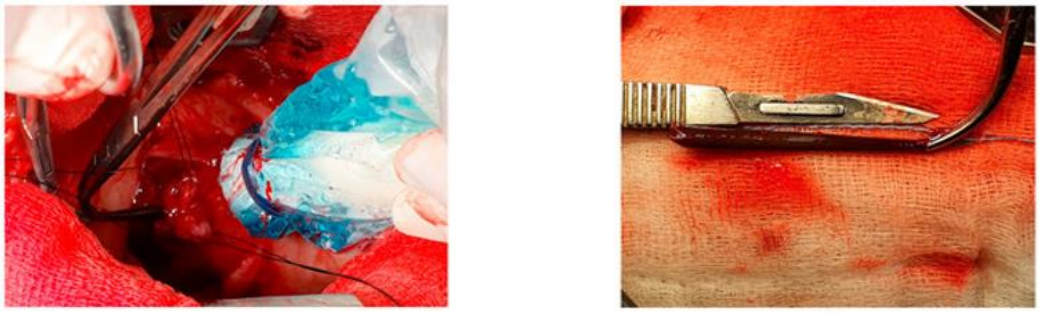
A sterilely covered ultrasound probe was positioned over the apex to provide continuous guidance. The quill and its distal point were identified, allowing precise localization. Around the region corresponding to the quill's tip (roughly 10 mm from the apex), a double horizontal mattress suture using 3-0 polypropylene was preplaced on the epicardial surface. Under direct sonographic guidance, an 8 mm incision (approximately 6 mm deep) was made in the ventricular wall using a No. 11 scalpel blade. Through this incision, a curved-tip hemostatic forceps was inserted, and the foreign body was carefully seized and gently withdrawn under ultrasound control **(Figure 5)**. No arrhythmias were recorded during extraction.

A sterile swab was collected from the cavity where the quill had been embedded, and the preplaced sutures were tightened to achieve hemostasis. Both the retrieved object and the swab were submitted for bacteriological evaluation under aerobic and anaerobic conditions. Intraoperative ultrasonography following removal confirmed that no fragments remained. The thoracic cavity was inspected to ensure the lung lobes were intact. Before closure, the area was rinsed with warm sterile saline and checked for any air leakage. A 12 French thoracostomy tube was introduced into the left thoracic cavity. Closure was performed using 18-gauge stainless steel wires around the sternebrae in an interrupted X-pattern. The pectoral muscles were closed with zero polydioxanone sutures in a

cruciate configuration, subcutaneous tissues with 3-0 polydioxanone in a simple continuous pattern, and the skin with 4-0 poliglecaprone in an intradermal continuous line.

The dog was successfully extubated 15 minutes after inhalant anesthesia was stopped and recovered without complications. The thoracostomy tube was withdrawn after 24 hours. Postoperative therapy included cefazolin (30 mg/kg IV every 12 h; Cefazolina Teva, Teva Italia S.r.l., Assago, Italy), lactated Ringer's infusion (2 mL/kg/h IV), and meloxicam (0.1 mg/kg SC every 24 h; Metacam, Boehringer Ingelheim Italia S.p.a., Noventana, Italy). Methadone (0.2 mg/kg IM every four h; Semfortan, Dechra Pharmaceutics, Northwich, UK) was used for analgesia.

After two days, culture results identified Pseudomonas aeruginosa resistant to amoxicillin but susceptible to amikacin, gentamicin, enrofloxacin, and marbofloxacin. Accordingly, antibiotic therapy was changed to enrofloxacin (5 mg/kg PO every 24 h for six weeks; Baytril Flavour, Elanco Italia S.p.a., Sesto Fiorentino, Italy). A few days later, infection of the sternal wound involving the pectoral muscles was observed. The lesion was treated by surgical curettage, culture sampling, and copious lavage. Two days afterward, preliminary results revealed Pseudomonas aeruginosa sensitive to clindamycin, amikacin, gentamicin, enrofloxacin, and marbofloxacin. Local amikacin (10 mg/kg; Amikacina Teva, Teva Italia S.r.l., Assago, Italy) injections were applied three times weekly. Healing progressed steadily, and the draining tract closed completely. The animal was discharged four weeks following surgery.



a) b)

Figure 5. Intraoperative view of porcupine quill extraction by midline sternotomy. (a) Quill removal using a curved hemostat under ultrasound monitoring via a small apical incision; (b) extracted quill following removal.

