

Universidade Estadual Paulista “Júlio de Mesquita Filho”
Faculdade de Medicina Veterinária e Zootecnia

**CARACTERIZAÇÃO IMAGINOLÓGICA DO ESQUELETO, TÓRAX
E ABDÔMEN EM PORQUINHO-DA-ÍNDIA (*Cavia porcellus*)**

MATHEUS SERRANO VASCONCELOS MONTEIRO

Botucatu, SP
2026

Universidade Estadual Paulista “Júlio de Mesquita Filho”
Faculdade de Medicina Veterinária e Zootecnia

**CARACTERIZAÇÃO IMAGINOLÓGICA DO ESQUELETO, TÓRAX
E ABDÔMEN EM PORQUINHO-DA-ÍNDIA (*Cavia porcellus*)**

Dissertação apresentada junto ao
Programa de Pós-graduação em
Biotecnologia Animal para obtenção do
título de Mestre.

Matheus Serrano Vasconcelos Monteiro
Orientadora: Prof.^a Titular Dra. Maria
Jaqueline Mamprim
Coorientadora: Dra. Jeana Pereira da
Silva.

Botucatu, SP
2026

M775c

Monteiro, Matheus Serrano Vasconcelos

CARACTERIZAÇÃO IMAGINOLÓGICA DO ESQUELETO, TÓRAX E
ABDÔMEN EM PORQUINHO-DA-ÍNDIA (*Cavia porcellus*) / Matheus Serrano
Vasconcelos Monteiro. – Botucatu, 2026

77 p. : tabs., fotos

Dissertação (mestrado) - Universidade Estadual Paulista (UNESP),
Faculdade de Medicina Veterinária e Zootecnia, Botucatu

Orientadora: Maria Jaqueline Mamprim

Coorientadora: Jeana Pereira da Silva

1. Anatomia comparada. 2. Cobaias. 3. Radiografia. 4. Tomografia. 5.
Ultrassonografia. I. Título.

Nome do autor: Matheus Serrano Vasconcelos Monteiro

Título: **CARACTERIZAÇÃO IMAGINOLÓGICA DO ESQUELETO, TÓRAX E ABDÔMEN EM PORQUINHO-DA-ÍNDIA (*Cavia porcellus*)**

BANCA EXAMINADORA

Profa. Dra. Maria Jaqueline Mamprim

Presidente e Orientadora

Departamento de Cirurgia Veterinária e Reprodução Animal

FMVZ - UNESP - Botucatu/SP

Prof. Dra. Sheila Canevese Rahal

Membro interno

Departamento de Cirurgia Veterinária e Reprodução Animal

FMVZ - UNESP - Botucatu/SP

Prof. Dra. Danuta Pulz Doiche

Membro interno

Departamento de Clínica e Cirurgia Veterinária

FCAV - UNESP - Jaboticabal/SP

Data da defesa: 29 de janeiro de 2026.

AGRADECIMENTOS

O presente trabalho foi realizado com o apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de Financiamento 001, com o apoio da Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), Brasil Processo nº 2023/16693-7 e apoio FINEP (Financiadora de Estudos e Projetos), convênio número 01.12.0530.00.

Agradeço à minha orientadora, professora Maria Jaqueline Mamprim, e à coorientadora Jeana Pereira da Silva. Obrigado pela oportunidade e pelo conhecimento compartilhado, que, sem ele, não seria possível a realização desse trabalho.

Aos meus pais, Virginia Serrano e Raimundo Monteiro, agradeço imensamente por todo o amor, apoio e por acreditarem em mim.

Também agradeço à minha família e amigos por todo o apoio, pela paciência e pelo entendimento nos meus momentos de ausência.

Felipe Suzuki, pela amizade, pelos conselhos e pelos incentivos nessa jornada.

Ricardo Shoiti, obrigado pela ajuda e pelo conhecimento fundamentais para a realização desse trabalho.

Ao Ricardo Camargo e à equipe do Centro Diagnóstico Veterinário - Cedivet de Rio Claro, pela oportunidade e pelo apoio na realização dos exames.

As professoras Sheila Canevese Rahal e Luciane Reis Mesquita, pelas sugestões e pelos conhecimentos fundamentais durante o exame de qualificação.

Também agradeço a todos os professores e profissionais que encontrei ao longo da minha jornada na medicina veterinária. Sem todas as lições e aprendizados que passei até aqui, não seria o mesmo profissional.

"Quem nunca cometeu um erro nunca tentou nada novo."

Albert Einstein

RESUMO

MONTEIRO, M.S.V. **CARACTERIZAÇÃO IMAGINOLÓGICA DO ESQUELETO, TÓRAX E ABDÔMEN EM PORQUINHO-DA-ÍNDIA (*Cavia porcellus*)**. Botucatu – SP. 2026. 77p. Defesa (Mestrado em Biotecnologia Animal) – Faculdade de Medicina Veterinária e Zootecnia, Campus de Botucatu, Universidade Estadual Paulista.

O presente estudo teve como objetivo caracterizar, por meio de métodos de diagnóstico por imagem, as principais estruturas do crânio, tórax, abdômen, bem como membros torácicos e pélvicos de porquinhos-da-índia (*Cavia porcellus*) adultos hígidos. Foram utilizados cinco animais, machos adultos, clinicamente saudáveis, com massa corpórea média de 750 g, submetidos a jejum alimentar de quatro horas e a sedação única para exames de radiografia e tomografia computadorizada. Esses exames permitiram avaliar as estruturas ósseas do esqueleto axial e apendicular, evidenciando no crânio arcos zigomáticos, processo angular da mandíbula, bulas timpânicas e cavidades nasais estreitas, com septo bem definido, e a ausência de seios frontais e esfenoidais. Na coluna vertebral, foram identificadas as vértebras e suas estruturas, bem como o alinhamento e os espaços intervertebrais. Nos membros torácicos e pélvicos, as estruturas ósseas foram caracterizadas por meio de tomografia computadorizada, com o objetivo de obter maior detalhamento das articulações. No tórax, foi possível observar coração globoso e centralizado, ocupando aproximadamente três espaços intercostais, e pulmões simétricos, delimitados lateralmente e dorsalmente. A tomografia permitiu a diferenciação dos grandes vasos, das cruras diafragmáticas e dos trajetos traqueobrônquicos. Na cavidade abdominal, foi realizado o exame ultrassonográfico, no qual, foram identificados fígado, vesícula biliar, baço, rins, glândulas adrenais, pâncreas, bexiga, trato gastrointestinal e estruturas do sistema reprodutor. As características ecográficas observadas foram compatíveis com as descritas para pequenos mamíferos, apresentando variações relacionadas à disposição anatômica e ecogenicidade relativa dos órgãos. Os achados deste estudo fornecem um atlas por imagem de *Cavia porcellus*, estabelecendo parâmetros de referência de normalidade para a interpretação radiográfica, ultrassonográfica e tomográfica de forma a contribuir para o aprimoramento do diagnóstico por imagem em pequenos mamíferos.

Palavras-chave: anatomia comparada; cobaia; radiografia; tomografia computadorizada; ultrassonografia

ABSTRACT

MONTEIRO, M.S.V. **IMAGING CHARACTERIZATION OF THE SKELETAL, THORACIC, AND ABDOMINAL ANATOMY OF GUINEA PIGS (*Cavia porcellus*)**. Botucatu – SP. 2026. 77p. Defesa (Mestrado em Biotecnologia Animal) – Faculdade de Medicina Veterinária e Zootecnia, Campus de Botucatu, Universidade Estadual Paulista.

The present study aimed to characterize, using diagnostic imaging methods, the main structures of the skull, thorax, and abdomen, as well as the thoracic and pelvic limbs, in healthy adult guinea pigs (*Cavia porcellus*). Five healthy adult male animals, with a mean body weight of 750 g, were subjected to a four-hour fast and to single sedation for radiographic and computed tomographic examinations. These exams allowed the evaluation of the bony structures of the axial and appendicular skeleton, revealing in the skull the zygomatic arches, the angular process of the mandible, tympanic bullae, and narrow nasal cavities with a well-defined septum, as well as the absence of frontal and sphenoidal sinuses. In the vertebral column, the vertebrae and their structures were identified, along with the alignment and intervertebral spaces. In the thoracic and pelvic limbs, the bony structures were characterized using computed tomography to obtain greater detail of the joints. In the thorax, a rounded and centralized heart occupying approximately three intercostal spaces and symmetrical lungs, delimited laterally and dorsally, were observed. Tomography enabled differentiation of the great vessels, diaphragmatic crura, and tracheobronchial pathways. In the abdominal cavity, an ultrasonographic examination was performed, in which the liver, gallbladder, spleen, kidneys, adrenal glands, pancreas, urinary bladder, gastrointestinal tract, and reproductive system structures were identified. The observed echographic characteristics were compatible with those described for small mammals, presenting variations related to the anatomical disposition and relative echogenicity of the organs. The findings of this study led to the development of an imaging-based anatomical atlas of *Cavia porcellus*, establishing reference parameters for normality in radiographic, ultrasonographic, and tomographic interpretation, thereby advancing diagnostic imaging in small mammals.

Keywords: Computed Tomography; Domestic Cavy; Radiography; Ultrasonography; Veterinary Anatomy

Sumário

CAPÍTULO 1	1
1. INTRODUÇÃO E JUSTIFICATIVA	2
2. REVISÃO DA LITERATURA.....	3
2.1 Porquinho-da-Índia	3
2.2 Anatomia.....	3
2.3. Exames de imagem.....	7
3. REFERÊNCIAS	10
CAPÍTULO 2	32
ABSTRACT.....	16
1. INTRODUCTION	17
2. MATERIALS AND METHODS	18
2.1 Animals and Ethical Considerations.....	18
2.2 Anesthetic Protocol.....	18
2.3 Radiography	18
2.4 Computed Tomography.....	19
2.5 Imaging Analysis.....	19
3. RESULTS	19
4. DISCUSSION.....	35
5. CONCLUSION	39
6. REFERENCES	40
CAPÍTULO 3	42
ABSTRACT.....	44
1. INTRODUCTION	45
2. MATERIAL AND METHODS.....	46
2.1 Animals and Ethical Considerations.....	46
2.2 Anesthetic Protocol.....	46
2.3 Image Acquisition	47
3. RESULTS	48
4. DISCUSSION	51
5. CONCLUSION.....	53
6. REFERENCES	54
CAPÍTULO 4	56

ABSTRACT	58
1. INTRODUCTION	59
2. MATERIALS AND METHODS	59
2.1 Animals and Ethical Considerations	59
2.2 Ultrasonographic examination	60
2.3 Scanning Protocol and Image Evaluation	60
2.4 Statistical analysis	61
3. RESULTS	61
4. DISCUSSION	70
5. CONCLUSION	74
6. REFERENCES	74

CAPÍTULO 1

1. INTRODUÇÃO E JUSTIFICATIVA

Nos últimos 10 anos, houve um aumento na aquisição de pequenos mamíferos, como porquinhos-da-índia e chinchilas, como pets exóticos. Assim, faz-se necessário maior conhecimento sobre estas espécies e sobre os dados de seus exames auxiliares, a fim de fornecer diagnósticos mais assertivos e precisos.

Os exames complementares de imagem desempenham papel crucial na medicina veterinária moderna, possibilitando uma avaliação detalhada e não invasiva das estruturas internas dos animais, considerados fundamentais para a detecção precoce de doenças, permitindo diagnósticos precisos, a elaboração de planos de tratamento e o planejamento cirúrgico (Quesenberry et al., 2020). Entre as técnicas, destacam-se a radiografia, a ultrassonografia e a tomografia computadorizada, que complementam o exame clínico, permitem a detecção de afecções e oferecem informações importantes sobre a anatomia e a fisiologia dos animais (Krautwald-Junghanns et al., 2011).

A radiografia é utilizada como exame de triagem devido à sua praticidade e acessibilidade, permitindo uma avaliação complementar do exame clínico inicial (Thrall, 2015). No entanto, as limitações da técnica, como a exposição à radiação, a resolução e a sobreposição de estruturas, podem dificultar a interpretação detalhada (Krautwald-Junghanns et al., 2011).

A ultrassonografia, por sua vez, permite uma análise dinâmica e em tempo real dos órgãos internos, especialmente útil para o exame do abdômen, permitindo a avaliação de tecidos moles sem a necessidade de sedação e exposição à radiação, embora esteja sujeito à presença de muitos artefatos (Quesenberry et al., 2020).

A tomografia computadorizada é utilizada na imagem veterinária para fins diagnósticos e estudos anatômicos, permitindo uma análise detalhada das estruturas e órgãos de interesse de forma rápida e com diagnóstico preciso de múltiplas afecções (Schwarz e Saunders, 2011). Esta técnica é indicada para a avaliação de doenças complexas e não elucidadas por outros exames complementares, tendo como seus principais limitantes a exposição à radiação, a necessidade de sedação e o custo (Krautwald-Junghanns et al., 2011).

Desta forma, a justificativa do projeto baseia-se na limitada disponibilidade de material científico que auxilie os laudos de exames de imagem em porquinhos-da-índia.

2. REVISÃO DA LITERATURA

2.1 Porquinho-da-Índia

Os porquinhos-da-índia se destacam por seu tamanho reduzido, comportamento dócil e manejo simples, os quais pertencem à família Caviidae, da ordem Rodentia (Teixeira, 2014). Esses animais apresentam massa corpórea entre 700 e 1200 gramas, com expectativa de vida de 2 a 8 anos (Hargaden e Singer, 2012). Além de sua popularidade como pets exóticos, são amplamente utilizados como modelos experimentais na pesquisa (Quesenberry et. al., 2020). Diante desse contexto, torna-se imprescindível que a medicina veterinária aprofunde seus conhecimentos sobre a biologia, as particularidades clínicas e as doenças que acometem essa espécie, bem como sobre os métodos diagnósticos que favorecem uma abordagem clínica mais precisa e eficaz (Krautwald-Junghanns et al., 2011).

2.2 Anatomia

2.2.1 Crânio

As principais estruturas do crânio dos porquinhos-da-índia incluem a cavidade craniana, a mandíbula, a maxila, o palato e os arcos zigomáticos, que são proeminentes e completos (Clemons e Seeman, 2011). A boca apresenta formato triangular e estreito, sendo composta pela maxila, palato e mandíbula, sendo esta última a maior estrutura óssea do crânio (Hargaden e Singer, 2012).

A fórmula dentária desses animais compreende 20 dentes, distribuídos da seguinte forma: incisivos 1/1, caninos 0/0, pré-molares 1/1 e molares 3/3 (Hargaden e Singer, 2012). Os porquinhos-da-índia são animais monofiodontes, ou seja, possuem apenas uma dentição ao longo da vida (Teixeira, 2014). Os pré-molares e molares inferiores têm o ponto de oclusão voltado medialmente em relação ao centro da cavidade oral, e seu crescimento excessivo, sendo uma afecção comum nessa espécie, pode levar ao aprisionamento da língua, sendo esses dentes os mais frequentemente acometidos (Quesenberry et. al., 2020).

2.2.2 Coluna vertebral

A coluna vertebral dos porquinhos-da-índia possui de 31 a 36 vértebras, sendo sete vértebras cervicais, 13 a 14 vértebras torácicas, seis vértebras lombares, três a quatro vértebras sacrais fusionadas e de quatro a seis vértebras caudais (Clemons e Seeman, 2011).

No segmento torácico, apresenta-se um par de costelas simétrico para cada vértebra torácica, com os seis primeiros pares articulando-se ao esterno, que, por sua vez, é formado pelo pré esterno, três esternébras, o manúbrio e o processo xifoide (Hargaden e Singer, 2012).

2.2.3 Tórax

A traqueia desses animais está localizada medialmente à laringe, desviando-se discretamente para a direita ao longo de seu trajeto até a bifurcação (Zehtabvar et al., 2023). É composta por 35 a 40 anéis cartilagosos incompletos, conectados dorsalmente por ligamentos anulares (Hargaden e Singer, 2012). Os brônquios primários originam-se na altura da terceira costela, sendo o brônquio esquerdo mais longo e estreito do que o direito (Zehtabvar et al., 2023).

Nos porquinhos-da-índia, o pulmão direito é dividido em quatro lobos: cranial, médio, caudal e acessório (Teixeira, 2014). De acordo com Zehtabvar et al. (2023), o lobo cranial é o menor lobo pulmonar direito, apresentando uma impressão côncava em sua face medial, em contato com o coração enquanto o lobo caudal apresenta contorno côncavo em sua porção posterior, devido ao contato com a superfície diafragmática, ao passo que o lobo acessório tem formato irregular, moldado pelas estruturas adjacentes.

O pulmão esquerdo destes animais é composto por três lobos: cranial, médio e caudal (Teixeira, 2014). Como descrito por Zehtabvar et al. (2023), o lobo cranial divide-se em duas porções: uma cranial menor e uma caudal maior, enquanto o lobo médio, menor entre os lobos esquerdos, apresenta discreta irregularidade devido ao contato com o esôfago em sua face medial e com o diafragma caudalmente, e por fim, o lobo caudal, por sua vez, apresenta concavidade caudal também em razão da interface com o diafragma.

Conforme Hargaden e Singer (2012), o coração dos porquinhos-da-índia é composto por quatro câmaras e está envolvido por um pericárdio seroso de dupla camada, localizado na linha média torácica, entre os lobos pulmonares,

com os átrios são separados dos ventrículos pelos sulcos coronários, que abrigam os vasos coronários, e são divididos entre si pelo septo interatrial.

2.2.4 Abdômen

O fígado dos porquinhos-da-índia está localizado na porção cranial da cavidade abdominal, em íntimo contato com o diafragma no qual é composto por seis lobos: lateral direito, medial direito, lateral esquerdo, medial esquerdo, caudado e quadrado (O'Malley, 2005). A vesícula biliar apresenta formato oval, paredes finas e localiza-se na fossa do lobo quadrado. Sua drenagem ocorre por meio do ducto cístico, que se une ao ducto hepático para formar o ducto biliar comum, que desemboca no duodeno (Hargaden e Singer, 2012).

Os porquinhos-da-índia apresentam um pâncreas compacto, de aspecto lobulado, dividido em três porções: lobo direito (ou duodenal), corpo e lobo esquerdo (ou esplênico) (Al-Saffar e Nasif, 2020).

O baço dos porquinhos-da-índia está localizado no aspecto cranioventral esquerdo da cavidade abdominal (Teixeira, 2014). O baço, curto e ovóide, recoberto uma túnica serosa transparente, encontra-se conectado à curvatura maior do estômago por meio do ligamento gastroesplênico, enquanto sua face cranial se liga ao diafragma pelo ligamento frênicoesplênico (Hargaden e Singer, 2012).

O porquinho-da-índia é um animal monogástrico, e seu estômago está localizado na região cranial esquerda da cavidade abdominal, sendo dividido em cárdia, fundo, corpo e piloro (Teixeira, 2014). Conforme descrito por Keeble e Heggie (2012), intestino delgado é composto por duodeno, jejuno e íleo, embora não existam estruturas anatômicas visíveis que delimitem essas porções com precisão e com o intestino grosso dividido em ceco e cólon, no qual o ceco armazena grande parte do conteúdo gastrointestinal e ocupa uma porção significativa da face ventral da cavidade abdominal e o cólon é subdividido, com base em sua disposição anatômica, em cólon ascendente, transverso e descendente, sendo continuado pelo reto.

Os rins dos porquinhos-da-índia estão localizados na região retroperitoneal, com o rim direito discretamente mais cranial do que o esquerdo, ambos têm formato de feijão, embora o rim esquerdo apresente uma conformação menos arredondada na porção medial, e os ureteres drenem diretamente para a vesícula urinária (Yousif e Rabee, 2019). A bexiga urinária

1 apresenta formato piriforme e está localizada na região ventrocaudal da
2 cavidade abdominal e, quando vazia, encontra-se inteiramente na cavidade
3 pélvica (Hargaden e Singer, 2012). Diferentemente de outros mamíferos, os
4 porquinhos-da-índia não possuem trígono vesical (Yousif e Rabee, 2019).

5 As glândulas adrenais desses animais têm formato de feijão e estão
6 localizadas medialmente à margem cranial de seu respectivo rim (Sheikhian et
7 al., 2019). Elas são divididas em zona cortical externa e zona medular interna
8 (Sheikhian et al., 2019).

9 De acordo com Hargaden e Singer (2012), o sistema reprodutor
10 masculino dos porquinhos-da-índia apresenta testículos extra-abdominais,
11 simétricos, localizados na bolsa escrotal na região perineal e dispostos
12 lateralmente em relação à abertura uretral; anteriormente a eles há uma estrutura
13 adiposa que mantém o canal inguinal aberto, permitindo a retração testicular
14 para a cavidade abdominal quando necessário. As glândulas acessórias incluem
15 vesículas seminais, próstata, glândulas coagulantes e glândulas bulbouretrais,
16 sendo que as vesículas seminais têm formato alongado e situam-se
17 ventralmente aos ureteres (O'Malley, 2005).

18 **2.2.5 Membro torácico**

19 O membro torácico do porquinho-da-índia é composto por clavícula,
20 escápula, úmero, rádio, ulna, carpos, metacarpos e falanges, sendo as
21 clavículas vestigiais e conectadas lateralmente aos processos coracoides da
22 escápula (Silverman e Tell, 2005).

23 Cada membro possui quatro dedos, cada um composto por três
24 falanges, que podem ser divididas em proximal, média e distal, sendo a falange
25 distal arqueada (Witkowska et. al., 2014). Os coxins palmares são bem
26 desenvolvidos nas porções palmares sem pelos (Hargaden e Singer, 2012).

27 **2.2.6 Membro pélvico**

28 A pelve é composta pelo ílio, ísquio, púbis e acetábulo, que articula com
29 o fêmur para formar a articulação coxofemoral (Silverman e Tell, 2005).

30 O membro pélvico do porquinho-da-índia é composto por fêmur, tíbia,
31 fíbula, tarsos, metatarsos e falanges, sendo a tíbia e a fíbula separadas
32 (Silverman e Tell, 2005). Cada membro possui três dedos, cada um composto
33 por três falanges, que podem ser divididas em proximal, média e distal, e as
34 unhas são mais longas nos membros pélvicos (Witkowska et al., 2014). Os

coxins plantares são bem desenvolvidos nas porções plantares sem pelos, semelhantes ao membro torácico (Hargaden e Singer, 2012).

