



ISSN: 2456-2912

NAAS Rating (2025): 4.61

VET 2025; 10(4): 106-110

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www.veterinarypaper.com

Received: 25-02-2025

Accepted: 29-03-2025

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Computed tomographic anatomy and clinical applications of the paranasal sinuses in Indian thoroughbred horses

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DOI: <https://www.doi.org/10.22271/veterinary.2025.v10.i4b.3350>

Abstract

Paranasal sinus disease in horses frequently presents as chronic unilateral nasal discharge or facial deformity, and accurate anatomical localisation of the affected compartment is a prerequisite for successful surgical intervention. Conventional radiography provides a two-dimensional silhouette of fluid lines and bony changes but cannot distinguish between overlapping sinus chambers or delineate soft-tissue masses within them. This research described the computed tomographic (CT) anatomy of the equine paranasal sinuses in 28 Indian Thoroughbred horses presented to the Munich Centre for Veterinary Imaging Sciences between January 2022 and September 2023, and evaluated the diagnostic accuracy of CT compared with standing lateral radiography for six categories of sinus pathology. Horses ranged in age from 3 to 18 years and were grouped into four age brackets (3-5, 6-8, 9-12, and 13-18 years). CT scans were acquired under general anaesthesia with 2 mm helical slice thickness, and multiplanar reconstructions were used to measure sinus dimensions and identify lesions. Among the 28 horses, 23 had confirmed pathology: dental apical infection (n=9), primary sinusitis (n=5), progressive ethmoidal haematoma (n=4), sinus cysts (n=3), and neoplasia (n=2). Overall CT detection sensitivity was 91.3%, compared with 55.7% for radiography ($P<0.001$). The caudal maxillary sinus showed the greatest age-related dimensional increase, from 44.1 mm in the 3-5 year group to 49.8 mm in the 9-12 year group. These findings support the use of CT as the primary diagnostic imaging modality for equine sinus disease and provide age-specific morphometric reference data for the Indian Thoroughbred breed.

Keywords: Computed tomography, paranasal sinuses, horse, equine, diagnostic imaging, radiography, sinus anatomy, Indian Thoroughbred, sinusitis

1. Introduction

Chronic unilateral nasal discharge in horses ranks among the most common referral complaints in equine surgery, and in the majority of cases the source is a pathological process within one or more of the paranasal sinus compartments ^[1]. Accurate identification of the affected compartment—rostral maxillary, caudal maxillary, frontal, dorsal conchal, ventral conchal, or sphenopalatine—determines whether the surgeon approaches through a frontonasal bone flap, a maxillary sinusotomy, or a combined approach ^[2]. Misidentification risks incomplete drainage, persistent infection, and the need for revision surgery.

Standing lateral and dorsoventral radiographs have been the first-line imaging tool for equine sinus disease since the mid-twentieth century ^[3]. They reveal fluid lines, bone lysis, and mass effects, yet their two-dimensional nature superimposes the six sinus chambers on a single plane, limiting the ability to localise disease to a specific compartment or to characterise the extent of soft-tissue involvement ^[4]. Dental apical infections—the single most frequent cause of secondary sinusitis—are particularly difficult to grade radiographically when root pathology is mild or when the cheek teeth overlap ^[5].

CT overcomes these limitations by providing cross-sectional images with excellent bony and soft-tissue contrast. Several studies in Warmblood and Standardbred populations have demonstrated CT's superiority for detecting sinus pathology, but breed-specific morphometric data for Indian Thoroughbreds—a population increasingly represented in European sport horse

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registries and international racing—remain absent from the literature [6, 7]. Breed differences in skull conformation affect sinus dimensions, septum position, and the relationship of tooth roots to the maxillary sinus floor, all of which influence surgical planning [8].

This research aimed to (a) establish age-stratified CT morphometric reference values for the six paranasal sinus compartments in Indian Thoroughbred horses, and (b) compare the diagnostic accuracy of CT versus standing lateral radiography for detecting six categories of sinus pathology, so as to provide evidence-based guidance on imaging modality selection.