At the six-month evaluation, the dog had regained full functional ability and displayed no signs of recurrence or clinical abnormalities.

To the authors' best knowledge, this report represents the first documented clinical case in which an intramyocardial *Hystrix cristata* quill was identified using both ultrasonography and CT, and successfully extracted through intraoperative ultrasound guidance.

Porcupine quills are distinctive among migrating foreign objects because of their complex structure and their potential to affect multiple regions of the body. In dogs, they are most frequently detected in the head and cervical regions, followed by the limbs and thoracic areas [8]. When quills are not located during the initial evaluation, they tend to migrate deeper into tissues rather than outward due to their characteristic backward-pointing cuticles. These structures also make them highly irritant and prone to bacterial contamination, which can lead to local microtrauma and infection [4, 13, 17].

Detecting small porcupine quills using current imaging technology is often difficult [13, 18]. Techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography have all been employed for quill visualization with varying degrees of diagnostic precision [7, 9, 11, 15–18]. Quills are usually radiolucent and not apparent on standard X-rays [6]. Ultrasonographically, they appear as two bright, parallel linear echoes that converge at the tapered end, often accompanied by additional parallel reflective lines when the quill lies parallel to the transducer. When oriented transversely, they may resemble small blood vessels, presenting as tubular echogenic foci that may or may not display acoustic shadowing [6, 7, 11, 15]. Previous veterinary studies have shown ultrasound to be effective for detecting quills lodged in ocular structures, joints, and tendons [7, 15]. Transthoracic echocardiography, in particular, has proven to be an effective tool for identifying quills within or adjacent to the pericardial region [8, 9, 16].

CT imaging remains the preferred modality for thoracic evaluations since its rapid acquisition reduces motion artifacts and produces clear cross-sectional images down to 1 mm in detail [19]. However, motion, pneumothorax, atelectasis, and section thickness can complicate accurate quill detection and localization. Moreover, quills may show a density comparable to that of inflamed soft tissue [9]. On CT, they typically appear as hyperdense, elongated structures [11, 15]. Although MRI has been used to identify quills in certain canine cases [11, 14, 17], it offers lower spatial resolution than ultrasound or CT despite its superior tissue contrast. Furthermore, the signal intensity of quills can mimic hemorrhagic lesions, reducing diagnostic clarity.

In the current case, both transthoracic and transesophageal echocardiography clearly demonstrated the quill's presence and trajectory, while intraoperative ultrasonography provided real-time assistance during removal and verified complete extraction without residual fragments. CT further corroborated the sonographic results by identifying a single intramyocardial quill. MRI was not accessible at our facility.

Migration of other types of foreign bodies, including grass awns, metallic fragments, needles, skewers, and catheter remnants into cardiac tissue, has been previously reported in animals [20–24]. In this patient, it is presumed that the long quill initially entered through the right cervical recess near the base of the neck, penetrating the *pectoralis superficialis* and *brachiocephalicus* muscles. It likely advanced through the surrounding soft tissues into the thoracic cavity, passed along the cranial mediastinum, and eventually perforated the heart, avoiding the major vessels at its base. The quill then lodged within the interventricular septum without breaching the cardiac chambers or affecting the valvular system.

At present, there are no standardized guidelines for the treatment of long quills embedded in the myocardium in veterinary practice. Debate exists regarding the necessity of surgical extraction for small intracardiac foreign bodies—such as quills, needles, or projectiles—in both human and animal patients [13, 21, 22, 25, 26]. In human medicine, early surgery is often favored for acute injuries due to the risk of life-threatening complications. Removal is generally advocated for intrachamber objects because of their embolic potential, whereas intramyocardial fragments may be managed conservatively unless symptoms develop [22, 27].

Within veterinary literature, information regarding the optimal management of cardiac porcupine quill migration remains scarce. Previous reports describing exploratory pericardiotomy for quill retrieval in dogs are limited and involve only a few documented cases [9, 13, 16]. Notably, none of these accounts detail the use of ultrasound to guide removal from myocardial tissue. Some studies suggest exploratory thoracotomy—either lateral or median sternotomy—to assess the pericardium and extract visible quills [9, 13, 16]. However, performing such invasive procedures without precise localization of the foreign object poses risks and should be carefully considered.