2.3. Exames de imagem

2.3.1 Radiografia

A radiografia é uma ferramenta diagnóstica amplamente utilizada na medicina veterinária por ser minimamente invasiva, de fácil acesso e relativamente de baixo custo utilizando a emissão de raios X que, ao atravessarem o corpo do animal, são absorvidos de forma diferenciada pelos tecidos, conforme sua densidade, gerando imagens em escala de cinza (Thrall, 2015). Essa modalidade permite a avaliação de estruturas ósseas e tecidos moles por meio das características observadas no exame radiográfico, no qual incluem localização, dimensões, radiodensidade, contraste e integridade das estruturas de interesse (Muhlbauer e Kneller, 2013; Thrall, 2015).

Para uma avaliação radiográfica fidedigna, são necessárias imagens de boa qualidade, no mínimo duas projeções ortogonais, além de um conhecimento anatômico adequado do paciente (Muhlbauer e Kneller, 2013; Thrall, 2015).

Em porquinhos-da-índia, o exame radiográfico é uma ferramenta essencial para triagem, definição diagnóstica e manejo eficaz de diversas enfermidades (Krautwald-Junghanns et al., 2011). Entre suas aplicações destacam-se: avaliação do sistema musculoesquelético em casos de traumatismo, análise do trato gastrointestinal em suspeitas de obstruções, investigação do sistema urinário para detecção de cálculos ou processos obstrutivos, diagnóstico de alterações pulmonares, além de sua importância em exame odontológicos e no acompanhamento gestacional (Riggs, 2009; Fetzer e Mans, 2017).

Por serem animais de pequeno porte e sensíveis ao estresse, é comum a realização de exames radiográficos de corpo inteiro em porquinhos-da-índia, com o objetivo de reduzir o tempo de contenção e evitar múltiplos reposicionamentos (Quesenberry et. al., 2020). A contenção física costuma ser suficiente, mas a sedação pode ser necessária em casos de dor, dificuldade de posicionamento ou quando se busca maior precisão nas imagens (Krautwald-Junghanns et al., 2011).

Krautwald-Junghanns et al. (2011) destacaram o valor da radiografia na caracterização da anatomia desses animais, permitindo a diferenciação de

estruturas torácicas e abdominais, mesmo com as limitações impostas pelo conteúdo gasoso intestinal. Eckert et al. (2019) relataram seu uso no diagnóstico da síndrome da dilatação gástrica com vólvulo, demonstrando que a radiografia pode ser determinante para a rápida identificação da condição e o planejamento terapêutico imediato. Além disso, Edell et al. (2022) utilizaram a radiografia como ferramenta auxiliar no diagnóstico de urolitíase, evidenciando sua aplicação em diversas afecções clínicas da espécie.

2.3.2 Ultrassonografia

A ultrassonografia diagnóstica é uma ferramenta essencial do diagnóstico por imagem, baseada na interação de ondas sonoras com tecidos vivos, permitindo a obtenção de imagens em tempo real com alta definição anatômica e funcional (Nyland et al., 2005). Essa técnica, amplamente aplicada em cães e gatos, também tem sido cada vez mais utilizada em pequenos mamíferos exóticos, como os porquinhos-da-índia, com adaptações específicas para sua fisiologia e anatomia (Krautwald-Junghauns, 2011).

As imagens ultrassonográficas são interpretadas com base na anatomia topográfica das estruturas avaliadas e na intensidade dos ecos gerados, classificados como ecogênicos, quando refletem intensamente as ondas sonoras, ou anecogênicos, quando não produzem ecos (Kealy e Mcallister, 2005). Durante o exame ultrassonográfico, avaliam-se aspectos como localização, tamanho, forma, ecotextura e ecogenicidade dos órgãos, utilizando-se principalmente os planos anatômicos longitudinal (ou sagital), transversal e dorsal (Pennick e D'anjou, 2015).

Uma das principais limitações da ultrassonografia abdominal em porquinhos-da-índia é a presença de conteúdo gasoso e ecogênico no trato gastrointestinal, especialmente no ceco, o que pode dificultar a visualização de estruturas profundas ou retroperitoneais (Krautwald-Junghauns, 2011). Ainda assim, a maioria dos órgãos abdominais pode ser avaliada com eficácia, incluindo bexiga, rins, adrenais, baço, fígado, vesícula biliar, pâncreas, intestino delgado e grosso, ovários, útero e glândulas seminais (Martin et al., 2023).

A utilização da ultrassonografia abdominal em porquinhos-da-índia tem se tornado uma prática comum na medicina veterinária, sendo empregada tanto para o diagnóstico de afecções quanto para o monitoramento clínico

(Quesenberry et al., 2020). Estudos realizados por Rosas-Navarro et al. (2023), Edell et al. (2022) e Azevedo (2024) demonstraram a eficácia da ultrassonografia abdominal e torácica na obtenção de informações relevantes para o manejo clínico desses animais.

2.3.3 Tomografia Computadorizada

Conforme Schwarz e Saunders (2011), a tomografia computadorizada permite uma avaliação multiplanar de órgãos e cavidades, possibilitando a detecção de diversas alterações por meio de reconstruções tridimensionais, as quais especialmente úteis no planejamento cirúrgico. A representação detalhada auxilia os médicos veterinários na visualização precisa das estruturas anatômicas, contribuindo para a identificação de variações morfológicas e doenças. As características avaliadas nos órgãos e estruturas durante a interpretação das imagens obtidas são a localização, dimensões, forma, textura interna, atenuação das estruturas e integridade das estruturas de administração de contraste intravenoso pode ser utilizada para análise do sistema circulatório e para auxiliar na detecção de processos inflamatórios ou neoplásicos (Schwarz e Saunders, 2011; Thrall, 2015).

Em porquinhos-da-índia, a tomografia computadorizada tem-se mostrado especialmente útil na avaliação de afecções dentárias, alterações ósseas cranianas e torácicas, bem como em investigações neurológicas, respiratórias e de massas abdominais por meio das imagens detalhadas obtidas no qual eliminam a sobreposição de estruturas, comum na radiografia, além de permitir reconstruções em múltiplos planos (Krautwald-Junghanns et al., 2011).

A técnica tem sido amplamente utilizada para fins diagnósticos e estudos anatômicos nos porquinhos-da-índia, tais como por Zehtabvar et al. (2023) empregaram a tomografia para descrever a anatomia torácica de porquinhos-da-índia. Além disso Witkowska et al. (2014) utilizaram-na no estudo morfológico e do desenvolvimento ósseo dos membros, e Mahdy et al. (2022) correlacionaram imagens de tomografia computadorizada e de ressonância magnética com estruturas cranianas.

3. REFERÊNCIAS*

- 1 AL-SAFFAR, F. J.; NASIF, R. H. Morphological study of the pancreas
2 and duodenum in adult guinea pigs (*Cavia porcellus*). **The Iraqi Journal of**
3 **Veterinary Medicine**, v. 44, n. 1, p. 1–9, 2020.
- 4 AZEVEDO, L. S. B. **Doenças do trato urinário:**
5 **estudo ultrassonográfico retrospectivo em porquinhos-da-Índia (*Cavia***
6 ***porcellus*)**. 2024. Tese (Doutorado em Biociência Animal) - Programa de Pós-
7 Graduação Stricto Sensu em Biociência Animal, Universidade de Cuiabá (UNIC),
8 Cuiabá, 2024.
- 9 CLEMONS, D. J.; SEEMAN, J. L. **The laboratory guinea pig**. 2. ed.
10 Boca Raton: CRC Press, 2011.
- 11 EDELL, A. S. et al. Retrospective analysis of risk factors, clinical features,
12 and prognostic indicators for urolithiasis in guinea pigs: 158 cases (2009–2019).
13 **Journal of the American Veterinary Medical Association**, v. 260, supl. 2, p.
14 S95–S100, 2022.
- 15 ECKERT, C.; HECHT, S.; MCCLAIN, T. Radiographic diagnosis and
16 surgical treatment of gastric dilatation-volvulus in a guinea pig. **Journal of Exotic**
17 **Pet Medicine**, [S. l.], v. 28, p. 1–5, 2019.
- 18 FETZER, T. J.; MANS, C. Jejuno-jejunal intussusception in a guinea pig
19 (*Cavia porcellus*). **Open Veterinary Journal**, [s.l.], v. 7, n. 3, p. 286-289, 2017.
- 20 HARGADEN, M.; SINGER, L. Anatomy, physiology, and behavior. In:
21 SUCKOW, M. A.; STEVENS, K. A.; WILSON, R. P. (ed.). **The laboratory rabbit,**
22 **guinea pig, hamster, and other rodents**. San Diego: Academic Press, 2012.
23 cap. 20, p. 575–602.
- 24 KEALY, J.K.; McALLISTER, H. **Radiologia e ultrassonografia do cão**
25 **e gato**. 3.ed. São Paulo: Manole, 2005. p.7-18, 41-45.
- 26 KEEBLE, E.; HEGGIE, H. Mammals: biology and husbandry. In: VARGA,
27 M.; LUMBIS, R.; GOTT, L. (ed.). **BSAVA manual of exotic pet and wildlife**
28 **nursing**. Gloucester: British Small Animal Veterinary Association, 2012. p. 34–
29 57.
- 30 NYLAND, T.G.; MATTOON, J.S.; HERRGESELL, E.J.; WISNER, E.R.
31 Princípios físicos, instrumentação e segurança do
32

* Referências organizadas de acordo com a Associação Brasileira de Normas Técnicas (ABNT) NBR 6023 informação e documentação – Referências – Elaboração. Rio de Janeiro, 2018. 74p.

- 1 diagnóstico do ultrassom. In: NYLAND, T.G.; MATTOON, J.S. **Ultra-som**
2 **diagnóstico em pequenos animais**. 2.ed. São Paulo: Roca, 2005a. cap.1, p.1-
3 20.
- 4 KRAUTWALD-JUNGHANNS, M.-E.; DZIALIAS, P.; REESE, S.
5 Diagnostic imaging in small mammals. In: KRAUTWALD-JUNGHANNS, M.-E.
6 (ed.). **Diagnostic imaging of exotic pets**. Hannover: Schlütersche, 2011. p. 85–
7 132.
- 8 MAHDY, M. A. A. Correlation between computed tomography, magnetic
9 resonance imaging and cross-sectional anatomy of the head of the guinea pig
10 (*Cavia porcellus*, Linnaeus 1758). **Anatomical Histology and Embryology**, v.
11 51, n. 1, p. 51–61, 2022.
- 12 MARTÍN, N. G.; MIÑO, E. D.; CARELLÁN, A. G.; SOLÉ, L. V. Abdominal
13 ultrasound features and reference values in healthy guinea pigs (*Cavia*
14 *porcellus*). **Veterinary Record**, v. 194, n. 2, 27, 2023.
- 15 MUHLBAUER, M. C.; KNELLER, S. K. **Radiography of the dog and**
16 **cat**. [s.l.] John Wiley & Sons, 2013.
- 17 O'MALLEY, B. Guinea pigs. In: O'MALLEY, Bairbre (Ed.). **Clinical**
18 **anatomy and physiology of exotic species: structure and function of**
19 **mammals, birds, reptiles, and amphibians**. Edinburgh; New York: Elsevier
20 Saunders, 2005. p. 197-208. ISBN 0-7020-2782-0.
- 21 PENNICK, D.; D' ANJO, M.A. **Atlas of small animal ultrasonography**.
22 2.ed. Iowa: John Wiley & Sons, Inc., 2015. 10
- 23 RIGGS, S. M. CHAPTER 17 - Guinea Pig. In: **manual of exotic pet**
24 **practice**. St. Louis, Missouri: Elsevier Inc, 2009. p. 456–473. 13
- 25 ROSAS-NAVARRO, J., et al. Epidemiological, clinical, radiographic,
26 echocardiographic findings and outcome in client-owned guinea pig (*Cavia*
27 *porcellus*) with cardiac disease: 80 cases (2010–2021). **Journal of the**
28 **American Veterinary Medical Association**, 261(6), 865-873, 2023.
- 29 SCHWARZ, T.; SAUNDERS, J. **Veterinary computed tomography**. 1.
30 20 ed. Chichester: Wiley-Blackwell, 2011.
- 31 SHEIKHIAN, A.; SAADATFAR, Z.; MOHAMMADPOUR, A. A. A
32 histological study of adrenal gland in guinea pig and hamster. **Comparative**
33 **Clinical Pathology**, v. 24, p. 1069–1074, 2015.
- 34 SILVERMAN, S.; TELL, L. A. **Radiology of rodents, rabbits and**

- 1 **ferrets: an atlas of normal anatomy and positioning.** St. Louis: Elsevier
2 Saunders, 2005.
- 3 TEIXEIRA, V. N. Rodentia: roedores exóticos (rato, camundongo,
4 hamster, gerbilo, porquinho-da-índia e chinchila). In: CUBAS, Z. S.; SILVA, J. C.
5 R.; CATÃO-DIAS, J. L. (org.). **Tratado de animais selvagens: medicina**
6 **veterinária.** 2. ed. São Paulo: Roca, 2014. v. 1, cap. 55, p. 1169-1208.
- 7 THRALL, D.E. **Diagnóstico de Radiologia Veterinária.** 6. ed. Rio de
8 Janeiro: Elsevier, 2015.
- 9 QUESENBERRY, K.; MANS, C.; ORCUTT, C.; CARPENTER, J.W.
10 **Ferrets, rabbits, and rodents: clinical medicine and surgery.** 4. ed. St. Louis:
11 Saunders, 2020.
- 12 YOUSIF, R. R.; RABEE, F. O. Anatomical and histological study of
13 kidney, ureter and urinary bladder in male guinea pig (*Cavia porcellus*). **The Iraqi**
14 **Journal of Veterinary Medicine**, Baghdad, v. 43, n. 1, p. 75–84, 2019.
- 15 ZEHTABVAR, O.; MASOUDIFARD, M.; ROSTAMI, A.; AKBAREIN, H.;
16 SERESHKE, A. H. A.; KHANAMOOEIASHI, M.; BORGHEIE, F. CT anatomy of
17 the lungs, bronchi and trachea in the mature guinea pig (*Cavia porcellus*).
18 **Veterinary Medicine and Science**, v. 9, n. 3, p. 1179–1193, 2023.
- 19 WITKOWSKA, A. et al. Computed tomography analysis of guinea pig
20 bone: architecture, bone thickness and dimensions throughout
21 development. **PeerJ**, v. 2, p. e615, 2014.

CAPÍTULO 2

ARTIGO CIENTÍFICO 1

Radiographic and tomographic anatomical atlas of the axial and appendicular skeleton of the guinea pig (*Cavia porcellus*): pictorial essay

Periódico a ser enviado: Anatomia, Histologia, Embryologia

<https://onlinelibrary.wiley.com/page/journal/14390264/homepage/forauthors.htm>
|

Monteiro, M.S.V^{1*}; Silva, J.P.¹; Ichikawa, R.S¹; Rahal, S.C.¹; Suzuki, F.S.F.²; Camargo, R.F³; Mamprim, M.J¹.

¹ Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu, São Paulo, Brazil

² Department of Clinic, Surgery and Animal Reproduction, Faculty of Veterinary Medicine of Araçatuba, São Paulo State University (UNESP), Araçatuba, São Paulo, Brazil

³ Centro de Diagnóstico Veterinário - CEDIVet, Rio Claro, São Paulo, Brazil.

Acknowledgments

The authors thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for financial support and the CEDIVET team for their assistance in conducting the examinations. This study was financed, in part, by the São Paulo Research Foundation (FAPESP), Brazil. Process Number FAPESP nº 2023/16693-7, and FINEP (Financiadora de Estudos e Projetos), Process Number 01.12.0530.00.

*Corresponding Author:

E-mail: matheus.serrano@unesp.br (M.S.V. Monteiro)

ABSTRACT

The study aimed to describe the structures of the skull, vertebral column, and thoracic and pelvic limbs of adult guinea pigs (*Cavia porcellus*) through radiographic and tomographic examinations. Five healthy adult males, with a mean weight of 750 g, were used. Radiography and computed tomography (CT) examinations were performed on the same day, following a four-hour fast, under sedation using ketamine and diazepam. Radiographically, the skull revealed thin bones, prominent zygomatic arches, and an evident angular process of the mandible. The tympanic bullae appeared proportionately large, and the nasal cavities were narrow, with a well-defined nasal septum. Anatomical reference lines were used for dental analysis and occlusal evaluation. Regarding the vertebral column, lateral and ventrodorsal projections demonstrated regular alignment of the vertebral bodies, uniform intervertebral spaces, and well-defined physiological curvatures. In the thoracic limbs, a scapula with a prominent acromion, a visible clavicle, and four digits were identified. The pelvic limbs presented a short, rounded pelvis, a wide patella, and three well-defined digits. Computed tomography complemented the anatomical evaluation, enabling detailed three-dimensional visualization of complex structures such as the cranial and nasal cavities, the absence of frontal and sphenoidal sinuses, the orbits, the tympanic bullae, tooth roots, and intervertebral joints. In the three-dimensional reconstructions, it was possible to clearly observe the cervical, thoracic, lumbar, sacral, and caudal vertebrae, as well as the conformation of the shoulder, elbow, pelvis, and stifle joints. This study presents an illustrated anatomical atlas of the main bony structures of the axial and appendicular skeletons of *Cavia porcellus*, obtained via radiography and computed tomography, to aid recognition of normal anatomical patterns and serve as a reference for diagnostic imaging studies in small mammals.

Keywords: comparative anatomy, computed tomography, veterinary radiology

1. INTRODUCTION

Guinea pigs (*Cavia porcellus*), rodents belonging to the order Rodentia and the family Caviidae, typically weigh 700-1,200 g and have a life expectancy of up to eight years (Quesenberry et al., 2021). Their docile temperament, ease of handling, and small body size have contributed to their growing popularity as companion animals and to their widespread use as experimental models in scientific research (Hargaden & Singer, 2012). In this context, there is a clear need to expand knowledge regarding the species' biology, clinical particularities, and applicable diagnostic approaches (Hargaden & Singer, 2012). Moreover, due to their distinct anatomical and physiological characteristics, a detailed understanding of guinea pig morphology is essential for the accurate interpretation of imaging examinations, reliable diagnosis of pathological conditions, and appropriate planning of clinical and surgical interventions (Krautwald-Junghanns et al., 2011).

Radiography and computed tomography are complementary diagnostic imaging examinations that enable detailed visualization of anatomical structures of the animals' axial and appendicular skeletons, contributing to morphological studies and the identification of anatomical variations (Krautwald-Junghanns et al., 2011). Such modalities are widely used, both in the investigation of musculoskeletal disorders and in comparative anatomical studies, and are distinguished by their precision in representing bony structures (Quesenberry et al., 2021).

Several previous studies have contributed to the anatomical knowledge of guinea pigs. Silverman & Tell (2005) described the anatomy of the skull, vertebral column, and thoracic and pelvic limbs of these animals, while Boehmer & Crossley (2009) reported anatomical reference lines for normality and criteria for the detection of dental alterations. Witkowska et al. (2014) detailed the bone morphology and growth of the scapula, humerus, and femur at different life stages. Subsequently, Mahdy (2022) conducted an anatomical study of the skull using computed tomography associated with magnetic resonance imaging. More recently, Yaghobzadeh et al. (2025) morphologically analyzed the vertebral column; Asl et al. (2025) described the thoracic and lumbar segments of the vertebral column; and Goli et al. (2025) addressed the lumbosacral region.

Although descriptive studies on specific segments exist, there remains a

lack of comprehensive visual compilations that integrate anatomical regions and imaging modalities. Therefore, the objective of this study was to develop a radiographic and tomographic pictorial essay of the axial and appendicular skeletons of *Cavia porcellus*, presenting labeled and comparative images across modalities, to provide an illustrated anatomical reference for academic and clinical purposes.

2. MATERIALS AND METHODS

2.1 Animals and Ethical Considerations

The ethical aspects recommended by the National Council for the Control of Animal Experimentation (CONCEA) were considered in all stages of this study, which was approved by the Institutional Ethics Committee on Animal Use (CEUA).

Five clinically healthy adult male guinea pigs (*Cavia porcellus*), with a mean body weight of 750 g, were included in the study. Physiological parameters were within the reference ranges described by Keeble and Heggie (2012), and no clinical signs of disease were observed throughout the experimental period. Prior to imaging, the animals were fasted for four hours.

2.2 Anesthetic Protocol

Radiographic and computed tomographic examinations were performed on the same day under a single sedation protocol using ketamine (30 mg/kg, intramuscular) combined with diazepam (3 mg/kg, intramuscular), as described by Carpenter and Harms (2022). Throughout the procedures, the animals were continuously monitored for vital parameters.

2.3 Radiography

Radiographic examinations were performed under the previously described sedation, encompassing the skull, vertebral column, thoracic limbs, and pelvic limbs regions. Images were acquired using a Shimadzu FXRD-4343VAW radiographic unit, with exposure parameters set at 40 kV and 400 mA and a focal-film distance of 80 cm.

Lateral, ventrodorsal, dorsoventral, craniocaudal, and mediolateral radiographic projections were performed, depending on the anatomical region evaluated. The obtained images were analyzed using eFilm 3.4 Dicom Viewer software.

2.4 Computed Tomography

The tomographic examinations were performed using the same sedation protocol previously described. Acquisitions were performed using a Canon Aquilion Start 20 MHU TSX scanner.

The animals were positioned in ventral recumbency, and the limbs were secured to the table using adhesive tape. The adopted tomographic technique was 120 kVp, 70 mA, a pitch of 1, 1 s/rotation, and a slice thickness of 1 mm for all evaluated segments. The tomographic images were acquired and processed using bone and soft-tissue windows. Analysis was performed using RadiAnt DICOM Viewer 2020.2 software.

2.5 Imaging Analysis

The radiographic and computed tomographic images obtained were analyzed descriptively and comparatively, with emphasis on identifying and characterizing the osseous components of the axial and appendicular skeletons.

The evaluation encompassed morphological aspects, including contours, symmetry, and anatomical positioning of the structures, with the objective of establishing visual normal reference parameters in *Cavia porcellus*. Images were organized by anatomical region, enabling direct comparison between radiographic and tomographic modalities. The analysis was qualitative, and no statistical methods were used.