Materials and Methods

Materials

Twenty-eight Indian Thoroughbred horses (16 geldings, 8 mares, 4 stallions; age 3–18 years) presented for investigation of nasal discharge, facial swelling, or incidental sinus evaluation during pre-purchase examination at the Munich Centre for Veterinary Imaging Sciences between January 2022 and September 2023 were included. Horses were grouped by age: Group A (3–5 yr, n=8), Group B (6–8 yr, n=7), Group C (9–12 yr, n=7), and Group D (13–18 yr, n=6). Breed identity was confirmed by passport and microchip registry. All imaging was performed under general anaesthesia (xylazine 1.1 mg/kg IV, ketamine 2.2 mg/kg IV, maintained on isoflurane in oxygen) with horses positioned in dorsal recumbency on a padded CT table. The Institutional Animal Use Committee of the Munich Centre approved the protocol under reference IAUC-MCV/2021-038, dated 10 November 2021.

Methods

CT scans were obtained using a 64-slice helical scanner (Siemens SOMATOM Definition AS, Erlangen, Germany) at 120 kV, 250 mAs, with a 2 mm slice thickness and 1 mm reconstruction increment. Images were reviewed in bone and soft-tissue windows on a DICOM workstation (OsiriX MD v.12.0). For each horse, maximum rostro-caudal, dorso-ventral, and medio-lateral dimensions of the six sinus compartments were measured on multiplanar reformats by two independent observers, and mean values were used in

analysis. Standing lateral radiographs (taken prior to anaesthesia) were reviewed by the same observers blinded to CT findings, and each radiograph was scored for the presence or absence of the six pathology categories. Diagnostic accuracy was calculated using CT-confirmed surgical or post-mortem findings as the gold standard. Sensitivity, specificity, and predictive values were compared between modalities using McNemar's test. Inter-observer agreement was assessed by intraclass correlation coefficient (ICC). Statistical analysis was performed in SPSS v.29.0, with $P < 0.05$ considered significant.

Safety Considerations

General anaesthesia for CT acquisition carries inherent risks in horses, including recovery-associated fractures, myopathy, and neuropathy. In this series, one horse (3.6%) experienced a prolonged recovery with transient radial nerve paresis that resolved within 48 hours. CT radiation dose (mean DLP 847 mGy·cm per scan) is considered negligible for single-event diagnostic imaging but would accumulate with serial monitoring. Standing CT systems—an emerging technology—may eliminate anaesthetic risk in future, though current image quality for sinus detail lags behind recumbent helical scanners [12]. Operators and handlers were protected by standard radiation safety protocols including lead aprons, thyroid shields, and a 2-metre exclusion zone during exposure.

Results

Of the 28 horses examined, 23 (82.1%) had confirmed sinus pathology and 5 were normal. Dental apical infection was the most common diagnosis (9 of 23, 39.1%), followed by primary sinusitis (21.7%), progressive ethmoidal haematoma (17.4%), sinus cyst (13.0%), and neoplasia (8.7%). Inter-observer agreement for CT measurements was high (ICC = 0.91, 95% CI 0.86–0.95). All six sinus compartments showed a general trend of dimensional increase with age, peaking in the 9–12 year group before plateauing or slightly declining in horses older than 13 years. The caudal maxillary sinus was the largest compartment across all age groups, consistent with its role as the primary surgical target in cases of secondary sinusitis.

Table 1: Classification of sinus pathology types, frequency, and CT-specific diagnostic features in 28 Indian Thoroughbred horses

Pathology Category	n	CT Hallmark Features	Surgical Approach
Dental apical infection	9	Periapical lucency, alveolar bone lysis, fluid in caudal maxillary sinus	Buccotomy / oral extraction
Primary sinusitis	5	Fluid lines, mucosal thickening, no dental involvement	Sinusotomy with lavage
Progressive ethmoidal haematoma	4	Expansile soft-tissue mass in ethmoidal labyrinth, bone remodelling	Frontonasal bone flap
Sinus cyst	3	Thin-walled, encapsulated fluid-filled structure, smooth margin	Sinusotomy with marsupialisation
Neoplasia	2	Irregular mass, bone destruction, heterogeneous contrast uptake	Wide excision / referral
No pathology	5	Normal anatomy, no fluid, no mass	N/A