In the present case, ultrasonography proved to be an essential diagnostic and intraoperative tool, providing precise localization of the intracardiac foreign body and ensuring its complete and safe extraction from the myocardium. Thoracoscopic evaluation and extraction of porcupine quills have previously been documented in human patients; however, postoperative complications due to continued quill migration were noted [28]. In the current case, a median sternotomy extending from the third sternebra to the xiphoid process was selected, allowing the use of ultrasonography to precisely locate the quill and its distal end. It is generally recommended to secure the quill at its tip rather than its base, as the barbed cuticle points backward. This surgical approach also provided a direct pulling trajectory, consistent with the quill's orientation along the longitudinal axis of the heart and interventricular septum. A left lateral thoracotomy would not have enabled such alignment, as the caudal rib would have hindered linear extraction. Safe retrieval of the quill depends on accurate ultrasonographic identification, which clarifies the orientation and insertion angle, ensuring controlled and correct extraction maneuvers. Because retained quills become more fragile and pliant over time, increasing their risk of fracture during removal [7], the quill must be withdrawn in one smooth, steady linear motion without changing the pulling angle to prevent breakage.

In this case, the quill was confined within the interventricular septum. In situations where a quill penetrates a cardiac chamber or valve, attempting removal without cardiopulmonary bypass could cause severe hemorrhage or systemic air embolism [29]. Bypass was unnecessary here because the quill did not breach the cardiac walls or valves but stayed embedded within the septal myocardium. A more invasive strategy, such as direct cardiac incision, could nonetheless be justified for safe extraction and repair of affected tissues [29]. Therefore, precise localization via CT and ultrasound is critical for surgical planning and ensuring complete, safe removal.

Initially, there were concerns that removal might be difficult due to deep embedding and potential closure complications of the myocardium. Fortunately, extraction was uncomplicated, requiring minimal force and

resulting in no fragmentation or retained pieces as confirmed by post-removal ultrasonography. Epicardial closure was achieved quickly using the same tension sutures already placed.

Interestingly, despite trans-thoracic migration, no pulmonary damage or air leakage was observed upon visual examination, indicating that none of the lung lobes were perforated.

A few days after surgery, the dog developed a surgical site infection (SSI) near the caudal end of the incision, within the pectoralis muscle area. Bacteriological culture identified Pseudomonas aeruginosa, consistent with that isolated from the quill and cardiac site. It is presumed that the infection spread along the sternum and pectoral pathway from the intracardiac quill site, leading to the SSI. P. aeruginosa is an opportunistic bacterium capable of causing multiple infections, particularly in immunocompromised hosts, and often displays broad antibiotic resistance, complicating therapeutic choices. In this case, prolonged treatment with enrofloxacin and locally infiltrated amikacin [30] effectively reduced infection and promoted wound healing.

Conclusion

Porcupine quill trauma occurs frequently in dogs, but intracardiac penetration and migration are extremely uncommon and often present with serious clinical manifestations. Diagnosing intracardiac quill migration in the absence of overt cardiac injury can be clinically challenging. Thus, accurate detection and localization using a multimodal imaging strategy are vital for planning a safe myocardial extraction. Additionally, intraoperative ultrasonography serves as an essential guidance tool during foreign body removal.

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References

1. Mori E, Maggini I, Menchetti M. When quills kill: The defense strategy of the crested porcupine Hystrix cristata L., 1758. Mammalia. 2014;78(2):229–34.
2. Chernova OF, Kuznetsov GV. Structural features of spines in some rodents (Rodentia: Myomorpha, Hystricomorpha). Biol Bull. 2001;28(4):371–82.
3. Cho WK, Ankruma JA, Guo D, Chester SA, Yang SY, Kashyap A, et al. Microstructured barbs on the North American porcupine quill enable easy tissue penetration and difficult removal. Proc Natl Acad Sci U S A. 2012;109(52):21289–94.
4. Costa A, Lahmers S, Barry SL, Stanton J, Stern JA. Fungal pericarditis and endocarditis secondary to porcupine quill migration in a dog. J Vet Cardiol. 2014;16(4):283–90.
5. Daoust PY. Porcupine quill in the brain of a dog. Vet Rec. 1991;128(18):436.
6. Grahn BH, Szentimery D, Pharr JW, Farrow CS, Fowler D. Ocular and orbital porcupine quills in the dog: A review and case series. Can Vet J. 1995;36(8):488–93.
7. Brisson B, Bersenas A, Etue S. Ultrasonographic diagnosis of septic arthritis secondary to porcupine quill migration in a dog. J Am Vet Med Assoc. 2004;224(9):1467–70.
8. Johnson MD, Magnusson KD, Shmon C, Waldner C. Porcupine quill injuries in dogs: A retrospective of 296 cases (1998–2002). Can Vet J. 2006;47(7):677–82.
9. Guevara JL, Holmes ES, Reetz J, Holt DH. Porcupine quill migration in the thoracic cavity of a German shorthaired pointer. J Am Anim Hosp Assoc. 2015;51(2):101–6.
10. Lamkin C, Hamner LR. An unusual cause of pericardial effusion. J Am Acad Physician Assist. 2016;29(4):32–4.
11. Le Roux C, Venter FJ, Kirberger RM. Cervical porcupine quill foreign body involving the spinal cord of a dog: A description of imaging findings. J S Afr Vet Assoc. 2017;88(1):e1–e7.