3. RESULTS

In the radiographic evaluation of the skull, multiple anatomical structures were identified in the lateral and dorsoventral projections, including the nasal, frontal, parietal, occipital, maxillary, and mandibular bones, with identification of the angular process, as well as the incisor, premolar, and molar teeth. Additionally, the tympanic bullae and external auditory canals were clearly visualized.

In the lateral projection (Figure 1), it was possible to visualize the nasal cavity, frontal sinuses, nasal turbinates, the supraorbital margin of the frontal bone, the occipital protuberance, and the occipital condyles.

In the dorsoventral projection (Figure 2), clearer visualization of the zygomatic bone, the zygomatic process of the mandible, the nasal septum, and the vomer, palatine, and sphenoid bones was achieved, as well as the occipital

protuberance.

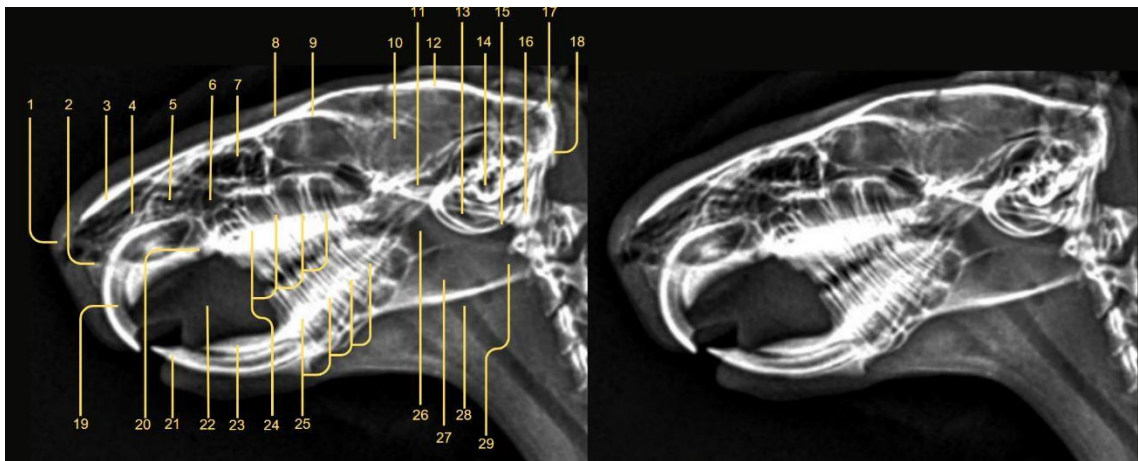


Figure 1. Radiographic image in lateral projection of the skull of a healthy adult guinea pig. 1. Nose; 2. Incisive bone; 3. Nasal bone; 4. Nasoturbinates; 5. Nasal cavity; 6. Infraorbital foramen; 7. Ethmoturbinates; 8. Frontal bone; 9. Supraorbital margin of the frontal bone; 10. Cranial cavity; 11. Temporal bone; 12. Parietal bone; 13. Tympanic cavity; 14. External acoustic meatus; 15. Tympanic bulla; 16. Occipital condyle; 17. Occipital protuberance; 18. Occipital bone; 19. Maxillary incisor tooth; 20. Maxilla; 21. Mandibular incisor tooth; 22. Oral cavity; 23. Mandible; 24. Maxillary cheek teeth; 25. Mandibular cheek teeth; 26. Nasopharynx; 27. Cricoid cartilage; 28. Trachea; 29. Angular process of the mandible.

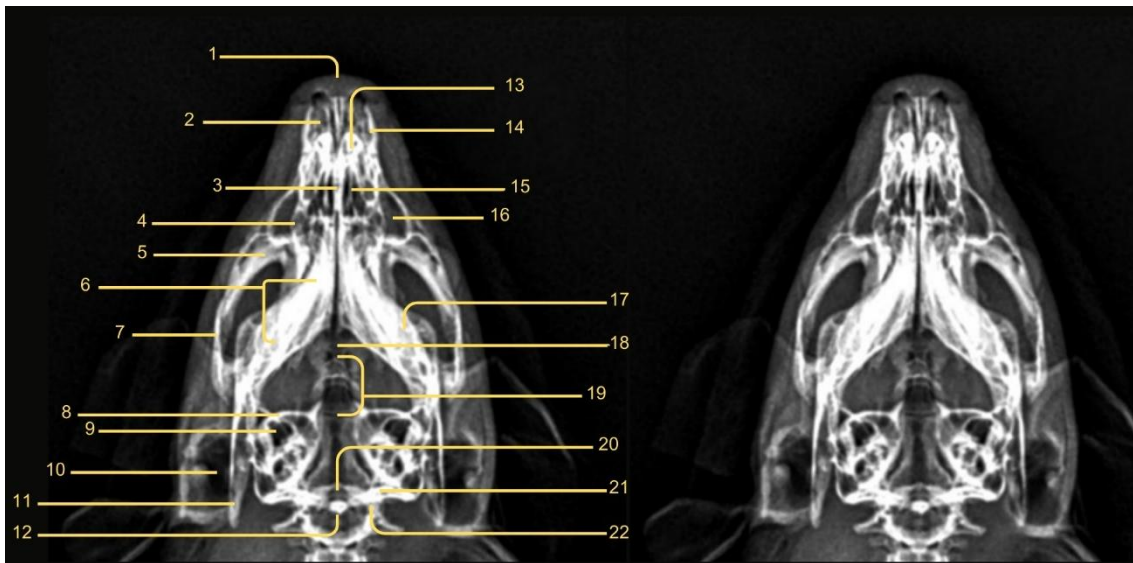


Figure 2. Radiographic image in dorsoventral projection of the skull of a healthy adult guinea pig. 1. Nose; 2. Nasoturbinates; 3. Vomer; 4. Maxilla; 5. Zygomatic process of the maxilla; 6. Right mandibular and maxillary cheek teeth; 7. Zygomatic arch; 8. Tympanic bulla; 9. Tympanic cavity; 10. Auditory canal; 11. Angular process of the mandible; 12. Occipital protuberance; 13. Left maxillary incisor tooth; 14. Nasal bone; 15. Nasal cavity; 16. Infraorbital foramen; 17. Mandible; 18. Palatine bone; 19. Sphenoid bone; 20. Foramen magnum; 21. Occipital bone; 22. Paracondylar process of the occipital bone.

On CT (Figures 3 and 4), cranial morphology was visualized in greater detail, allowing enhanced assessment of bone thickness, delineation of the

frontal sinuses, and detailed evaluation of the nasal cavity and the three-dimensional arrangement of the cranial bones. Three-dimensional reconstructions enabled spatial visualization of cranial sutures and clear differentiation between the facial skeleton and the neurocranium.

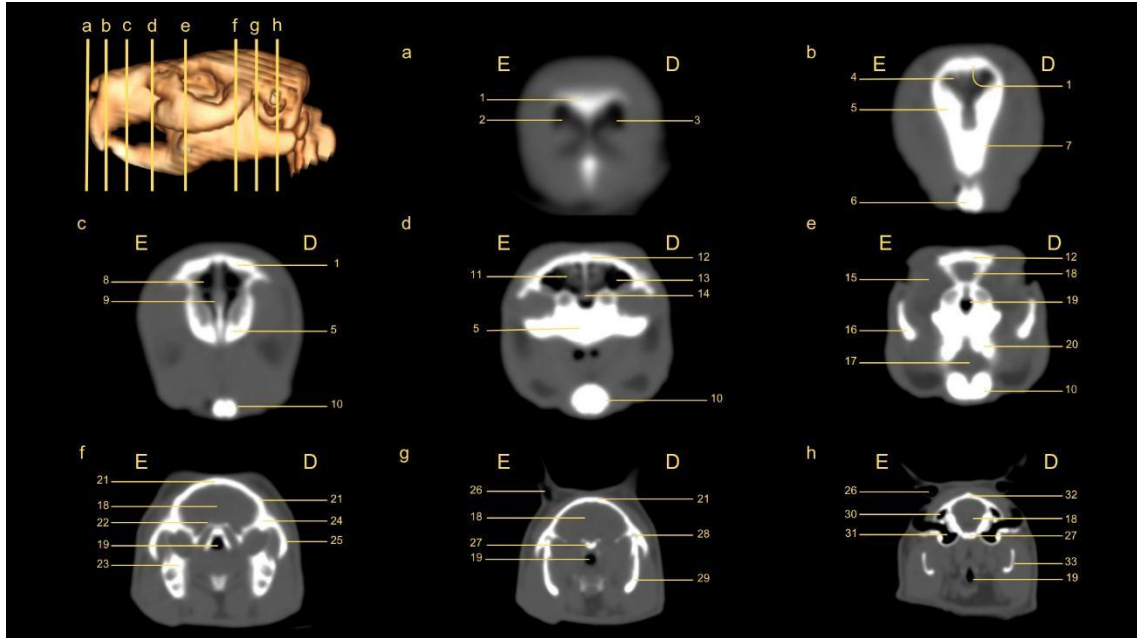


Figure 3. Computed tomography image of axial section of the skull (Bone window) of a healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1. Nasal bone; 2. Left nasal cavity; 3. Right nasal cavity; 4. Nasoturbinates; 5. Maxillary bone; 6. Left mandibular incisor tooth; 7. Right maxillary incisor tooth; 8. Left maxillary sinus; 9. Nasal septum; 10. Right mandibular incisor tooth; 11. Ethmoturbinates; 12. Frontal bone; 13. Right nasal concha; 14. Vomer; 15. Left orbit; 16. Left zygomatic arch; 17. Oral cavity; 18. Cranial cavity; 19. Nasopharynx; 20. Right 4th maxillary premolar tooth; 21. Parietal bone; 22. Palatine bone; 23. Left mandibular 3rd molar tooth; 24. Temporal bone; 25. Right zygomatic arch; 26. Left external auditory canal; 27. Basisphenoid bone; 28. Right temporomandibular joint; 29. Right mandible; 30. Dorsal tympanic bulla; 31. Ventral tympanic bulla; 32. Occipital bone; 33. Angular process of the right mandible.

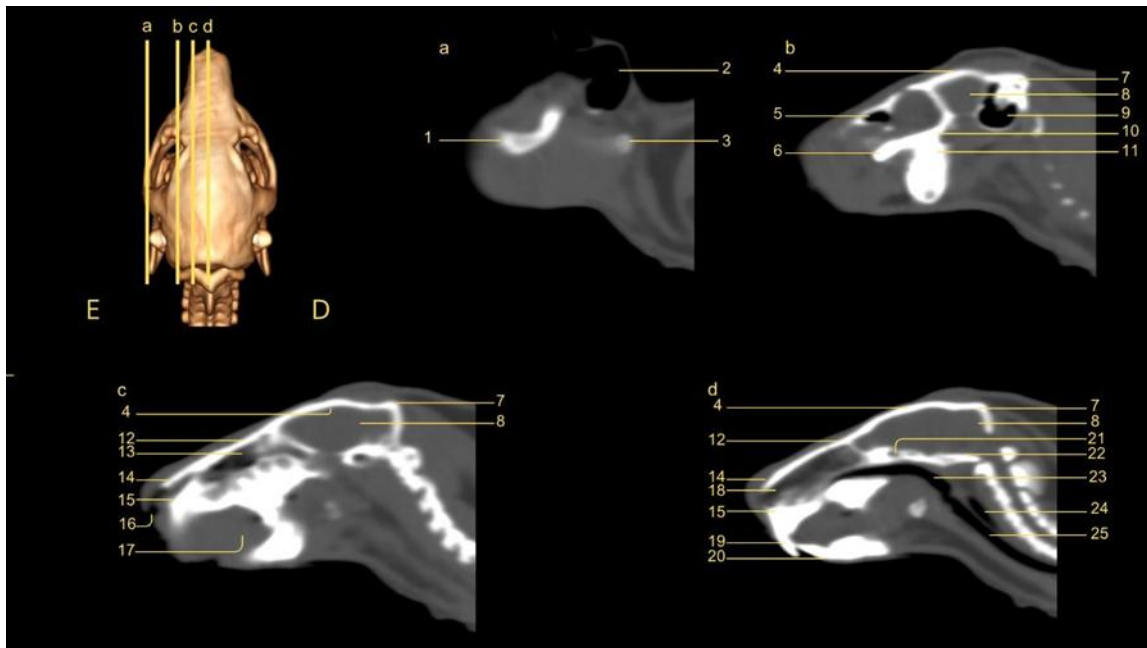


Figure 4. Computed tomography image of sagittal section of the skull (Bone window) of a healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1. Left zygomatic arch; 2. Left external auditory canal; 3. Angular process of the left mandible; 4. Parietal bone; 5. Left nasal concha; 6. Maxillary bone; 7. Occipital bone; 8. Cranial cavity; 9. Tympanic bulla; 10. Temporal bone; 11. Left mandible; 12. Frontal bone; 13. Ethmoturbinates; 14. Nasal bone; 15. Incisive bone; 16. Nostril; 17. Oral cavity; 18. Nasal cavity; 19. Left maxillary incisor tooth; 20. Left mandibular incisor tooth; 21. Palatine bone; 22. Basisphenoid bone; 23. Nasopharynx; 24. Esophagus; 25. Trachea.

In the radiographic evaluation of the vertebral column, the cervical, thoracic, lumbar, sacral, and caudal segments were identified in the lateral and ventrodorsal projections.

The cervical column consisted of seven vertebrae. The first vertebra, the atlas, exhibited a dorsal arch, lateral vertebral foramen, and alar wings, whereas the second vertebra, the axis, presented a more prominent and rounded spinous process (Figures 5 and 6).

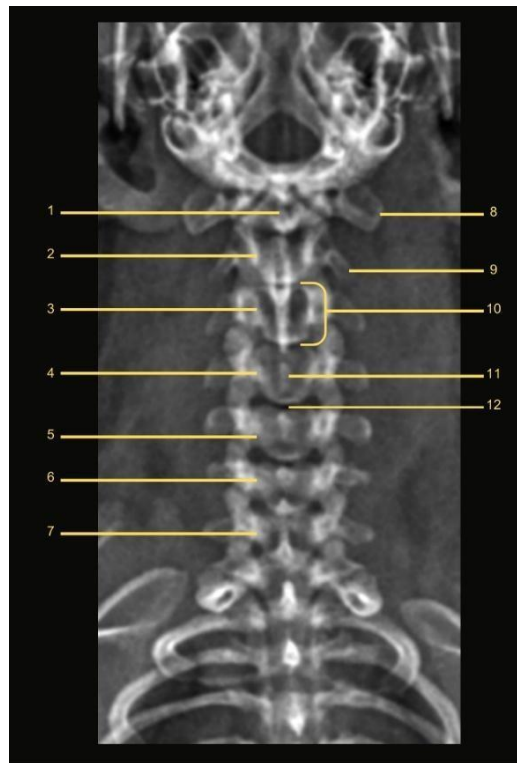


Figure 5. Radiographic image in ventrodorsal projection of the cervical column of a healthy adult guinea pig. 1. Atlas; 2. Axis; 3. 3rd cervical vertebra; 4. 4th cervical vertebra; 5. 5th cervical vertebra; 6. 6th cervical vertebra; 7. 7th cervical vertebra; 8. Wing of the atlas; 9. Transverse process of the axis; 10. Vertebral body of the 3rd cervical vertebra; 11. Spinous process of the 4th cervical vertebra; 12. Intervertebral space between the 4th and 5th cervical vertebrae.

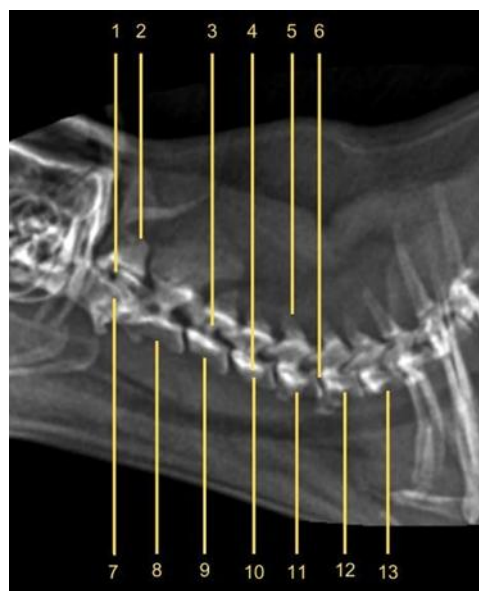


Figure 6. Radiographic image in lateral projection of the cervical column of a healthy adult guinea pig. 1. Lateral vertebral foramen; 2. Dorsal arch; 3. Intervertebral foramen; 4. Vertebral body of the 4th cervical vertebra; 5. Spinous process of the 5th cervical vertebra; 6. Intervertebral space between the 5th and 6th cervical vertebrae. 7. Atlas; 8. Axis; 9. 3rd cervical

vertebra; 13. 4th cervical vertebra; 11. 5th cervical vertebra; 12. 6th cervical vertebra; 13. 7th cervical vertebra.

Thirteen vertebrae were identified in the thoracic column. The ribs were visualized as elongated structures arranged in bilateral and symmetrical arches. Originating from the cranial region of the thoracic vertebrae, they exhibited a slight caudal curvature, following the external contour of the thoracic cavity, and articulated with the sternum up to the sixth rib pair. The sternum was located in the ventromedial region and consisted of three radiodense components: the manubrium, three sternbrae, and the xiphoid process (Figures 7 and 8).

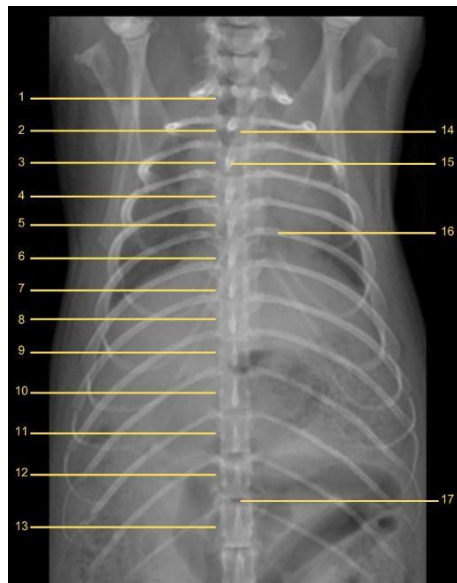


Figure 7. Radiographic image in ventrodorsal projection of the thoracic column of a healthy adult guinea pig. 1. 1st thoracic vertebra; 2. 2nd thoracic vertebra; 3. 3rd thoracic vertebra; 4. 4th thoracic vertebra; 5. 5th thoracic vertebra; 6. 6th thoracic vertebra; 7. 7th thoracic vertebra; 8. 8th thoracic vertebra; 9. 9th thoracic vertebra; 10. 10th thoracic vertebra; 11. 11th thoracic vertebra; 12. 12th thoracic vertebra; 13. 13th thoracic vertebra; 14. Vertebral body of the 2nd thoracic vertebra; 15. Spinous process of the 4th thoracic vertebra; 16. Right rib of the 6th thoracic vertebra; 17. Intervertebral space of the 12th and 13th thoracic vertebrae.

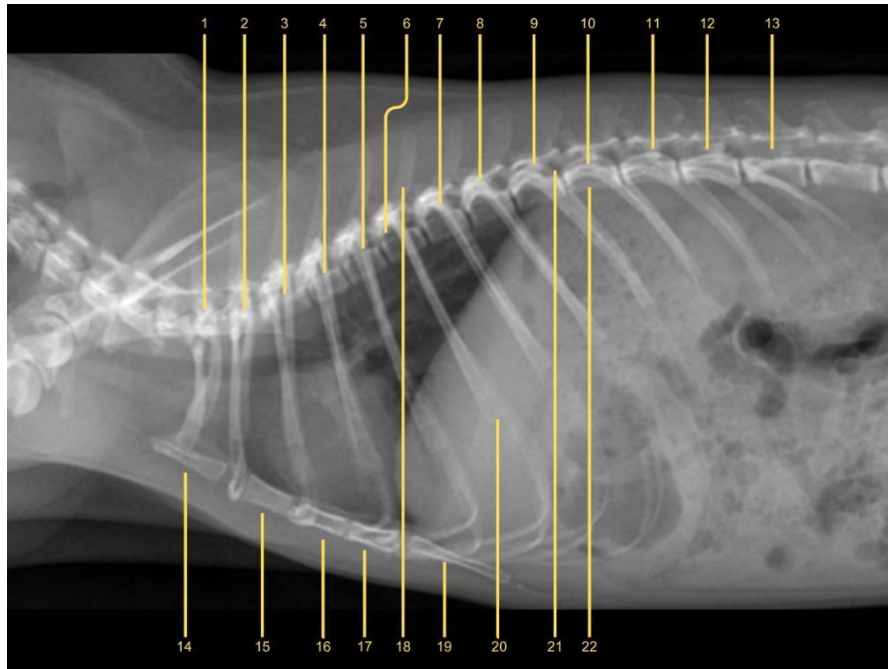


Figure 8. Radiographic image in lateral projection of the thoracic column of a healthy adult guinea pig. 1. 1st thoracic vertebra; 2. 2nd thoracic vertebra; 3. 3rd thoracic vertebra; 4. 4th thoracic vertebra; 5. 5th thoracic vertebra; 6. 6th thoracic vertebra; 7. 7th thoracic vertebra; 8. 8th thoracic vertebra; 9. 9th thoracic vertebra; 10. 10th thoracic vertebra; 11. 11th thoracic vertebra; 12. 12th thoracic vertebra; 13. 13th thoracic vertebra; 14. Manubrium; 15. 1st sternebra; 16. 2nd sternebra; 17. 3rd sternebra; 18. Spinous process of the 6th thoracic vertebra; 19. Xiphoid process; 20. Rib pair of 5th thoracic vertebra; 21. Intervertebral foramen of the 9th and 10th thoracic vertebrae; 22. Vertebral body of the 10th thoracic vertebra.

Six vertebrae were characterized in the lumbar column. The sacral column consisted of four fused vertebrae, articulating bilaterally with the ilium to form the sacroiliac joint, and the caudal column was characterized by five to six vertebrae (Figures 9 and 10).