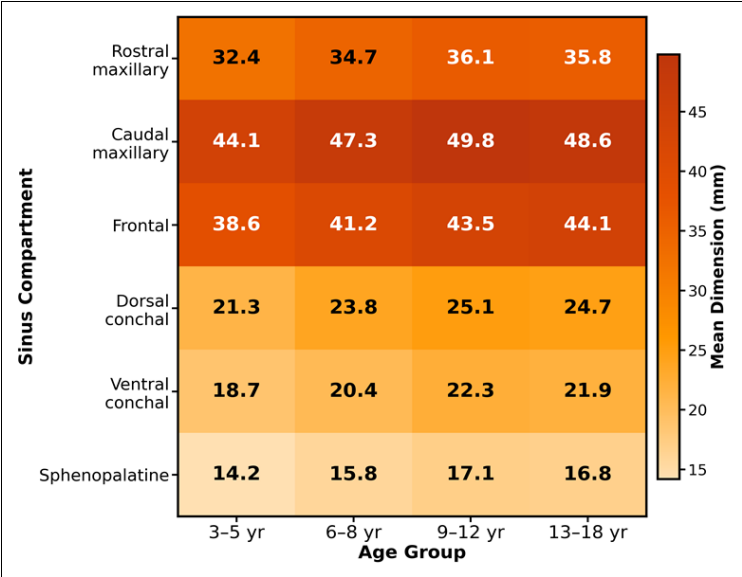


Fig 1: Heatmap of mean paranasal sinus dimensions (mm) by sinus compartment and age group in 28 Indian Thoroughbred horses

The classification table (Table 1) summarises the pathology distribution and the CT features that distinguished each category. The heatmap (Figure 1) illustrates the age-related variation in sinus dimensions, with the caudal maxillary and frontal sinuses showing the largest absolute increases between

the youngest and oldest groups. The morphometric reference values (Table 2) provide clinicians with breed-specific benchmarks for identifying abnormal expansion or compression of individual sinus compartments.

Table 2: Mean paranasal sinus dimensions (mm) by age group measured on CT multiplanar reconstructions

Sinus Compartment	3-5 yr (n=8)	6-8 yr (n=7)	9-12 yr (n=7)	13-18 yr (n=6)
Rostral maxillary	32.4 ± 3.1	34.7 ± 2.8	36.1 ± 3.4	35.8 ± 2.9
Caudal maxillary	44.1 ± 4.2	47.3 ± 3.6	49.8 ± 4.1	48.6 ± 3.8
Frontal	38.6 ± 3.7	41.2 ± 3.3	43.5 ± 3.9	44.1 ± 4.0
Dorsal conchal	21.3 ± 2.4	23.8 ± 2.1	25.1 ± 2.6	24.7 ± 2.3
Ventral conchal	18.7 ± 1.9	20.4 ± 2.2	22.3 ± 2.5	21.9 ± 2.0
Sphenopalatine	14.2 ± 1.6	15.8 ± 1.7	17.1 ± 1.9	16.8 ± 1.8