12. Shank AMM, Teixeira LBC, Dubielzig RR. Ocular porcupine quilling in dogs: Gross, clinical and histopathologic findings in 17 cases (1986–2018). Vet Ophthalmol. 2021;24(1):114–24.
13. Walker MA, Hoddinott KL, Ogilvie AT. Treatment and outcomes of five dogs with intrathoracic migration of porcupine quills. Vet Surg. 2022;51:in press.
14. Schneider AR, Chen AV, Tucker RL. Imaging diagnosis: Vertebral canal porcupine quill with presumptive secondary arachnoid diverticulum. Vet Radiol Ultrasound. 2010;51(2):152–4.
15. Sauvé CP, Sereda NC, Sereda CW. Identification of an intracranial intra-axial porcupine quill foreign body with computed tomography in a canine. Can Vet J. 2012;53(2):187–9.
16. Nucci DJS, Liptak J. Diagnosis and surgical management of intracardiac quill foreign body in a dog. J Am Anim Hosp Assoc. 2016;52(2):73–6.
17. Flesher K, Lam N, Donovan TA. Diagnosis and treatment of massive porcupine quill migration in a dog. Can Vet J. 2017;58(3):280–4.
18. Captanian N, Palma D. Limitation of CT in identifying intranasal porcupine quills in a dog. J Am Anim Hosp Assoc. 2019;55(5):e55404.
19. Tidwell AS, Jones JC. Advanced imaging concepts: A pictorial glossary of CT and MRI technology. Clin Tech Small Anim Pract. 1999;14(2):65–111.
20. Gentile JM, Bulmer BJ, Heaney AM, Bordelon S. Endovascular retrieval of embolized jugular catheter fragments using nitinol snare in dogs. J Vet Cardiol. 2008;10(2):81–5.
21. Crosara SS, Zabarino S, Morello E, Lussich S, Buracco P, Borgarelli M. Migration of a Kirschner wire to the heart in a Yorkshire terrier. J Small Anim Pract. 2008;49(3):100–2.
22. Elliott JM, Mayhew PD. Diagnostic challenges in a suspected pericardial metallic projectile foreign body. J Vet Emerg Crit Care. 2011;21(6):684–91.
23. Calvo I, Weilland L, Pratschk K. Traumatic myocardial laceration from suspected migration of a sewing needle. Aust Vet J. 2011;89(11):444–6.
24. Caivano D, Birettoni F, Marchesi MC, Moretti G, Corda A, Petrescu VF, et al. Septic pericarditis and cardiac tamponade caused by migrating grass awn in a dog. Isr J Vet Med. 2019;74(2):82–7.
25. Yang L, Wang J, Wu W. Echocardiographic detection of intracardiac non-metallic foreign body with infective endocarditis. Eur Heart J. 2007;28(1):58.
26. Darmawan H. An unusual foreign body in the heart: Case report. Ann Thorac Cardiovasc Surg. 2018;24(4):205–7.
27. Robison RJ, Brown JW, Caldwell R, Stone KS, King H. Management of asymptomatic intracardiac missiles. J Trauma. 1988;28(9):1402–3.
28. McCarthy TC. Porcupine quill retrieval with thoracoscopy. Vet Med. 2004;99(1):15–6.
29. Sereda NC, Towl S, Maisenbacher HW 3rd, Bleweis MS, Levy JK, Byrne BJ, et al. Intracardiac foreign body in a dog. J Vet Cardiol. 2009;11(1):53–8.
30. Hunt GB, Bellenger CR, Allan GS, Malik R. Suspected cranial migration of sewing needles from the stomach of a dog. Vet Rec. 1991;128(14):329–30.