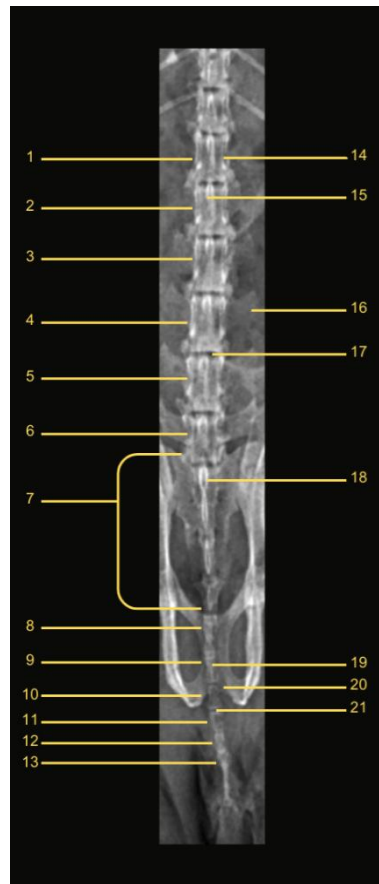


Figure 9. Radiographic image in ventrodorsal projection of the lumbar column, sacrum, and coccygeal column of a healthy adult guinea pig. 1. 1st lumbar vertebra; 2. 2nd lumbar vertebra; 3. 3rd lumbar vertebra; 4. 4th lumbar vertebra; 5. 5th lumbar vertebra; 6. 6th lumbar vertebra; 7. Sacrum; 8. 1st coccygeal vertebra; 9. 2nd coccygeal vertebra; 10. 3rd coccygeal vertebra; 11. 4th coccygeal vertebra; 12. 5th coccygeal vertebra; 13. 6th coccygeal vertebra; 14. Vertebral body of 1st lumbar vertebra; 15. Spinous process of the 2nd lumbar vertebra; 16. Transverse process of the 3rd lumbar vertebra; 17. Intervertebral space between the 4th and 5th lumbar vertebrae; 18. Spinous process of sacrum; 19. Vertebral body of 2nd coccygeal vertebra; 20. Transverse process of 3rd coccygeal vertebra; 21. Intervertebral space of the 3rd and 4th coccygeal vertebrae.

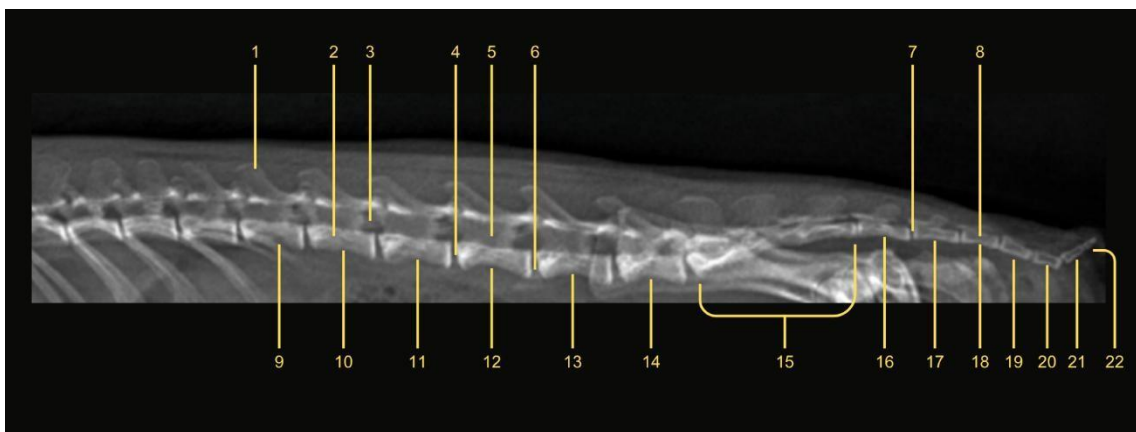


Figure 10. Radiographic image in lateral projection of the lumbar column, sacrum, and coccygeal column of a healthy adult guinea pig. 1. Spinous process of the 1st lumbar vertebra; 2. Vertebral body of the 2nd lumbar vertebra; 3. Intervertebral foramen of 2nd and 3rd lumbar vertebrae; 4. Intervertebral space of the 3rd and 4th lumbar vertebrae; 5. Vertebral foramen of the 4th lumbar vertebra; 6. Transverse process of the 5th lumbar vertebra; 7. Intervertebral space of 1st and 2nd coccygeal vertebrae; 8. Vertebral body of 3rd coccygeal vertebra; 9. 1st lumbar vertebra; 10. 2nd lumbar vertebra; 11. 3rd lumbar vertebra; 12. 4th lumbar vertebra; 13. 5th lumbar vertebra; 14. 6th lumbar vertebra; 15. Sacrum; 16. 1st coccygeal vertebra; 17. 2nd coccygeal vertebra; 18. 3rd coccygeal vertebra; 19. 4th coccygeal vertebra; 20. 5th coccygeal vertebra; 21. 6th coccygeal vertebra; 22. 7th coccygeal vertebra.

In the lateral projection, the vertebral bodies exhibited regular alignment, with uniform intervertebral spaces and preservation of the vertebral column's physiological curvature. The spinous and transverse processes were well defined, particularly in the thoracic and lumbar regions.

In the ventrodorsal projection, symmetrical intervertebral joints, a parallel arrangement of the transverse processes, and the gradual morphological transition of the thoracic vertebrae toward the lumbar and sacral segments were observed.

On CT (Figures 11 and 12), vertebral morphology and the articulations between the vertebral arches were visualized in greater detail, and three-dimensional reconstructions enabled spatial visualization of the vertebral processes and foramina.

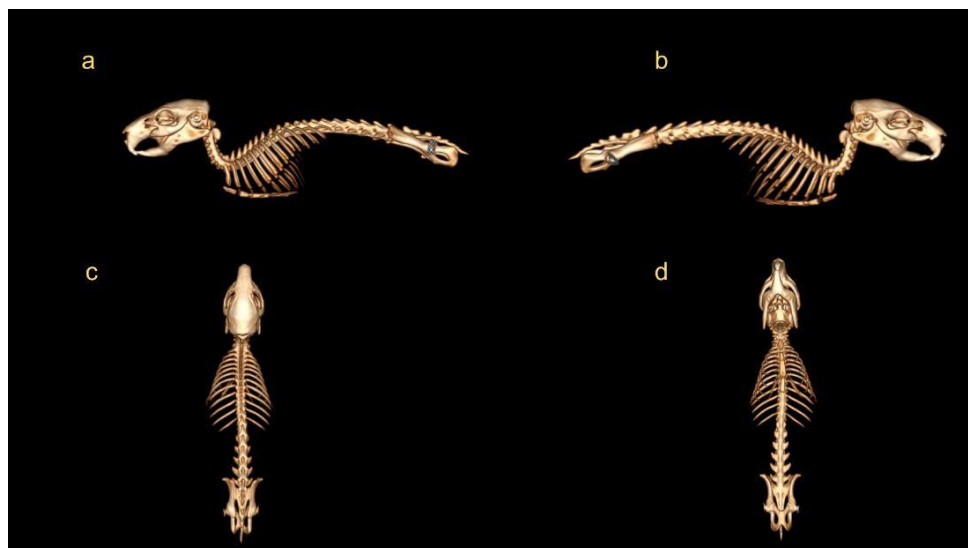


Figure 11: 3D reconstruction image of the skull and vertebral column of a healthy adult guinea pig. a. Left lateral; b. Right lateral; c. Dorsal; d. Ventral.

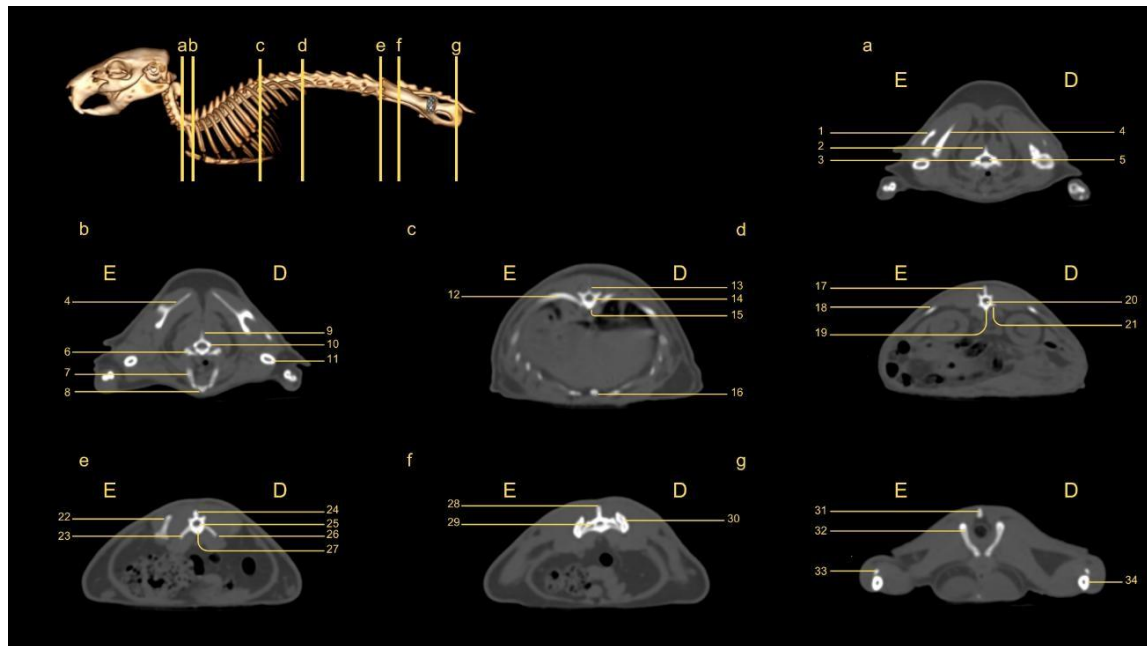


Figure 12: Computed tomography image of axial section of vertebral column (Bone window) of healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1.

Left acromion; 2. Spinous process of the 7th cervical vertebra; 3. Vertebral body of the 7th cervical vertebra; 4. Left scapula; 5. Vertebral canal of the 7th cervical vertebra; 6. Left rib of 2nd thoracic vertebra; 7. Left rib of 1st thoracic vertebra; 8. Manubrium; 9. Spinous process of the 2nd thoracic vertebra; 10. Vertebral body of the 2nd thoracic vertebra; 11. Right humerus; 12. Left Rib of the 10th thoracic vertebra; 13. Spinous process of the 10th thoracic vertebra; 14. Vertebral canal of the 10th thoracic vertebra; 15. Vertebral body of 10th thoracic vertebra; 16. Xiphoid process; 17. Spinous process of the 1st lumbar vertebra; 18. Left rib of 13th thoracic vertebra; 19. Vertebral body of 1st lumbar vertebra; 20. Vertebral canal of 1st lumbar vertebra; 21. Right transverse process of 1st lumbar vertebra; 22. Left wing of the ilium; 23. Left transverse process of the 6th lumbar vertebra; 24. Spinous process of the 6th lumbar vertebra; 25. Vertebral canal of the 6th lumbar vertebra; 26. Right transverse process of the 6th lumbar vertebra; 27. Vertebral body of the 6th lumbar vertebra; 28. Spinous process of sacrum; 29. Left wing of the sacrum; 30. Right wing of the ilium; 31. 5th coccygeal vertebra; 32. Left ischium; 33. Left fibula; 34. Left tibia.

In the radiographic evaluation of the thoracic limbs, the main osseous structures were clearly identified in the craniocaudal and mediolateral projections (Figures 13 and 14). Proper alignment of the epiphyses and diaphyses of the humerus, radius, and ulna was observed, along with visualization of the shoulder joint and the scapular outline. The elbow joint appeared intact, with evident articular congruence and regular bone margins.

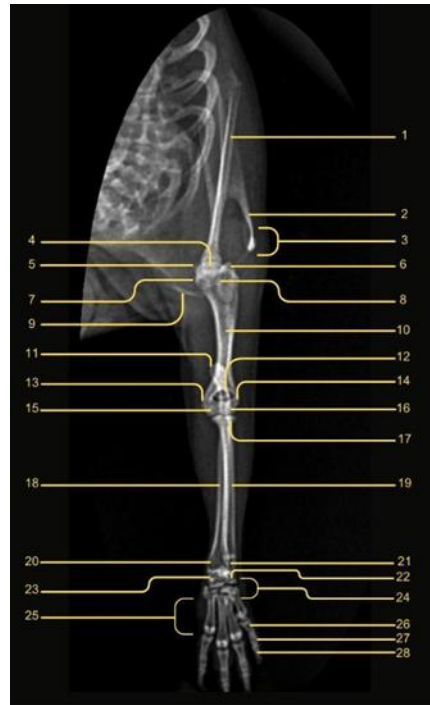


Figure 13. Radiographic image in craniocaudal and dorsopalmar projection of the thoracic limb of a healthy adult guinea pig 1. Spine of the scapula; 2. Acromion; 3. Hamate and supramammary processes; 4. Supraglenoid tubercle; 5. Coracoid process of the scapula; 6. Greater tubercle of the humerus; 7. Lesser tubercle of the humerus; 8. Humeral head; 9. Clavicle; 10. Humerus; 11.

Olecranon; 12. Supratrochlear foramen; 13. Medial epicondyle of the humerus; 14. Lateral epicondyle of the humerus; 15. Trochlea of the humeral condyle; 16. Capitulum of the humeral condyle; 17. Head of the radius; 18. Radius; 19. Ulna. 20. Medial styloid process of the radius; 21.

Lateral styloid process of the ulna; 22. Ulnar carpal bone; 23. 1st carpal bone; 24. Carpal bones; 25. Metacarpals; 26. Proximal phalanx of the 5th digit; 27. Middle phalanx of the 5th digit; 28. Distal phalanx of the 5th digit.

The scapula appeared elongated, with a well-defined spine and prominent acromion, articulating with the humerus via an elliptical glenoid surface. The humerus appeared straight and robust, with well-delimited proximal and distal tubercles. The radius and ulna could be distinguished throughout their entire length, evidencing a parallel and distinct articulation up to the carpal region.

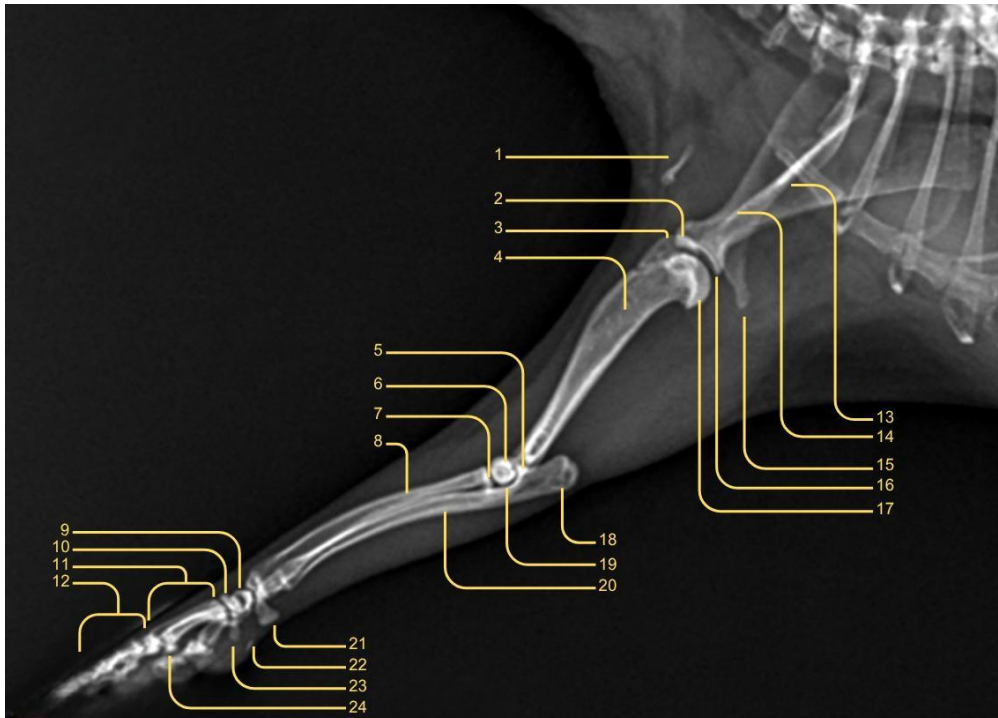


Figure 14. Radiographic image in mediolateral projection of the thoracic limb of a healthy adult guinea pig. 1. Clavicle; 2. Supraglenoid tubercle; 3. Greater tubercle of the humerus; 4. Humerus; 5. Anconeal process of the ulna; 6. Humeral condyle; 7. Head of the radius; 8. Radius; 9. Radial carpal bone; 10. Carpal bones; 11. Metatarsals; 12. Proximal, middle, and distal phalanges of digits 13. Spine of the scapula; 14. Acromion; 15. Hamate process; 16. Infraglenoid tubercle; 17. Humeral head; 18. Olecranon; 19. Trochlear notch of the ulna; 20. Ulna; 21. Accessory carpal; 22. Falciform carpal; 23. 1st carpal bone; 24. Proximal sesamoids.

On CT (Figure 15), osseous definition was superior, allowing more precise visualization of the scapular fossae, the humeral head and trochlea, and the olecranon and coronoid processes of the ulna. Three-dimensional reconstructions highlighted the morphology and spatial relationships among the scapula, humerus, radius, and ulna, as well as the anatomical configuration of the shoulder, elbow, and carpal joints.

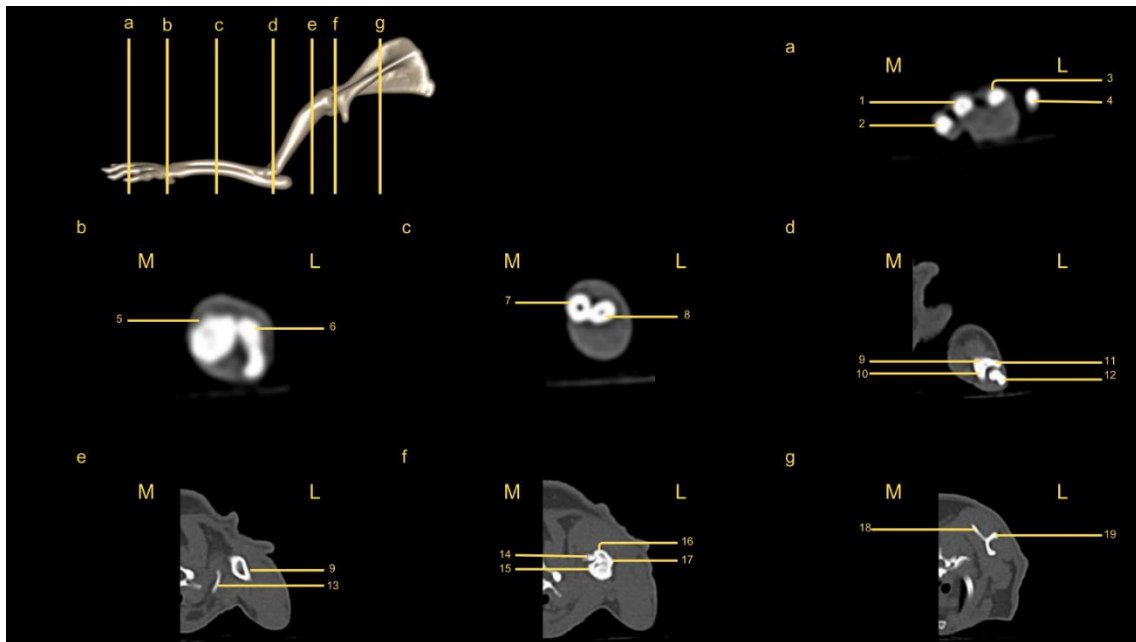


Figure 15. Computed tomography image of axial section of the thoracic limb (Bone window) of a healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1. Proximal phalanx of 4th digit; 2. Middle phalanx of 5th digit; 3. Middle phalanx of 3rd digit; 4. Distal phalanx of 3rd digit; 5. Radial carpal bone; 6. Accessory carpal; 7. Radius; 8. Ulna; 9. Humerus; 10. Medial condyle of humerus; 11. Lateral condyle of humerus; 12. Olecranon; 13. Clavicle; 14. Supraglenoid tubercle; 15. Head of the humerus; 16. Greater tubercle; 17. Lesser tubercle; 18. Scapula; 19. Spine of the scapula.

In the radiographic evaluation of the pelvic limbs, the craniocaudal and mediolateral projections (Figures 16, 17, 18, and 19) allowed clear visualization of the main osseous structures of the pelvis and hind limbs. The ilium, ischium, pubis, femur, patella, tibia, fibula, tarsal bones, metatarsals, and phalanges were identified, as well as the hip, knee, and tarsal joints.

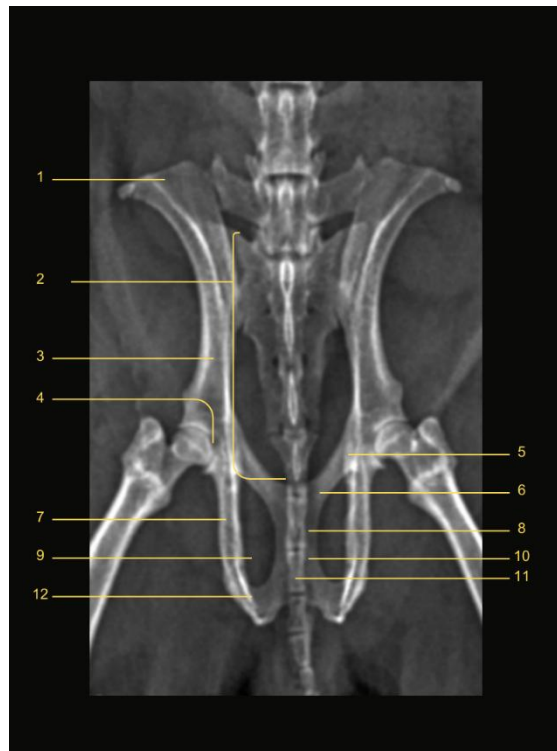


Figure 16. Radiographic image in ventrodorsal projection of the pelvis of a healthy adult guinea pig. 1. Wing of the ilium; 2. Sacrum; 3. Body of the ilium; 4. Acetabulum; 5. Body of the pubis; 6. Cranial ramus of the pubis; 7. Body of the ischium; 8. Caudal ramus of the pubis; 9. Obturator foramen; 10. Ramus of the ischium; 11. Pelvic symphysis; 12. Ischial table.