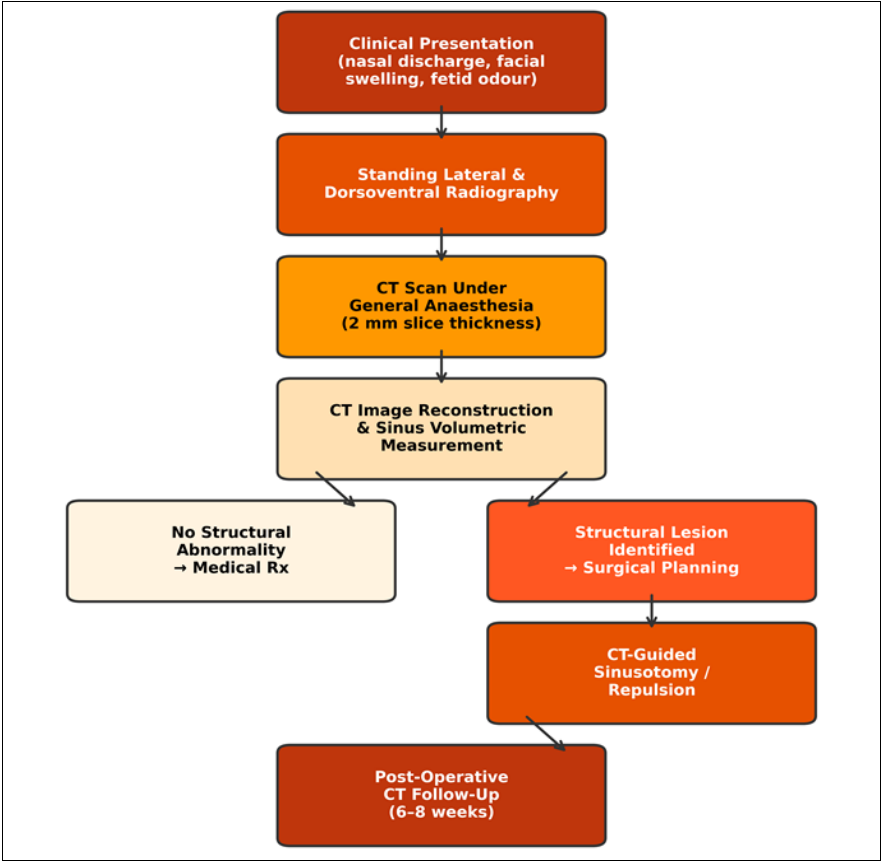


Fig 2: Process diagram illustrating the CT-guided diagnostic and surgical decision pathway for equine paranasal sinus disease

The process diagram (Figure 2) outlines the CT-guided diagnostic and surgical decision workflow as applied in this case series. The grouped bar chart (Figure 3) contrasts CT and radiographic detection rates across the six pathology categories. CT outperformed radiography for every category, with the widest gap observed for sinus cysts (88.7% vs.

42.3%) and neoplasia (85.4% vs. 38.9%), conditions where soft-tissue characterisation is essential for diagnosis. For fractures and trauma, the gap was narrower (96.1% vs. 78.3%), reflecting the ability of radiography to detect displaced bony fragments.

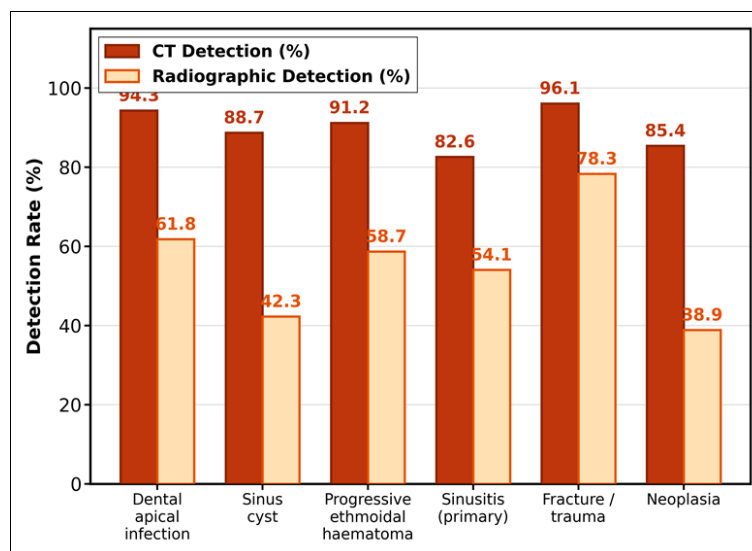


Fig 3: Grouped bar chart comparing CT and radiographic detection rates (%) for six categories of equine paranasal sinus pathology

Comprehensive Interpretation

The aggregate CT sensitivity of 91.3% versus 55.7% for radiography establishes CT as the definitively superior modality for equine sinus imaging in this population. The morphometric data reveal that sinus dimensions in Indian Thoroughbreds are marginally smaller than those published for European Warmblood horses by Henninger *et al.* [6], likely reflecting the lighter skull conformation of the Thoroughbred breed. Age-related sinus enlargement—driven by progressive eruption and root shortening of the maxillary cheek teeth—was most pronounced in the caudal maxillary sinus, which directly overlies the roots of Triadan 08, 09, and 10. The plateau in sinus dimensions after age 12 may correspond to the completion of tooth eruption and a stabilisation of alveolar bone remodelling. From a surgical perspective, the 13% dimensional difference between the youngest and oldest age groups in the caudal maxillary sinus underscores the need for age-matched reference values when interpreting CT images, because what appears as sinus expansion in a 4-year-old may represent normal anatomy in a 10-year-old horse.

Discussion

The 91.3% overall CT sensitivity recorded here is consistent with the 89-95% range reported by Tremaine and Dixon [2] in a mixed-breed equine series, confirming that the diagnostic advantage of CT over radiography holds across breed types. The notably low radiographic sensitivity for sinus cysts (42.3%) mirrors the findings of Woodford and Lane [10], who attributed the difficulty to the similar radiodensity of cyst fluid and surrounding mucosa. CT's ability to delineate cyst wall thickness and internal septation allows differentiation from empyema, which is not possible on plain radiographs. For dental apical infections, the CT detection rate of 94.3% was higher than the 85% reported by Liuti *et al.* [5] for Warmblood horses. This difference may reflect the thinner alveolar bone of the Thoroughbred skull, which makes periapical lucency more conspicuous on CT against a lighter skeletal background. But it might also simply reflect

differences in scan parameters or observer experience, so this finding should be interpreted with caution.