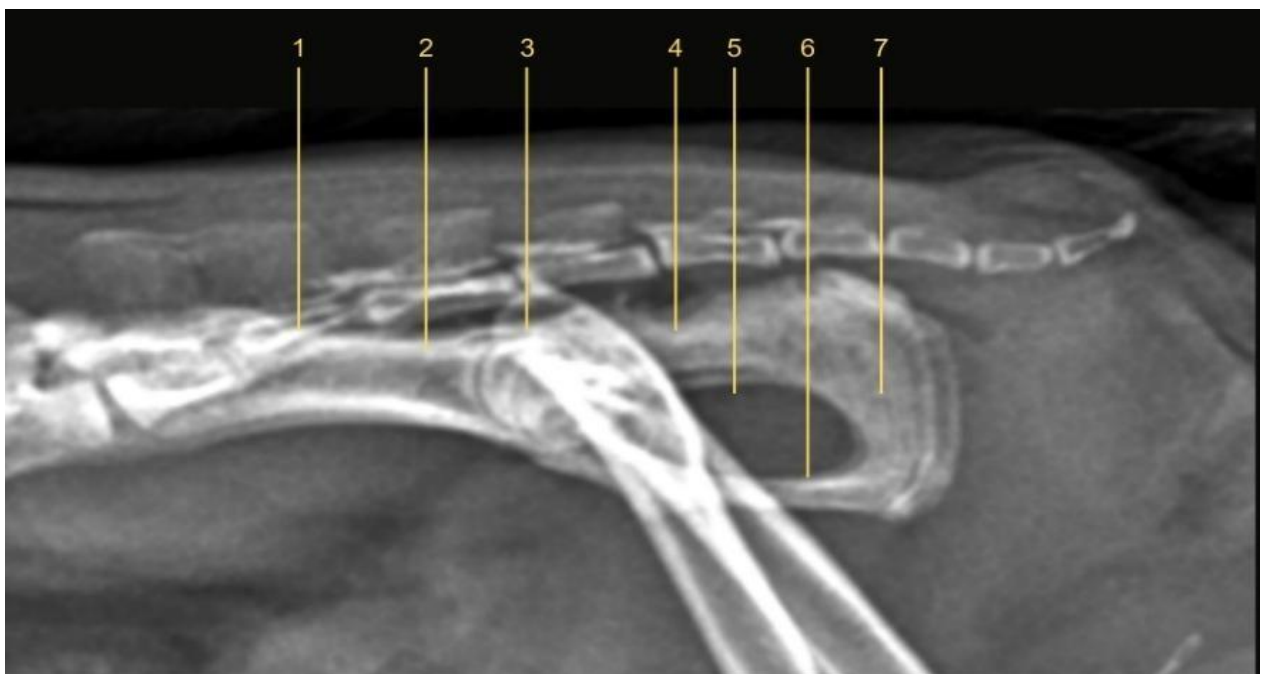


Figure 17. Radiographic image in lateral projection of the pelvis of a healthy adult guinea pig. 1. Wing of the ilium; 2. Body of the ilium; 3. Acetabulum; 4. Body of the ischium; 5. Obturator foramen; 6. Pubis; 7. Ischium.

In the craniocaudal projection, the acetabular margins and the

symmetrical alignment of the femurs relative to the pelvis were clearly observed, with preservation of hip joint congruence. In the mediolateral projection, the acetabular contour, femoral head, patella, and femoral trochlea were visualized, as well as the continuity of the femoral, tibial, and fibular diaphysis.

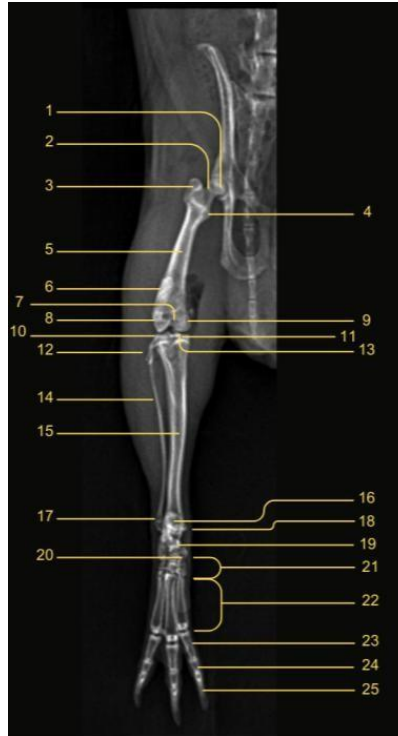


Figure 18. Radiographic image in craniocaudal and dorsoplantar projection of the pelvic limb of a healthy adult guinea pig. 1. Head of the femur; 2. Femoral neck; 3. Greater trochanter; 4. Lesser trochanter; 5. Femur; 6. Patella; 7. Intercondylar fossa; 8. Lateral condyle of the femur; 9. Medial condyle of the femur; 10. Lateral condyle of the tibia; 11. Medial condyle of the tibia; 12. Head of the fibula; 13. Intercondylar eminence; 14. Fibula; 15. Tibia; 16. Calcaneus; 17. Lateral malleolus of the fibula; 18. Medial malleolus of the tibia; 19. Talus; 20. Medial tibial tarsal bone; 21. Tarsal bones; 22. Metatarsals; 23. Proximal phalanx of the 2nd digit; 24. Middle phalanx of the 2nd digit; 25. Distal phalanx of the 2nd digit.



Figure 19. Radiographic image in mediolateral projection of the pelvic limb of a healthy adult guinea pig. 1. Hip joint; 2. Head of the femur; 3. Greater trochanter; 4. Femur; 5. Patella; 6. Caudodistal sesamoids; 7. Femoral condyles; 8. Head of the fibula; 9. Tibial tuberosity; 10. Fibula; 11. Tibia; 12. Calcaneus; 13. Talus; 14. Tarsal bones; 15. Metatarsals; 16. Proximal sesamoids; 17. Phalanges.

On CT (Figures 20 and 21), detailed visualization of the pelvic bones and the hip joint was achieved, allowing assessment of the acetabular fossa, the femoral head and neck, the iliac crests, and the pelvic symphysis. Three-dimensional reconstructions enabled spatial visualization of the pelvic joints and the anatomical arrangement of the pelvic limbs in relation to the pelvis.

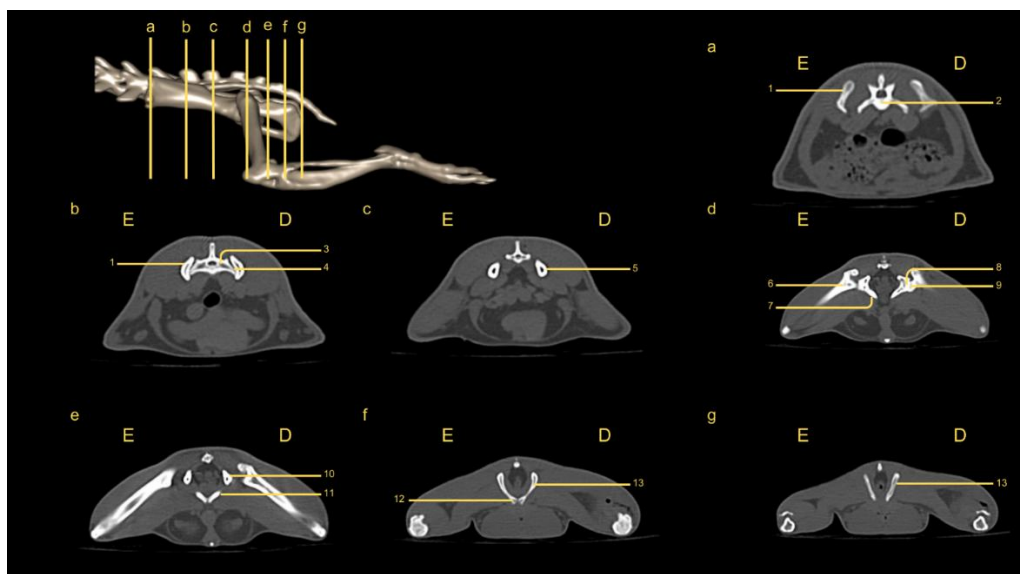


Figure 20. Computed tomography image of axial section of the pelvis (Bone window) of a healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1.

Left wing of the ilium; 2. Vertebral body of the 6th lumbar vertebra; 3. Sacrum; 4. Right sacroiliac joint; 5. Body of the right ilium; 6. Left femur; 7. Left cranial ramus of the pubis; 8. Right hip joint; 9. Head of the right femur; 10. Body of the ischium; 11. Left caudal ramus of the pubis; 12. Left ischium; 13. Right ischium.

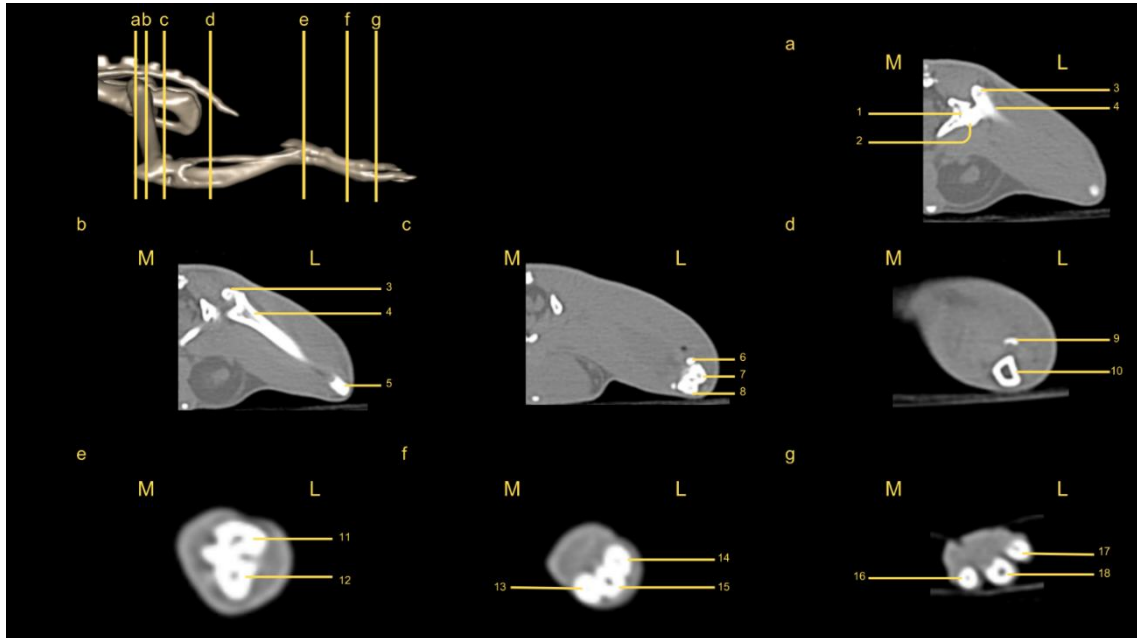


Figure 21. Computed tomography image of axial section of the pelvic limb (Bone window) of a healthy adult guinea pig. In the 3D reconstruction image, the slice locations were marked. 1.

Acetabulum; 2. Head of the femur; 3. Greater trochanter; 4. Femur; 5. Patella; 6. Lateral sesamoid; 7. Lateral condyle of the femur; 8. Medial condyle of the femur; 9. Fibula; 10. Tibia; 11. Calcaneus; 12. Talus; 13. Metatarsal of the 2nd digit; 14. Metatarsal of the 3rd digit; 15. Metatarsal of the 4th digit; 16. Middle phalanx of the 2nd digit; 17. Proximal phalanx of the 3rd digit; 18. Middle phalanx of the 4th digit.

4. DISCUSSION

The cranial conformation observed in the guinea pigs of this study was consistent with previous descriptions by Silverman and Tell (2005) and Boehmer and Crossley (2009), being characterized by a relatively small skull, thin osseous structures, and wide zygomatic arches. The angular process of the mandible extended caudally to the level of the atlanto-occipital joint, representing a distinctive morphological feature of the species.

The nasal sinuses appeared narrow, and the nasal septum was well defined, resembling the pattern described in chinchillas and rats, differing from that observed in rabbits, which exhibit wider sinuses (Brenner et al., 2005; Phillips

et al., 2009). The frontal sinuses, in contrast, were not clearly identifiable on radiographic images, a finding that corroborates the observations of Silverman and Tell (2005), who described these structures as rudimentary in this species.

The tympanic bullae appeared relatively large and well delineated on radiographic examination, in agreement with the descriptions provided by Krautwald-Junghanns et al. (2011) and similar to chinchillas, and in contrast to those observed in rabbits and rats, in which these structures are proportionally smaller (Brenner et al., 2005; Silverman & Tell 2005).

Radiographic evaluation of the skull in *Cavia porcellus* is clinically relevant, given the high prevalence of dental disorders and malocclusion in this species (Quesenberry et al., 2021). The anatomical structures visualized in the lateral and dorsoventral projections enable detailed assessment of osseous and dental morphology, thereby providing a foundation for clinical applications and future comparative anatomical studies.

Radiographic evaluation of the vertebral column in guinea pigs allowed identification of the cervical, thoracic, lumbar, sacral, and caudal segments, with anatomical alignment consistent with the descriptions provided by Silverman and Tell (2005). The vertebral arrangement exhibited smooth physiological curvatures and predominantly rectangular vertebral bodies, with no evidence of vertebral fusion or structural deviation.

In the cervical column, mild lordosis and spinous processes with limited projection were observed, findings consistent with those reported by Yaghobzadeh et al. (2025). The thoracic vertebrae exhibited elongated spinous processes oriented caudally, whereas the lumbar vertebrae showed broad and well-defined transverse processes, in agreement with the observations of Asl et al. (2025). The thoracic skeletal components, including the vertebrae, ribs, and sternum, demonstrated morphology consistent with previous anatomical descriptions. Guinea pigs possess 13 thoracic vertebrae associated with 13 pairs of ribs, a number comparable to that reported in rabbits and rats (Silverman & Tell, 2005; Krautwald-Junghanns et al., 2011). In contrast, chinchillas have 14 thoracic vertebrae (Özkadif et al., 2017). The regular rib arrangement and sternovertebral alignment are consistent with the typical pattern described for small mammals, with no marked morphological variation.

Cavia porcellus has six lumbar vertebrae, similar to chinchillas and fewer

than those reported for rats and rabbits, which typically have seven. In contrast, both rabbits, guinea pigs and rats have four sacral vertebrae, exceeding the number observed in chinchillas, which generally present two (Silverman & Tell, 2005; Krautwald-Junghanns et al., 2011; Özkadif et al., 2017; Soroori, 2022).

The lumbosacral region exhibited a gradual anatomical transition, characterized by partial fusion of the sacral vertebrae and widening of the sacral wings, a feature also described by Goli et al. (2025). Three-dimensional reconstructions allowed precise visualization of this region, reinforcing the applicability of CT for detailed morphological assessment of the axial skeleton in this species.

Radiographically, the intervertebral joints and the vertebral contour lines appeared regular and well-delineated, with no significant anatomical variations observed among the evaluated specimens. These findings reinforce the normality parameters described in the literature and contribute to the recognition of the anatomical particularities of the species in comparative and clinical studies (Silverman & Tell, 2005; Krautwald-Junghanns et al., 2011; Quesenberry et al., 2021; Yaghobzadeh et al., 2025; Asl et al., 2025; Goli et al., 2025).

The radiographic and CT images demonstrated an elongated and well-defined acromion scapulae in guinea pigs, a feature comparable to that observed in rabbits and distinct from rats and chinchillas, in which this structure is proportionally shorter (Silverman & Tell, 2005; Krautwald-Junghanns et al., 2011). The tuberculum majus and tuberculum minus of the humerus appeared discretely developed, a finding that is also consistent with descriptions reported for lagomorphs (Silverman & Tell, 2005).

The clavicle appeared predominantly cartilaginous yet radiographically identifiable, as previously reported by Silverman & Tell (2005), exhibiting a morphology comparable to that described in rabbits and chinchillas (Silverman & Tell, 2005).

The thoracic limbs of the guinea pig present four digits, in contrast to rabbits, chinchillas and rats, which typically possess five (Silverman & Tell, 2005; Valadares et al., 2018; Barbera et al., 2019). This reduction in the number of digits is regarded as an evolutionary adaptation of the species and was clearly demonstrated in the three-dimensional reconstructions obtained in the present study.

The pelvis of the guinea pigs exhibited a short and rounded conformation, comparable to that observed in chinchillas, although less elongated than in rabbits and rats (Silverman & Tell, 2005; Quesenberry et al., 2021). The angle between the wing of the ilium and the sacrum appeared more open, similar to chinchillas, than that described for other species, giving the pelvis a wider appearance (Silverman & Tell, 2005; Quesenberry et al., 2021).

The guinea pig patella appeared relatively wider than that observed in the previously compared species, in which this bone typically exhibits a more elongated morphology (Silverman & Tell, 2005).

In the pelvic limbs, three digits were observed. This finding contrasts with the typical digital pattern reported for rabbits and chinchillas, which generally present four digits, and for rats, which characteristically exhibit five (Silverman & Tell, 2005; Valladares et al., 2018; Barbera et al., 2019). This characteristic, also reported by Barbera et al. (2019), was confirmed by the three-dimensional reconstructions obtained in this study, further supporting the applicability of CT in the morphological characterization of the species.

CT proved highly valuable for anatomical characterization of the axial and appendicular skeletons of guinea pigs, enabling high-resolution three-dimensional visualization of osseous structures and precise tissue differentiation. The availability of multiplanar and three-dimensional reconstructions allowed detailed assessment of bone conformations and articular surfaces, particularly of the shoulder, elbow, hip, and stifle joints, confirming the applicability of this technique for comparative anatomical and diagnostic imaging studies.

According to Krautwald-Junghanns et al. (2011) and Mahdy (2022), CT provides complementary information to conventional radiography by overcoming limitations related to structural superimposition and reduced discrimination of tissue densities. In the specimens evaluated in the present study, CT enabled clear delineation of the boundaries between adjacent bones, cranial sutures, vertebral joints, and osseous cavities, thereby offering a more accurate representation of three-dimensional anatomy.

The obtained images demonstrated high definition of bone margins and articular surfaces, particularly in anatomically complex regions such as the skull, pelvis, shoulder, elbow, and stifle, consistent with findings reported by Mahdy (2022). The tomographic technique enabled identification of subtle individual

anatomical variations without structural abnormalities, reinforcing CT as a reference method for morphological studies and establishing normality standards in small mammals (Yaghobzadeh et al., 2025; Asl et al., 2025; Goli et al., 2025).

The integration of radiography and computed tomography provided comprehensive analysis of the axial and appendicular skeletons, establishing a foundation for future clinical, diagnostic, and comparative anatomy applications in *Cavia porcellus*.

5. CONCLUSION

The images obtained enabled detailed identification of osseous and articular structures, contributing to the establishment of reference parameters for normality and advancing anatomical and radiological knowledge of the species.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

6. REFERENCES

- Asl, M. M. S., Goodarzi, N., & Soroori, S. (2025). Morphometric and Morphological Study of Thoracic and Lumbar Intervertebral Discs in Guinea Pigs (*Cavia porcellus*). *Anatomia, histologia, embryologia*, 54(1), e70012. <https://doi.org/10.1111/ahe.70012>
- Barbera, A. M., Delaunay, M. G., Dougill, G., & Grant, R. A. (2019). Paw morphology in the domestic guinea pig (*Cavia porcellus*) and brown rat (*Rattus norvegicus*). *The Anatomical Record*, 302(12), 2300–2310. <https://doi.org/10.1002/ar.24271>
- Boehmer, E., & Crossley, D. (2009). Objective interpretation of dental disease in rabbits, guinea pigs and chinchillas: Use of anatomical reference lines. *Tierärztliche Praxis Ausgabe K: Kleintiere/Heimtiere*, 37(4), 250–260. <https://doi.org/10.1055/s-0038-1622802>
- Brenner, S. Z. G., Hawkins, M. G., Tell, L. A., Hornof, W. J., Plopper, C. G., & Verstraete, F. J. M. (2005). Clinical anatomy, radiography, and computed tomography of the chinchilla skull. *Compendium on Continuing Education for the Practising Veterinarian – North American Edition*, 27(12), 933–942.
- Carpenter, J. W., & Harms, C. A. (2022). *Exotic animal formulary* (6th ed.). Elsevier.
- Coulson, A., & Lewis, N. (2008). *An atlas of interpretative radiographic anatomy of the dog and cat* (2nd ed.). Wiley-Blackwell.
- Goli, E., Alizadeh, S., & Hosseini, M. (2025). Morphologic and morphometric study of the lumbosacral vertebrae in guinea pig (*Cavia porcellus*) based on CT scan images. *Iranian Veterinary Journal*, 21(1), 57–72. <https://doi.org/10.22055/ivj.2025.482863.2744>
- Hargaden, M., & Singer, L. (2012). Anatomy, physiology, and behavior. In M. A. Suckow, K. A. Stevens, & R. P. Wilson (Eds.), *The laboratory rabbit, guinea pig, hamster, and other rodents* (pp. 575–602). Academic Press.
- Keeble, E., & Heggie, H. (2012). Mammals: biology and husbandry. In M. Varga, R. Lumbis, & L. Gott (Eds.), *BSAVA manual of exotic pet and wildlife nursing* (pp. 34–57). British Small Animal Veterinary Association.
- Krautwald-Junghanns, M.-E., Dziallas, P., & Reese, S. (2011). Diagnostic imaging in small mammals. In M.-E. Krautwald-Junghanns (Ed.), *Diagnostic imaging of exotic pets* (pp. 85–132). Schlütersche.
- Mahdy M. A. A. (2022). Correlation between computed tomography, magnetic resonance imaging and cross-sectional anatomy of the head of the guinea pig (*Cavia porcellus*, Linnaeus 1758). *Anatomia, histologia, embryologia*, 51(1), 51–61. <https://doi.org/10.1111/ahe.12752>

Özkadif, S., Eken, E., Dayan, M. O., & Beşoluk, K. (2017). Determination of sex-related differences based on 3D reconstruction of the chinchilla (*Chinchilla lanigera*) vertebral column from MDCT scans. *Veterinární Medicina*, 62(4), 204–210. <https://doi.org/10.17221/19/2015-VETMED>

Phillips, J. E., Ji, L., Rivelli, M. A., Chapman, R. W., & Corboz, M. R. (2009). Three-dimensional analysis of rodent paranasal sinus cavities from X-ray computed tomography (CT) scans. *Canadian Journal of Veterinary Research*, 73(3), 205–211. <https://pmc.ncbi.nlm.nih.gov/articles/PMC2705075/>

Thrall, D. E. (2015). *Textbook of veterinary diagnostic radiology* (7th ed.). Elsevier

Quesenberry, K. E., Orcutt, C. J., Mans, C., & Carpenter, J. W. (Eds.). (2021). *Ferrets, rabbits, and rodents: clinical medicine and surgery* (4th ed.). Elsevier.

Silverman, S., & Tell, L. A. (2005). *Radiology of rodents, rabbits, and ferrets*. Saunders.

Soroori, S. , Zehtabvar, O. , Shateri-Amiri, B. , Rostami, A. and Vali, Y. (2022). Computed Tomographic and Morphometric Study of Lumbosacral and Coccygeal Vertebrae in Healthy White New Zealand Rabbit (*Oryctolagus Cuniculus*). *Iranian Journal of Veterinary Surgery*, 17(1), 55-61. doi: 10.30500/ivsa.2022.321066.1288

Valladares F., P., Spotorno, Á. E., Cortes M., A., & Zuleta R., C. (2018). Chinchilla chinchilla (Rodentia: Chinchillidae). *Mammalian Species*, 50(960), 51–58. <https://doi.org/10.1093/mspecies/sey007>

Witkowska, A., Alibhai, A., Hughes, C., Price, J., Klisch, K., Sturrock, C. J., & Rutland, C. S. (2014). Computed tomography analysis of guinea pig bone: architecture, bone thickness and dimensions throughout development. *PeerJ*, 2, e615. <https://doi.org/10.7717/peerj.615>

Yaghobzadeh, Z., Hosseini, M., & Alizadeh, S. (2025). Radioanatomical study of guinea pig cervical vertebrae based on CT scan findings. *Iranian Journal of Veterinary Clinical Sciences*, 19(1), 21–35. <https://doi.org/10.22034/ijvcs.2025.15053.1119>

CAPÍTULO 3

ARTIGO CIENTÍFICO 2

Guinea Pig (*Cavia porcellus*) Radiographic and Tomographic Anatomical Atlas of Thorax: Correlation Between Imaging Modalities.

Periódico a ser enviado: Anatomia, Histologia, Embryologia

<https://onlinelibrary.wiley.com/page/journal/14390264/homepage/forauthors.html>

Monteiro, M.S.V^{1*}; Silva, J.P.¹; Ichikawa, R.S¹; Rahal; S.C.¹; Suzuki; F.S.F.²; Camargo; R.F³; Mamprim; M.J¹.

¹ Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu, São Paulo, Brazil

² Department of Clinic, Surgery and Animal Reproduction, Faculty of Veterinary Medicine of Araçatuba, São Paulo State University (UNESP), Araçatuba, São Paulo, Brazil

³ Centro de Diagnóstico Veterinário - CEDIVet, Rio Claro, São Paulo, Brazil.

Acknowledgments

The authors thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for financial support and the CEDIVET team for their assistance in conducting the examinations. This study was financed, in part, by the São Paulo Research Foundation (FAPESP), Brazil. Process Number FAPESP nº 2023/16693-7, and FINEP (Financiadora de Estudos e Projetos), Process Number 01.12.0530.00.

*Corresponding Author:

E-mail: matheus.serrano@unesp.br (M.S.V. Monteiro)

ABSTRACT

The present study aimed to characterize and correlate the thoracic anatomy of guinea pigs (*Cavia porcellus*) using radiography and computed tomography (CT), with the objective of developing an anatomical reference atlas for the species. Five clinically healthy adult male animals were included, subjected to a four-hour fast and a single sedation protocol with ketamine (30 mg/kg, IM) and diazepam (3 mg/kg, IM). Radiographic examinations were performed in right lateral and ventrodorsal projections, while CT images were acquired in transverse, sagittal, and dorsal planes with a slice thickness of one mm. Radiographically, the thorax appeared proportionally small, with a globular and centrally positioned cardiac silhouette occupying approximately three intercostal spaces, narrow and symmetrical lung fields, and a poorly delineated mediastinum. CT allowed detailed three-dimensional visualization of the pulmonary lobes, great vessels, diaphragmatic crura, and costovertebral joints. Pulmonary parenchyma showed mean attenuation values ranging from –350 to –600 HU, consistent with normal aeration. In conclusion, the integration of radiography and CT provides detailed thoracic anatomical characterization in *Cavia porcellus*, enabling correlation between imaging modalities and establishing reference parameters applicable to clinical practice and diagnostic imaging in small mammals.

Keywords: Radiography; Tomography; Anatomy, Comparative; Thoracic Cavity

1. INTRODUCTION

The thoracic anatomy of guinea pigs (*Cavia porcellus*), rodents of the order Rodentia and family Caviidae, exhibits distinct characteristics that differ substantially from those observed in other small mammals (Krautwald-Junghanns et al., 2011). With body weights ranging from 700 to 1,200 g and a life expectancy of up to eight years, these animals present a proportionally reduced thoracic cavity relative to body size, which accommodates vital structures such as the heart, lungs, trachea, and great vessels (Hargaden & Singer, 2012). The increasing interest in guinea pigs as companion animals underscores the importance of detailed anatomical investigations to support accurate interpretation of imaging findings and improve the clinical diagnosis of thoracic disorders (Krautwald-Junghanns et al., 2011).

Accurate knowledge of thoracic morphology is essential for evaluating cardiopulmonary and mediastinal structures, particularly in species with a constrained thoracic cavity, such as *Cavia porcellus*. Respiratory disorders are reported to be prevalent in this species (Yarto-Jaramillo, 2011; Garcia et al., 2021). This underscores the necessity for detailed anatomical characterization to enable precise clinical and radiological assessment. Anatomical information obtained via diagnostic imaging not only facilitates the establishment of normal reference parameters but also supports the early detection of thoracic abnormalities (Redrobe, 2001; Thrall, 2015).

Among the complementary diagnostic tools used for thoracic evaluation, radiography and computed tomography (CT) are particularly valuable, as they enable detailed visualization of anatomical structures and provide critical information for the diagnosis and monitoring of thoracic disorders (Krautwald-Junghanns et al., 2011).

Radiography, a widely available and low-cost technique, is a first-choice tool in veterinary clinical practice (Krautwald-Junghanns et al., 2011). In *Cavia porcellus*, it is used both as a screening test and as a complementary method for assessing thoracic structures (Yarto-Jaramillo, 2011). Previous studies include the anatomical descriptions performed by Krautwald-Junghanns et al. (2011); the cardiac morphometric characterization described by De Silva et al. (2022); the normality indices for vertebral heart size established by Masoudifard et al. (2021);

and the correlation between radiographic and echocardiographic findings reported by Rosas-Navarro et al. (2023).

CT enables the three-dimensional reconstruction of anatomical structures from multiplanar images, allowing for a more precise and detailed assessment of the thoracic cavities, especially in cases of pulmonary or cardiovascular alterations (Schwarz & Saunders, 2011; Thrall, 2015). In guinea pigs, thoracic CT has been employed in both anatomical and clinical investigations, including the topographic characterization of the lungs, trachea, and bronchi described by Zehtabvar et al. (2023), the identification of vascular anomalies reported by Costas et al. (2024), and the documentation of bacterial pulmonary consolidation presented by Minich et al. (2022).

The objective of this study was to describe and correlate the thoracic anatomical structures of *Cavia porcellus* using radiography and CT, with the aim of developing a reference anatomical atlas for the species.

2. MATERIAL AND METHODS

2.1 Animals and Ethical Considerations

The present study was conducted in accordance with the ethical guidelines established by the National Council for the Control of Animal Experimentation (CONCEA) and was approved by the Ethics Committee on the Use of Animals (CEUA).

Five adult male guinea pigs (*Cavia porcellus*) were included in the experiment and were considered clinically healthy based on a complete physical examination. The animals had a mean body weight of approximately 750 g and physiological parameters consistent with the species' reference values (Keeble & Heggie, 2012). For the imaging procedures, a four-hour fast was adopted to ensure adequate restraint and the quality of the radiographic and tomographic acquisitions.

2.2 Anesthetic Protocol

Radiography and computed tomography examinations were performed under general anesthesia using a single sedation protocol. The anesthetic protocol consisted of intramuscular administration of ketamine (30 mg/kg) combined with diazepam (3 mg/kg), with animals maintained under spontaneous breathing as described by Carpenter and Marion (2018).

2.3 Image Acquisition

2.3.1 Radiography

Radiographic examinations were performed under the sedation protocol previously described. Standard lateral and ventrodorsal projections were obtained, encompassing the entire thoracic cavity. Images were acquired using a Shimadzu FXRD-4343VAW radiographic unit with exposure parameters of 40 kV, 400 mA, and an exposure time of 0.16 s, at a focal-to-film distance of 80 cm.

The obtained images were analyzed using eFilm 3.4 Dicom Viewer software.

2.3.2 Computed Tomography

The animals underwent tomographic examination using a Canon Aquilion Start 20 MHU TSX scanner, with the individuals positioned in ventral decubitus, with the thorax centered in the examination field. Acquisition was performed with parameters of 120 kVp, 70 mA, a pitch of 1, 1 s/rotation, and a slice thickness of 1 mm for evaluated segment.

Images were reconstructed in the transverse, sagittal, and dorsal planes using lung and soft-tissue windows. The reconstructions were processed and analyzed using RadiAnt DICOM Viewer 2020.2.

2.4 Imaging Analysis

Image interpretation used a descriptive and comparative method, covering key thoracic structures such as the heart, lungs, trachea, bronchi, ribs, sternum, thoracic vertebrae, and diaphragm.

Characteristics such as contours, symmetry, radiopacity/density, and anatomical references between organs and osseous structures were evaluated. Additionally, cardiac anatomical measurements were obtained from lateral and ventrodorsal radiographs, including the number of intercostal spaces occupied by the cardiac silhouette and the position of the cardiac apex relative to the midline and sternum.

Computed tomography evaluation involved identifying the great vessels and assessing the spatial relationships between the heart and lungs to establish three-dimensional anatomical correlations across imaging modalities.

Representative images were selected, identified, and labeled to compose a comparative anatomical atlas of the *Cavia porcellus* thorax.

3. RESULTS

On the radiographic images, the cardiac contour was oval, occupying approximately three intercostal spaces and located between the third and sixth intercostal spaces. The cardiac axis appeared cranioventrally oriented in the right lateral-lateral projection and was slightly displaced to the left in the ventrodorsal projection. The cardiac silhouette exhibited regular margins and homogeneous radiopacity.

In CT, the heart was identified as a structure of intermediate density, bounded by the middle mediastinum and the pulmonary lobes. The ascending aorta, descending aorta, pulmonary trunk, and vena cava were partially distinguishable.

The lung appeared symmetrically aerated on radiographs, with homogeneous radiolucency and well-defined cranial boundaries by the thoracic wall and caudal boundaries by the diaphragmatic dome. Bronchovascular markings were evident in the perihilar regions.

On CT, the right and left pulmonary lobes were identified, each with specific anatomical distributions: the right lung comprised the cranial, middle, caudal, and accessory lobes, while the left lung consisted of the cranial, middle, and caudal lobes. The pulmonary parenchyma exhibited a mean density ranging from -350 to -600 HU, with areas of atelectasis present.

In the lateral projection, the trachea appeared straight, with a well-defined air-filled lumen, extending dorsally to the heart and bifurcating at the level of the cardiac base.

On CT, the trachea appears as a hypodense tubular structure with mildly hyperattenuating cartilaginous walls and a clear bifurcation into the right and left main bronchi, which are directed ventrally toward their respective pulmonary lobes.

The mediastinum was identified on radiographs as a band of soft-tissue radiopacity in the cranial and central regions, delimiting the cranial lung fields. On tomographic images, the cranial, middle, and caudal mediastinum were observed, containing structures such as the heart, great vessels, and trachea.

The diaphragm showed a convex shape with a well-defined dome, located roughly at the seventh intercostal space on the lateral radiograph. On tomographic images, the diaphragmatic crura were clearly visible, allowing for distinction between the thoracic and abdominal cavities.

The ribs and thoracic vertebrae were visualized with homogeneous bone radiopacity and regular interspaces in both radiographic projections. The sternum appeared well-aligned with the vertebral column.

On CT, the ribs, sternum, and thoracic vertebrae were visualized in greater detail, enabling assessment of three-dimensional bone morphology and the costovertebral articulation. The thoracic wall exhibited uniform thickness and density consistent with muscle tissue, without asymmetries.

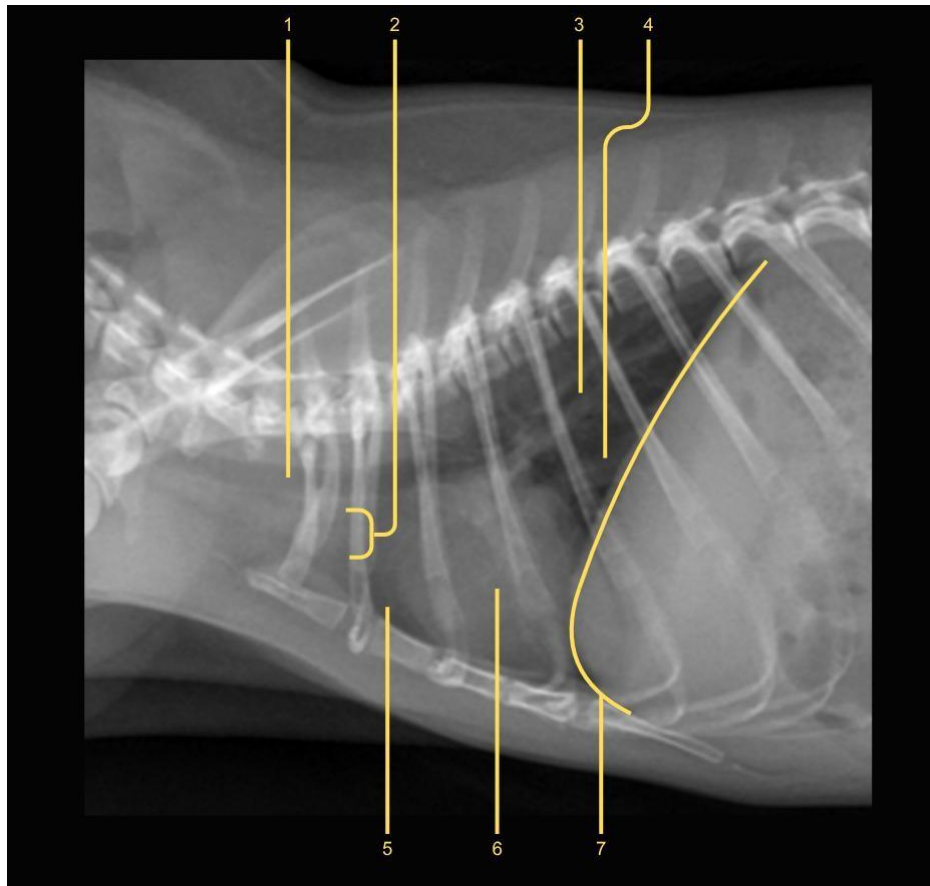


Figure 1. Radiographic image in lateral projection of the thoracic cavity of a healthy adult guinea pig. 1. Trachea; 2. Cranial mediastinum; 3. Caudodorsal lung fields; 4. Caudal vena cava; 5. Cranioventral lung fields; 6. Cardiac silhouette; 7. Diaphragmatic crura.

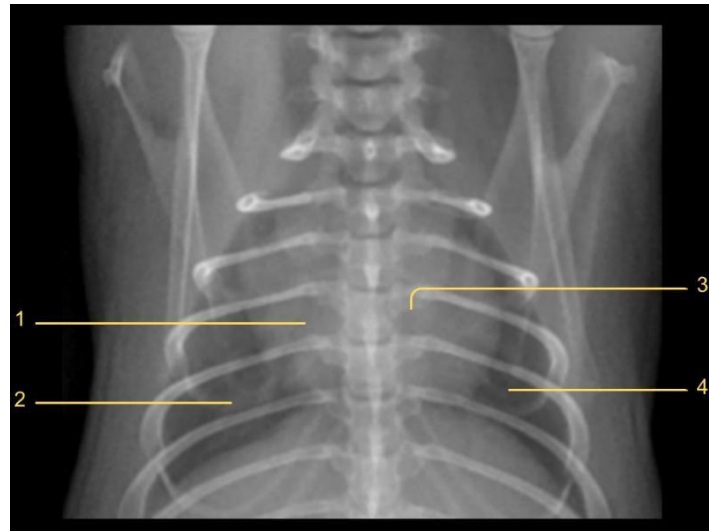


Figure 2. Radiographic image in ventrodorsal projection of the thoracic cavity of a healthy adult guinea pig. 1. Right primary bronchus; 2. Right caudal lung field; 3. Cardiac silhouette; 4. Left caudal lung field.

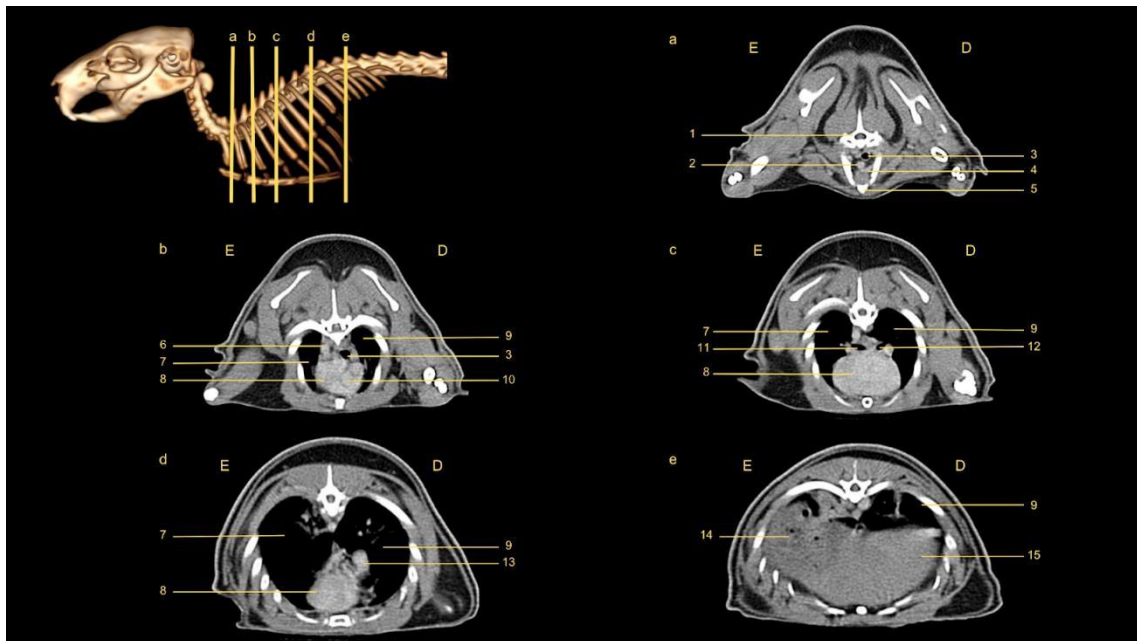


Figure 3. Axial computed tomography image of the thorax (soft-tissue window) of a healthy adult guinea pig. Slice locations are marked on the 3D reconstruction image. 1. 1st thoracic vertebra; 2. Brachiocephalic trunk; 3. Trachea; 4. Subclavian artery; 5. Manubrium; 6. Descending aorta; 7. Left lung; 8. Heart; 9. Right lung; 10. Ascending aorta; 11. Left primary bronchus; 12. Right primary bronchus; 13. Caudal vena cava; 14. Stomach; 15. Liver.

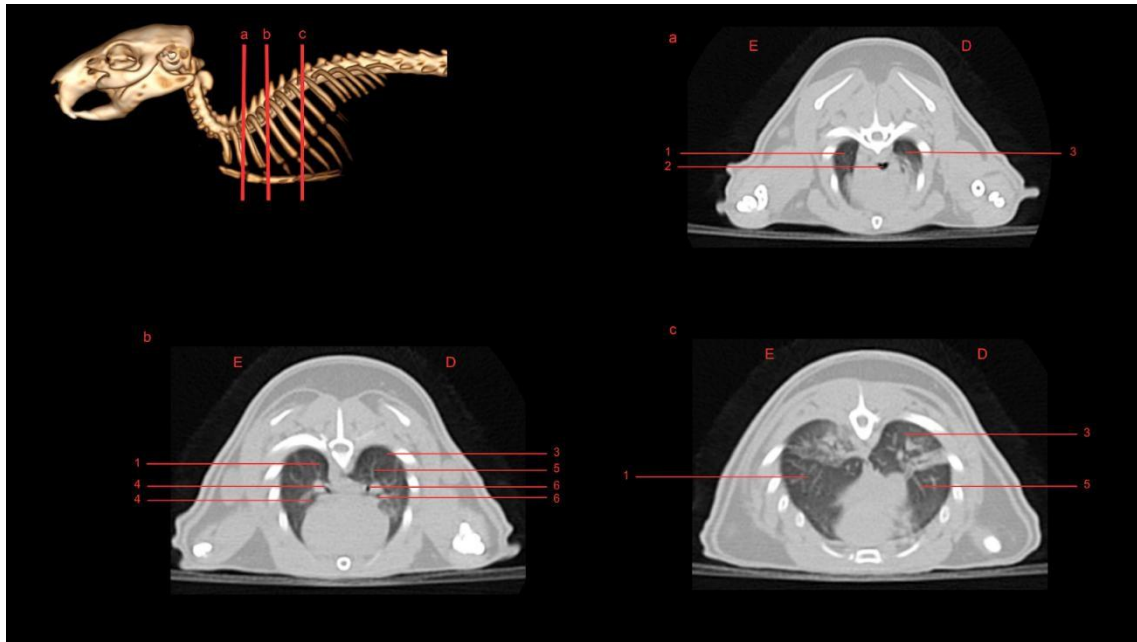


Figure 4. Axial computed tomography image of the thorax (lung window) of a healthy adult guinea pig. Slice locations are marked on the 3D reconstruction image. 1. Left pulmonary parenchyma; 2. Carina; 3. Right pulmonary parenchyma; 4. Left secondary bronchus; 5. Pulmonary vessel; 6. Right secondary bronchus.