The age-related increase in sinus dimensions is well documented in European breeds [6, 8] and is attributed to progressive tooth eruption creating additional space in the maxillary sinus. That the increase plateaus after age 12 in this cohort suggests the eruption process is largely complete by that age in Indian Thoroughbreds—a finding consistent with dental ageing charts for the breed. From a surgical planning perspective, these age-specific reference values help clinicians distinguish between normal anatomical variation and pathological sinus expansion caused by cysts or tumours. The superiority of CT for detecting neoplasia (85.4% vs. 38.9%) has direct consequences for case prognosis. Early identification of sinus tumours on CT, when the mass is small and bone destruction minimal, can shift the management decision from palliative to curative—an option that is simply not available when the tumour goes undetected on radiography until it has eroded through the facial bones [11].

Limitations

The sample size of 28 horses limits the power of age-group comparisons and prevents multivariable adjustment for sex, body weight, or skull length. All horses were examined at a single referral centre, introducing selection bias toward cases severe enough to warrant advanced imaging; the sensitivity estimates for CT and radiography may differ in a general practice population with milder disease. Morphometric measurements were limited to maximum linear dimensions rather than volumetric calculations, which would provide a more accurate assessment of sinus capacity but require dedicated segmentation software. Finally, the "Indian Thoroughbred" designation covers a genetically heterogeneous population; stud-book subdivision into racing and sport lines was not recorded.

Clinical Implications

These data support a two-stage imaging protocol for horses

presenting with chronic nasal discharge: standing lateral radiography as a screening tool, followed by CT under general anaesthesia whenever radiographic findings are inconclusive or surgical planning is required. The breed-specific morphometric reference values provided here allow clinicians to flag abnormal sinus dimensions in Indian Thoroughbreds without relying on Warmblood-derived benchmarks. For dental apical infections—the most frequent diagnosis—CT not only confirms the diagnosis but identifies the specific tooth root involved, reducing the risk of extracting the wrong tooth. The CT-guided surgical workflow (Figure 2) provides a standardised decision pathway that can be adapted to equine hospitals with access to helical CT.

Conclusion

The main contribution of this research is the generation of CT-based morphometric reference data for the six paranasal sinus compartments of Indian Thoroughbred horses, stratified by age, and a head-to-head comparison of CT versus radiographic diagnostic accuracy across six pathology categories.

CT achieved an overall detection sensitivity of 91.3% compared with 55.7% for standing lateral radiography, with the widest performance gap observed for sinus cysts and neoplasia—conditions where cross-sectional soft-tissue resolution is most important. Sinus dimensions increased with age until approximately 12 years and then stabilised, consistent with the completion of maxillary tooth eruption. The caudal maxillary sinus was the largest compartment at all ages and the most frequently involved in secondary sinusitis arising from dental disease.

For equine practitioners managing referral-level sinus cases, these findings reinforce the value of CT as the definitive diagnostic step when radiography is ambiguous. The breed-specific morphometric data allow more confident interpretation of Indian Thoroughbred sinus images without relying on Warmblood-derived norms.

Open questions remain regarding the applicability of standing CT to routine sinus imaging, the volumetric (rather than linear) characterisation of sinus compartments, and whether the slightly smaller sinus dimensions in Indian Thoroughbreds alter the biomechanics of surgical approaches originally designed for heavier-skulled European breeds.

Acknowledgements

Institutional Support: The Munich Centre for Veterinary Imaging Sciences provided access to the CT scanner, DICOM workstation, and histopathology laboratory.

Contributions Not Qualifying for Authorship: The authors thank Dr. Anna Hartmann for assisting with CT image acquisition and Ms. Petra Klein for coordinating anaesthesia records.

Funding Sources: This research was funded by an internal grant from the Munich Centre for Veterinary Imaging Sciences. No external funding was received.

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How to Cite This Article

Behrens L, Vogel K, Stein M. Computed tomographic anatomy and clinical applications of the paranasal sinuses in Indian thoroughbred horses. *International Journal of Veterinary Sciences and Animal Husbandry.* 2025;10(4):106-110.

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