4. DISCUSSION

The guinea pig's thorax is proportionally small compared to its body, accounting for about one-fifth of the abdominal volume, which aligns with previous descriptions by Krautwald-Junghanns et al. (2011) and Zehtabvar et al. (2023). This characteristic, combined with the heart's central position and large size, limits the space available for the lung fields and complicates radiographic interpretation of the thoracic cavity. This constraint is similar to what observed in rabbits, but it is more noticeable in guinea pigs due to their smaller thoracic structure (Redrobe, 2001).

The heart appeared globose and centrally located, occupying approximately three intercostal spaces, a finding consistent with descriptions by Masoudifard et al. (2021) and De Silva et al. (2022). This shape differs from that seen in rabbits, where the heart is more elongated and shifted to the left (Silverman & Tell, 2005). In contrast, in rats and chinchillas, the heart is oval-shaped with a narrow apex oriented to the left (Doss et al., 2017; Rekabdar et al., 2024). These morphological differences highlight the importance of establishing species-specific reference values for cardiac assessment in small mammals.

CT provided visualization of the major thoracic vessels, especially the ascending aorta and pulmonary trunk, corroborating previously reported anatomical findings by Zehtabvar et al. (2023).

Atelectasis in lung regions is a common finding in CT studies of small mammals under anesthesia, particularly when animals are maintained with spontaneous breathing. The combination of positional factors and lack of positive pressure ventilation contributes to hypoventilation of dependent lung areas, resulting in increased attenuation and loss of lung volume in these regions (Müllhaupt et al., 2017).

The lung fields of guinea pigs are symmetrical and proportionally smaller than those of other small species due to the limited space of the thoracic cavity (Silverman & Tell, 2005). The lobar distribution observed on CT, with four lobes in the right lung (cranial, middle, caudal, and accessory) and three in the left (cranial, middle, and caudal), is in agreement with Zehtabvar et al. (2023). Chinchillas exhibit a different pulmonary lobulation pattern, with the right lung divided into three lobes (cranial, caudal, and accessory) and the left lung composed of four lobes (cranial, middle, caudal, and accessory) (Yarto-Jaramillo, 2011). In contrast, rats present a markedly different arrangement, with the right lung consisting of four lobes (apical, cardiac, diaphragmatic, and accessory), while the left lung lacks distinct lobulation and comprises only one lobe (Rekabdar et al., 2024). Notably, in both rabbits and guinea pigs, the visceral pleura or pleural fissure lines are rarely visible on CT images, making lobe identification possible only through visualization of lobar bronchi and accompanying pulmonary vessels (Müllhaupt et al., 2017; Zehtabvar et al., 2023).

The average pulmonary density measured is consistent with aerated lung tissue and supports the use of CT for morphometric assessment in small mammals.

The mediastinum appeared narrow and radiopaque on radiographs, indicating the small amount of mediastinal fat and the overlap of structures within the thoracic cavity (Thrall, 2015). Similar to rabbits, differentiating its subdivisions (cranial, middle, and caudal) is not clear on conventional radiographs. It is better observed with tomography, which helps identify the heart, trachea, bronchi, and

great vessels (Zehtabvar et al., 2023). In rabbits, all three lobes of the thymus were identified in the cranial and middle mediastinum using CT (Müllhaupt et al., 2017). An important anatomical distinction in guinea pigs is that the thymus is located surrounding the trachea rather than lying within the thoracic cavity as observed in other rodent species, including chinchillas (Yarto-Jaramillo, 2011). This unique thymic positioning may contribute to the narrow radiographic appearance of the mediastinum in guinea pigs.

The diaphragm presented a convex contour and a position similar to that described in rabbits, rats and chinchillas (Krautwald-Junghanns et al., 2011; Yarto-Jaramillo, 2011), clearly delimiting the thoracic and abdominal cavities. On tomography, the diaphragmatic crura were clearly visualized, standing out as an anatomical reference for sectional planes and three-dimensional reconstructions.

The integration of radiographic and tomographic findings enabled a comprehensive characterization of thoracic anatomy in *Cavia porcellus*, demonstrating the superior diagnostic value of computed tomography for detailed evaluation of cardiopulmonary and mediastinal structures. These findings establish foundational anatomical reference data essential for accurate diagnostic interpretation and clinical decision-making in exotic animal medicine.

5. CONCLUSION

The findings allow the establishment of normality parameters, essential for distinguishing normal variations from pathological processes.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

6. REFERENCES

- Costas, A., Battiato, P., Magro, C., & Cervera, V. (2024). CT findings of an incidental segmental aplasia of the caudal vena cava with azygos continuation in a guinea pig (*Cavia porcellus*). *Open Veterinary Journal*, 14(4), 1076–1080. <https://doi.org/10.5455/OVJ.2024.v14.i4.15>
- Coulson, J. D., & Lewis, N. (2008). The thoracic radiograph. In J. K. Kealy, H. McAllister, & J. P. Graham (Eds.), *Diagnostic radiology and ultrasonography of the dog and cat* (5th ed., pp. 37–63). Saunders Elsevier
- De Silva, M., Bo, P., Genocchi, E. D., Tagliavia, C., Roccaro, M., Grandis, A., & Baron Toaldo, M. (2022). Radiographic and anatomical morphometric assessments of heart size in presumed healthy pet guinea pigs (*Cavia porcellus*). *Veterinary Radiology & Ultrasound*, 63(1), 8–17. <https://doi.org/10.1111/vru.13020>
- Doss, G. A., Mans, C., Hoey, S., Di Girolamo, N., Stepien, R. L., & Waller III, K. R. (2017). Vertebral heart size in chinchillas (*Chinchilla lanigera*) using radiography and CT. *Journal of Small Animal Practice*, 58(12), 1–6. <https://doi.org/10.1111/jsap.12715>
- García, M. A., Barceló, A. M., Nadeu, C. B., & Jekl, V. (2021). Respiratory diseases in guinea pigs, chinchillas and degus. *Veterinary Clinics of North America: Exotic Animal Practice*, 24(2), 419–457. <https://doi.org/10.1016/j.cvex.2021.02.001>
- Hargaden, M., & Singer, L. (2012). Anatomy, physiology, and behavior. In M. A. Suckow, K. A. Stevens, & R. P. Wilson (Eds.), *The laboratory rabbit, guinea pig, hamster, and other rodents* (pp. 575–602). Academic Press.
- Keeble, E., & Heggie, H. (2012). Mammals: biology and husbandry. In M. Varga, R. Lumbis, & L. Gott (Eds.), *BSAVA manual of exotic pet and wildlife nursing* (pp. 34–57). British Small Animal Veterinary Association.
- Krautwald-Junghanns, M.-E., Dziallas, P., & Reese, S. (2011). Diagnostic imaging in small mammals. In M.-E. Krautwald-Junghanns (Ed.), *Diagnostic imaging of exotic pets* (pp. 85–132). Schlütersche.
- Masoudifard, M., Rostami, A., Shahmohamadi Nodolaghi, M., Esmailinejad, M. R., & Bahonar, A. (2021). Development and evaluation of methods for vertebral heart score determination in guinea pig (*Cavia porcellus*). *Veterinary research forum : an international quarterly journal*, 12(3), 357–360. <https://doi.org/10.30466/vrf.2020.108629>
- Minich, D. J., Agrawal, A., Kania, S. A., Hespel, A. M., Cushing, A., Meraz, D., & Sheldon, J. (2022). Disseminated *Mycobacterium genavense* infection in a guinea pig (*Cavia porcellus*): a case report. *BMC veterinary research*, 18(1), 93. <https://doi.org/10.1186/s12917-022-03198-4>

Müllhaupt, D., Wenger, S., Kircher, P., Pfammatter, N., Hatt, J.-M., & Ohlerth, S. (2017). Computed tomography of the thorax in rabbits: A prospective study in ten clinically healthy New Zealand White rabbits. *Acta Veterinaria Scandinavica*, 59(1), 72. <https://doi.org/10.1186/s13028-017-0340-x>

Redrobe, S. (2001). Imaging techniques in small mammals. *Seminars in Avian and Exotic Pet Medicine*, 10(4), 187–197. <https://doi.org/10.1053/saep.2001.24677>

Rekabdar, T., Yousefi, M., Masoudifard, M., Zehtabvar, O., & Ahmadpanahi, S. J. (2024). Computed tomographic anatomy and topography of the lower respiratory system of the mature rat (*Rattus norvegicus*). *Archives of Razi Institute*, 79(5), 981-988. <https://doi.org/10.32592/ARI.2024.79.5.981>

Rosas-Navarro, J., Gaillot, H., Agoulon, A., Ferri, C., Ruel, Y., Paoletti, C., Quinton, J., Curros-Moreno, Á., & Gouni, V. (2023). Epidemiological, clinical, radiographic, echocardiographic findings and outcome in client-owned guinea pigs (*Cavia porcellus*) with cardiac disease: 80 cases (2010–2021). *Journal of the American Veterinary Medical Association*, 261(6), 865-873. Retrieved Nov 12, 2025, <https://doi.org/10.2460/javma.22.10.0462>

Schwarz, T., & Saunders, J. (2011). *Veterinary computed tomography*. Wiley-Blackwell.

Silverman, S., & Tell, L. A. (2005). *Radiology of rodents, rabbits, and ferrets*. Saunders.

Thrall, D. E. (2015). *Textbook of veterinary diagnostic radiology* (7th ed.). Elsevier

Yarto-Jaramillo, E. (2011). Respiratory diseases in guinea pigs. In K. E. Quesenberry & J. W. Carpenter (Eds.), *Ferrets, rabbits, and rodents: Clinical medicine and surgery* (3rd ed., pp. 279–286). Elsevier.

Zehtabvar, O., Masoudifard, M., Rostami, A., Akbarein, H., Sereshke, A. H. A., Khanamooeiashi, M., & Borgheie, F. (2023). CT anatomy of the lungs, bronchi, and trachea in the Mature Guinea pig (*Cavia porcellus*). *Veterinary medicine and science*, 9(3), 1179–1193. <https://doi.org/10.1002/vms3.1131>

CAPÍTULO 4

ARTIGO CIENTÍFICO 3

Ultrasonographic Evaluation of the Abdominal Cavity in the Guinea Pig (*Cavia porcellus*): Anatomical Description and Reference Parameters

Periódico a ser enviado: Anatomia, Histologia, Embryologia

<https://onlinelibrary.wiley.com/page/journal/14390264/homepage/forauthors.html>

Monteiro, M.S.V^{1*}; Silva, J.P.¹; Ichikawa, R.S¹; Rahal; S.C.¹; Suzuki; F.S.F.²; Camargo; R.F³; Mamprim; M.J¹.

¹ Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu, São Paulo, Brazil

² Department of Clinic, Surgery and Animal Reproduction, Faculty of Veterinary Medicine of Araçatuba, São Paulo State University (UNESP), Araçatuba, São Paulo, Brazil

³ Centro de Diagnóstico Veterinário - CEDIVet, Rio Claro, São Paulo, Brazil.

Acknowledgments

The authors thank CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for financial support and the CEDIVET team for their assistance in conducting the examinations. This study was financed, in part, by the São Paulo Research Foundation (FAPESP), Brazil. Process Number FAPESP nº 2023/16693-7, and FINEP (Financiadora de Estudos e Projetos), Process Number 01.12.0530.00.

*Corresponding Author:

E-mail: matheus.serrano@unesp.br (M.S.V. Monteiro)

ABSTRACT

The objective of this study was to describe the ultrasonographic characteristics of abdominal structures in *Cavia porcellus* and to establish imaging appearance reference parameters for the species. Five healthy adult males were evaluated and underwent ultrasonographic examination with a 13-18 MHz multifrequency linear transducer. The liver, gallbladder, spleen, kidneys, adrenal glands, pancreas, urinary bladder, gastrointestinal tract, and reproductive system structures were identified and described. Wall thickness measurements of the gallbladder, gastrointestinal tract, and urinary bladder were also performed. Regarding the kidneys, length and width were measured; for the adrenal glands, length and thickness of the cranial and caudal poles were recorded; for the vesicular glands, length, width, and height were measured; and for the testes, length and width were obtained. Pancreatic thickness was measured at the right lobe. The observed echographic features were consistent with those described for small mammals, presenting variations related to anatomical disposition and relative organ echogenicity. This study provides reference parameter data and serves as an anatomical and diagnostic reference for imaging examinations in guinea pigs.

Keywords: Anatomy, Comparative; Diagnostic Imaging; Guinea Pigs; Ultrasonography; Veterinary

1. INTRODUCTION

Guinea pigs present a relatively large abdominal cavity in proportion to their body size, which houses the liver, spleen, gastrointestinal tract and its accessory organs, urinary system, adrenal glands, and reproductive structures (Hargaden & Singer, 2012).

Among diagnostic modalities that complement clinical evaluation, imaging techniques, including radiography, ultrasonography, and computed tomography, play a prominent role in diagnostic assessment (Thrall, 2015). These modalities allow precise visualization of abdominal anatomy, enabling early detection of abnormalities, accurate diagnosis, and therapeutic planning (Krautwald-Junghanns et al., 2011).

In *Cavia porcellus*, ultrasonography has been successfully employed to evaluate multiple abdominal organs, including the kidneys, urinary bladder, liver, spleen, adrenal glands, intestines, and reproductive structures, generally without the need for sedation (Martin et al., 2024).

The ultrasonographic evaluation is primarily hindered by intestinal gas, particularly in the cecum, which may compromise visualization of deeper or retroperitoneal structures (Krautwald-Junghanns et al., 2011). Nonetheless, recent evidence supports the diagnostic reliability and clinical utility of ultrasonography in this species for both the identification and longitudinal monitoring of abdominal pathological conditions, such as urolithiasis, pyometra, and hepatic alterations (Bustolin et al., 2015; Waugh et al., 2021; Azevedo, 2024).

In this context, the present study proposes a detailed ultrasonographic characterization of the *abdomen of Cavia porcellus*, based on images obtained from clinically healthy animals. The aim is to describe normal echographic patterns and compare these characteristics with those of small domestic and exotic animals.

2. MATERIALS AND METHODS

2.1 Animals and Ethical Considerations

The present study was conducted in compliance with the guidelines of the National Council for the Control of Animal Experimentation (CONCEA)

and the Ethics Committee on the Use of Animals (CEUA).

Five clinically healthy adult male guinea pigs (*Cavia porcellus*) were included in the study, with a mean body weight of 750 g. Before the examinations, all individuals underwent a clinical evaluation, with physiological parameters within normal limits, as described by Keeble & Heggie (2012).

The animals were housed under controlled environmental conditions, with ad libitum access to water and a balanced commercial diet. A four-hour fasting period was implemented prior to ultrasonographic examination to reduce intraluminal food material, minimize gas artifacts, and improve image quality.

2.2 Ultrasonographic examination

All ultrasonographic examinations were performed using a Canon Aplio a® ultrasound system equipped with a 13–18 MHz multifrequency linear transducer. Prior to examination, animals were positioned in dorsal recumbency without sedation to ensure stability and comfort during the procedure. A wide abdominal region was clipped, extending from the xiphoid process to the pubic symphysis, followed by cleansing with isopropyl alcohol to remove debris and optimize acoustic contact.

Focal zone depth was adjusted between 1 and 2 cm according to the anatomical structure being evaluated, and a mean gain setting of 85 was maintained throughout the examination. Each ultrasonographic examination lasted approximately 8 minutes per animal.

2.3 Scanning Protocol and Image Evaluation

The ultrasonographic evaluation criteria followed the recommendations of Penninck and D'Anjou (2015), adapted for the species based on the available literature.

- Liver and gallbladder: assessing dimensions, margins, echogenicity, and parenchymal homogeneity; the gallbladder was analyzed regarding its content and wall thickness.
- Kidneys: evaluated bilaterally regarding position, dimensions (length and width), corticomedullary differentiation, and relative echogenicity.
- Adrenal glands: evaluated regarding topography, echogenicity, dimensions, and morphology

- Spleen: assessing the capsule, echotexture, and vascular pattern.
- Gastrointestinal tract: stomach and intestinal segments were evaluated regarding wall thickness, wall layering, degree of distension and luminal content, with particular attention to gas artifacts.
- Urinary bladder: regarding location, content, and wall thickness.
- Male reproductive system: included the analysis of the seminal glands (shape, size, echogenicity, and echotexture) and testes (symmetry, contours, echotexture, and presence of the mediastinal line).

2.4 Statistical analysis

Descriptive analysis of morphometric variables was performed, including linear measurements and qualitative observations of abdominal structures.

Morphometric measurements were assessed for normality using the Shapiro-Wilk test at 5% significance level ($p < 0.05$) in Jamovi® software. Bilateral structures were compared using paired t-test, and measurements were pooled when no significant differences were detected between contralateral organs.

All data followed normal distribution and were reported as mean $\pm$ standard deviation.

3. RESULTS

The following abdominal structures were evaluated in all animals: urinary bladder, seminal glands, testes, kidneys, spleen, liver, gallbladder, pancreas, adrenal glands, and gastrointestinal tract.

The liver was identified in the cranial portion of the abdominal cavity, in contact with the diaphragm and extending caudally past the last rib. The left portion was related to the stomach, and the right portion to the right kidney. The organ presented as isoechoic to slightly hyperechoic relative to the renal cortex, with a homogeneous echotexture and regular margins, allowing visualization of hepatic vessels (Figure 1).

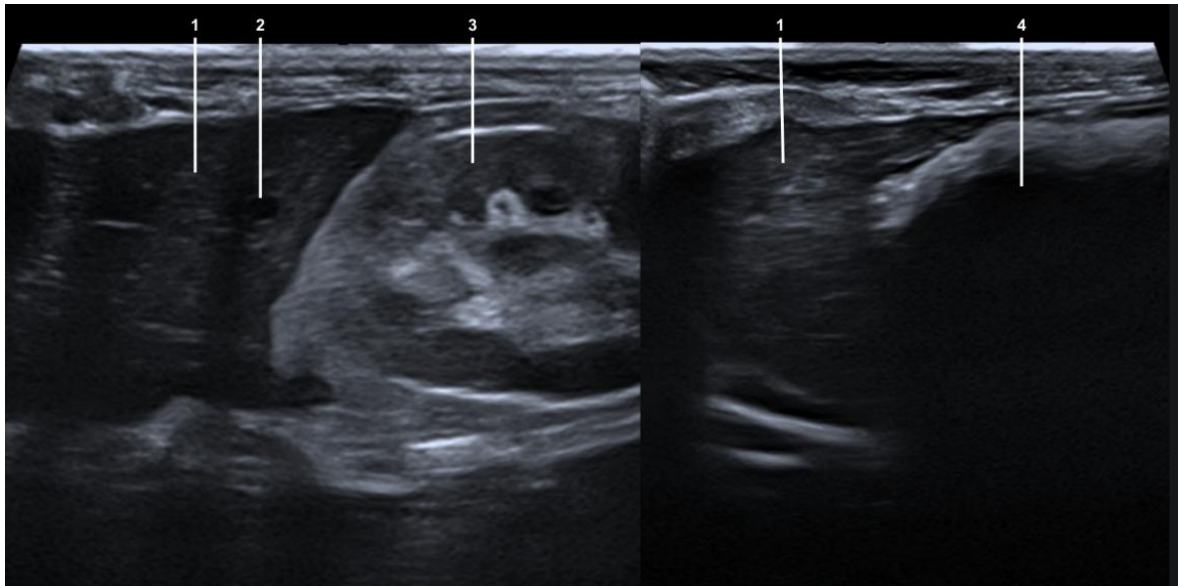


Figure 1. Ultrasonographic images of the liver of a healthy guinea pig in longitudinal view, right side (a) and left side (b). 1. Echogenic parenchyma with smooth and homogeneous echotexture; 2. Intrahepatic vessel; 3. Right kidney; 4. Stomach.

The gallbladder, with a pyriform shape, was located craniomedially to the liver and exhibited a hyperechoic wall with homogeneous anechoic content (Figure 2).

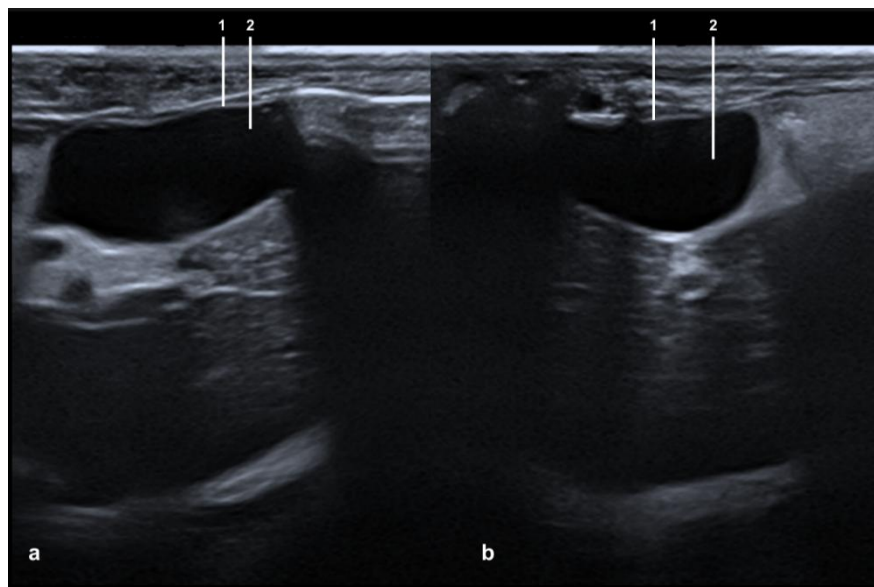


Figure 2. Ultrasonographic image in the longitudinal view (a) and in the transverse view (b) of the gallbladder of a healthy guinea pig. 1. Anechoic and homogeneous content; 2. Smooth and well-defined hyperechoic wall.

The spleen exhibited an ovoid shape and was identified in the left lateral aspect of the abdomen, lateral to the stomach, caudal to the liver, and cranial to the left kidney. It displayed a hyperechoic capsule and homogeneous parenchyma, with echogenicity ranging from isoechoic to

slightly hypoechoic relative to the renal cortex (Figure 3).

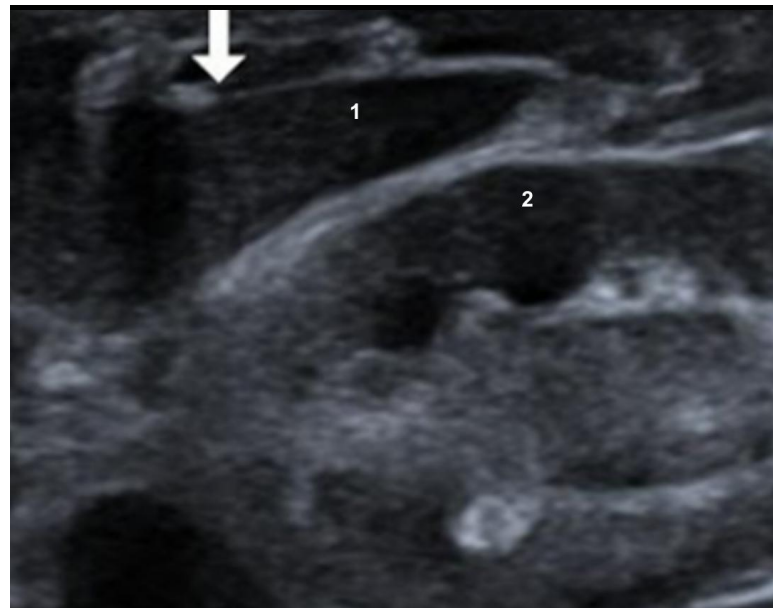


Figure 3. Ultrasonographic image in the longitudinal view of the spleen of a healthy guinea pig.

Thin hyperechoic capsule (white arrow) relative to the parenchyma. 1. Ovoid-shaped splenic parenchyma, discretely hypoechoic relative to the renal cortical region, presenting with smooth and homogeneous echotexture; 2. Renal cortex of the left kidney.

The pancreas was identified by its right (duodenal) lobe, positioned lateral to the abdominal midline, situated between the curvatures of the descending and ascending duodenum. It exhibited an elongated shape and a homogeneous, slightly striated parenchyma, appearing mildly hyperechoic relative to the liver and slightly hypoechoic to the adjacent fat (Figure 4).

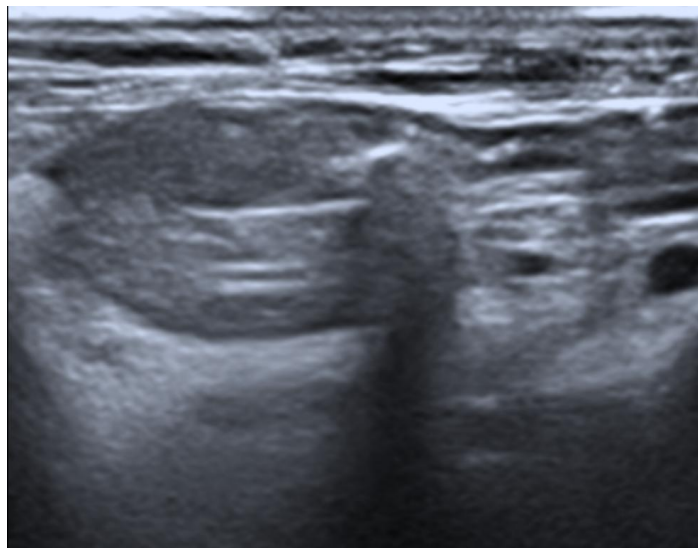


Figure 4. Ultrasonographic image in the longitudinal view of the right lobe of the pancreas of a healthy guinea pig. It presents homogeneous parenchyma that is discretely striated and discretely hypoechoic relative to the adjacent fat.

The stomach was visualized in the craniomedial aspect of the abdomen, caudal to the liver. In all animals, four distinct layers were identified: a hypoechoic mucosa, a hyperechoic submucosa, a hypoechoic muscularis, and a hyperechoic serosa (Figure 5a). Regarding gastric repletion, moderate distension of the gastric cavity was observed in four animals, while one animal exhibited minimal intraluminal content. In the individual with minimal gastric content, reduction in luminal size and difficulty distinguishing the wall layers (Figure 5b) were noted.

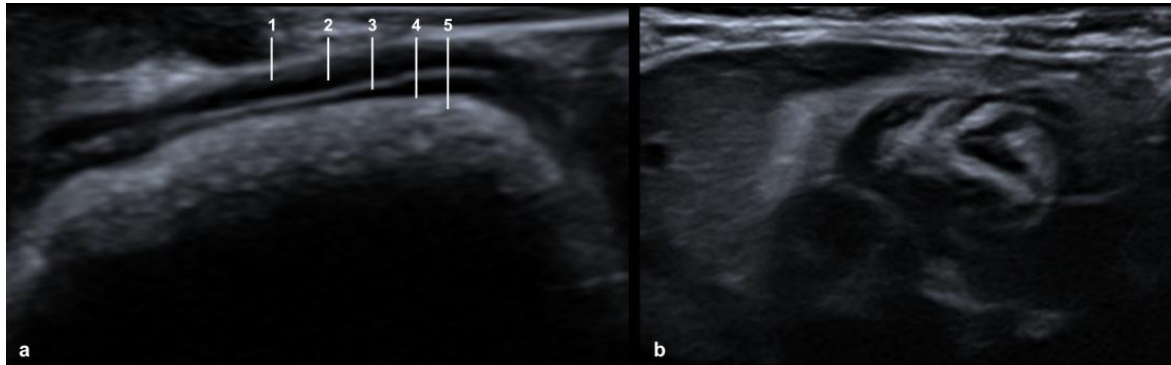


Figure 5. Ultrasonographic image in the longitudinal view of the gastric body with contents (a) and longitudinal view of the gastric body without contents, indicated by white crosses (b), of a healthy guinea pig. 1. Hyperechoic serosa layer; 2. Hypoechoic muscular layer; 3. Hyperechoic submucosal layer; 4. Hypoechoic mucosal layer; 5. Echogenic food content in the gastric lumen.

The duodenum was identified medioventrally to the right kidney (Figure 6a), whereas the jejunum was located cranially and caudally to the left kidney (Figure 6b). Both segments presented wall layers comparable to those of the stomach, with four distinct layers identifiable on ultrasonography. Duodenal luminal content varied among individuals, being absent in three animals, minimal in one, and markedly distended in one case. In the evaluated jejunal segments, diffuse intraluminal content was observed in four animals, while one animal exhibited an empty jejunal lumen.

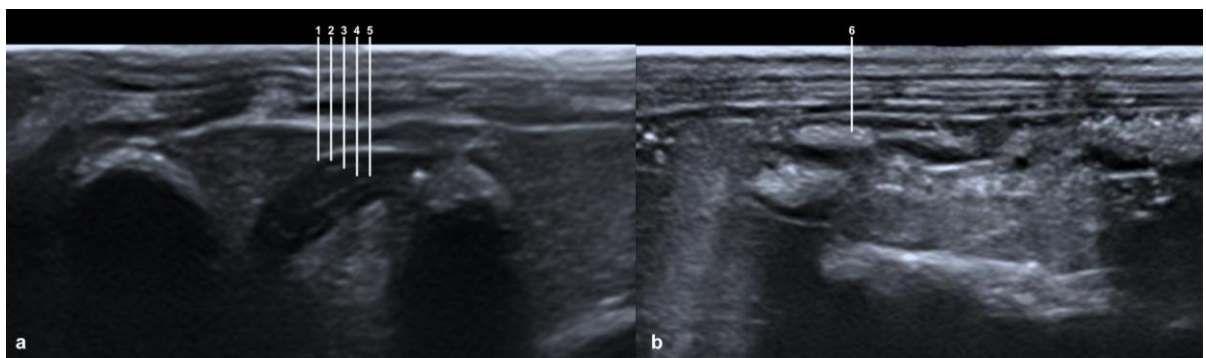


Figure 6. Ultrasonographic image in the longitudinal view of the duodenum without contents (a) and longitudinal view of the jejunum with echogenic food contents (b) of a healthy guinea pig. 1.

Hyperechoic serosa layer; 2. Hypoechoic muscular layer; 3. Hyperechoic submucosal layer; 4. Hypoechoic mucosal layer; 5. Duodenal lumen without contents; 6. Echogenic food contents in the jejunal lumen.

The ileum was identified by the presence of the ileoceccocolic valve, observed as a circular structure in transverse section, located caudal to the right kidney. Its wall layers (mucosa, submucosa, and muscularis) were clearly distinguishable (Figure 7). No echogenic intraluminal content was observed within the ileoceccocolic valve in any of the examined animals.

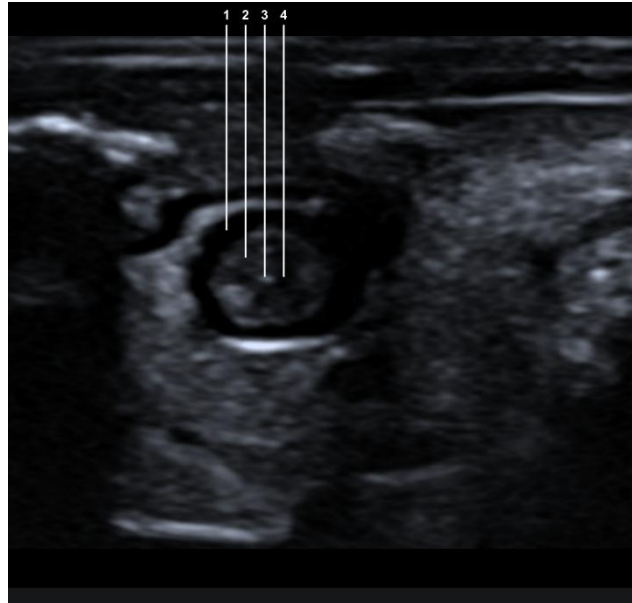


Figure 7. Ultrasonographic image in the transverse view of the ileoceccocolic valve of a healthy guinea pig. 1. Hypoechoic muscular layer; 2. Hyperechoic submucosal layer; 3. Ileoceccocolic valve lumen with discrete gaseous content; 4. Hypoechoic mucosal layer.

The large cecum was located ventrally in the mid-abdomen, exhibiting echogenic and gaseous content with posterior acoustic shadowing. The four typical wall layers were identified, all presenting similar thickness (Figure 8). Four animals exhibited marked cecal distension, while one animal presented reduced cecal filling, which allowed improved visualization of adjacent abdominal structures in the superficial ventral region of the abdomen.

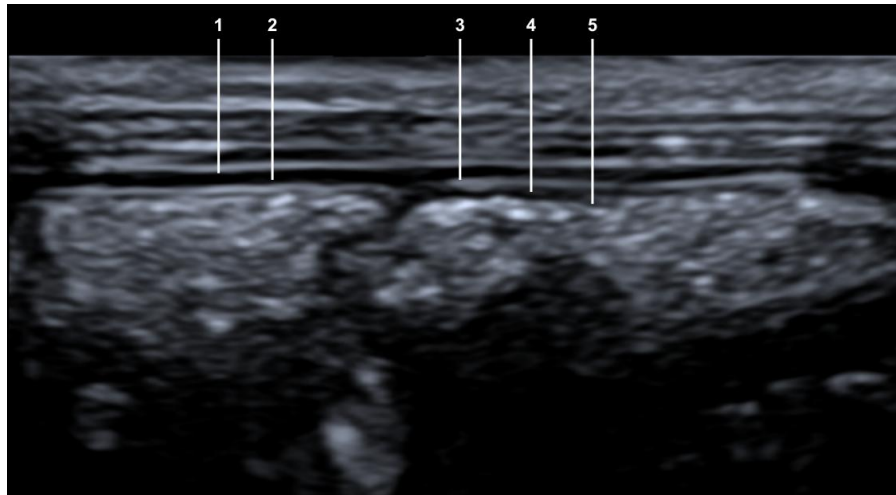


Figure 8. Ultrasonographic image in the longitudinal view of the cecum with contents of a healthy guinea pig. 1. Hyperechoic serosa layer; 2. Hypoechoic muscular layer; 3. Hyperechoic submucosal layer; 4. Hypoechoic mucosal layer; 5. Cecal lumen with echogenic food contents.

Only the descending colon segment was visualized, identified dorsal to the urinary bladder, presenting wall layers similar to those of the cecum (Figure 9). Fecal content was observed in two animals, while three animals exhibited minimal to absent solid content with predominant gas accumulation.

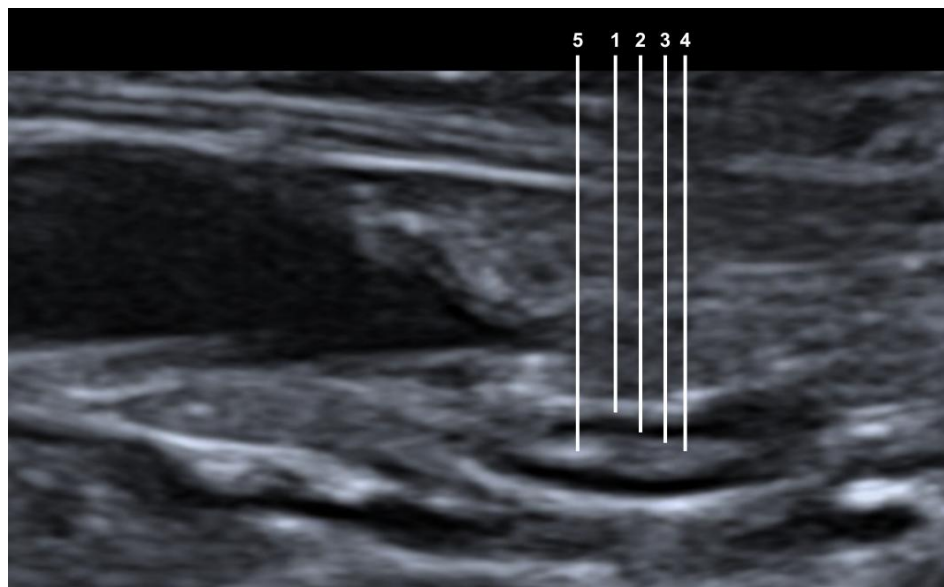


Figure 9. Ultrasonographic image in the longitudinal view of the descending colon of a healthy guinea pig. 1. Hyperechoic serosa layer; 2. Hypoechoic muscular layer; 3. Hyperechoic submucosal layer; 4. Hypoechoic mucosal layer; 5. Descending colon lumen with discrete gaseous content.

The left kidney was identified caudal to the stomach and spleen, while the right kidney was located caudal to the liver, positioned slightly cranial to the left one. Both exhibited distinct differentiation among the

capsule, cortex, medulla, renal crest, and renal sinus.

On longitudinal scans, the renal capsule appeared as a thin, external hyperechoic line. The renal cortex presented a smooth, homogeneous appearance with hypoechoic to isoechoic echogenicity relative to hepatic parenchyma. The medulla demonstrated distinct zonation: the external medulla was uniformly hypoechoic relative to the cortex, while the internal medulla was hyperechoic compared to the cortical region (Figure 10a).

In transverse sections, the renal crest and renal sinus were identified, constituting the renal pelvis. The crest appeared hyperechoic and homogeneous, centrally located, while the renal sinus was smooth and hyperechoic, delimiting the medial aspect of the organ (Figure 10b).

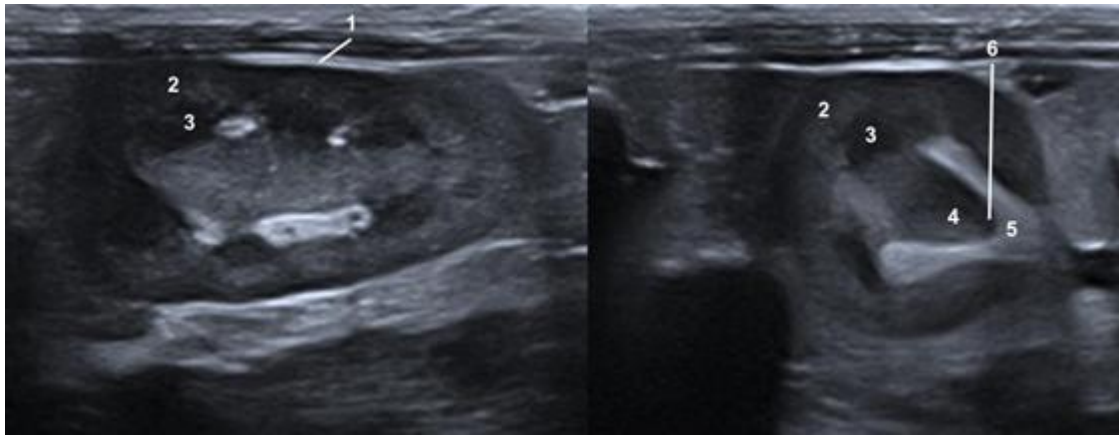


Figure 10. Ultrasonographic image in the longitudinal view (a) and in the transverse view (b) of the left kidney of a healthy guinea pig. 1. Well-defined hyperechoic renal capsule; 2. Echogenic cortical region with smooth and homogeneous echotexture; 3. Medullary region, hypoechoic relative to the cortex, with smooth and homogeneous echotexture; 4. Renal crest, hyperechoic relative to the cortex, with discretely granular and homogeneous echotexture; 5. Renal sinus, hyperechoic relative to the renal crest, with smooth and homogeneous echotexture; 6. Renal pelvis region.

The adrenal glands, located cranial to their respective kidneys, were ovoid and showed a distinct cortical-medullary boundary. The cortex appeared hypoechoic, while the medulla was hyperechoic and centrally located (Figure 11).

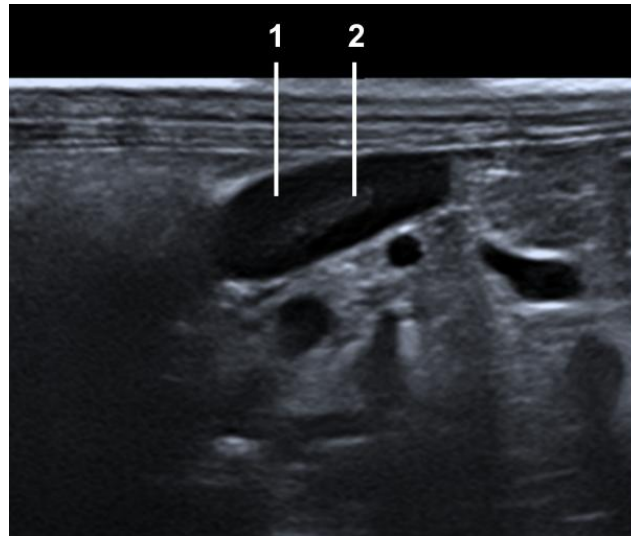


Figure 11. Ultrasonographic image in the longitudinal view of the left adrenal gland of a healthy guinea pig. 1. Cortical region, hypoechoic relative to the medullary region, located in the peripheral area with smooth and homogeneous echotexture; 2. Medullary region, hyperechoic relative to the cortical region, located in the medial area with smooth and homogeneous echotexture.

The urinary bladder was identified in the caudocentral portion of the abdominal cavity, presenting a wall composed of three distinct echographic layers: a hyperechoic inner (luminal) layer, a hypoechoic middle layer, and a hyperechoic outer layer. The bladder content was predominantly anechoic, with mobile echogenic debris compatible with physiological sediment (Figure 12).

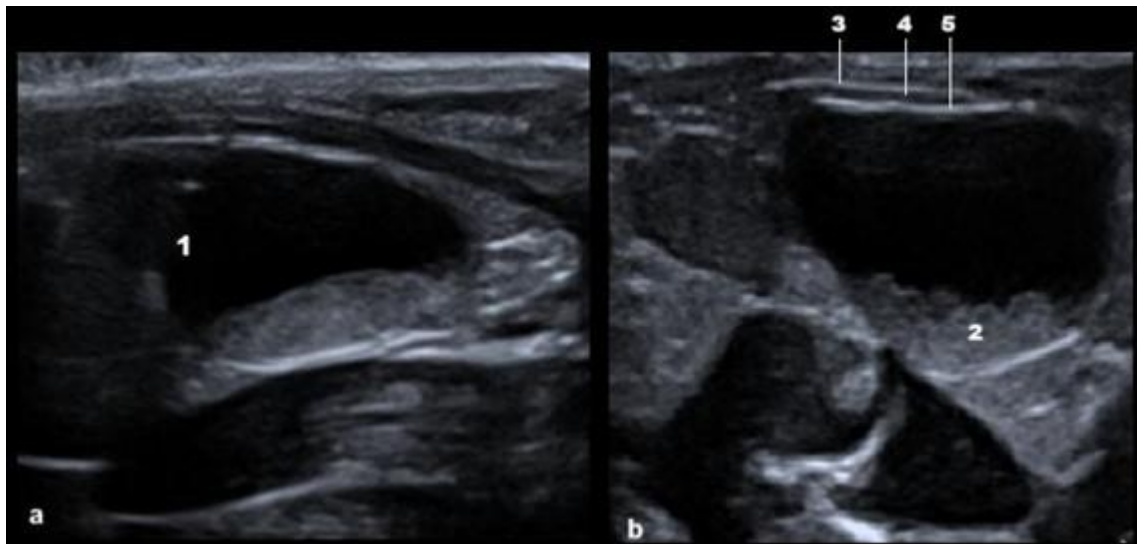


Figure 12. Ultrasonographic images in the longitudinal view (a) and transverse view (b) of the urinary bladder of a healthy guinea pig. 1. Anechoic liquid content; 2. Sediment; 3. Hyperechoic outer layer; 4. Hypoechoic middle layer; 5. Hyperechoic inner layer.

The seminal glands were located craniodorsal to the urinary bladder and extended dorsocaudally. They exhibited an elongated shape, regular contours,

and well-defined boundaries, with a thin hyperechoic capsule. The parenchyma was isoechoic to slightly hyperechoic relative to the renal cortex, with a homogeneous, finely granular echotexture (Figure 13).

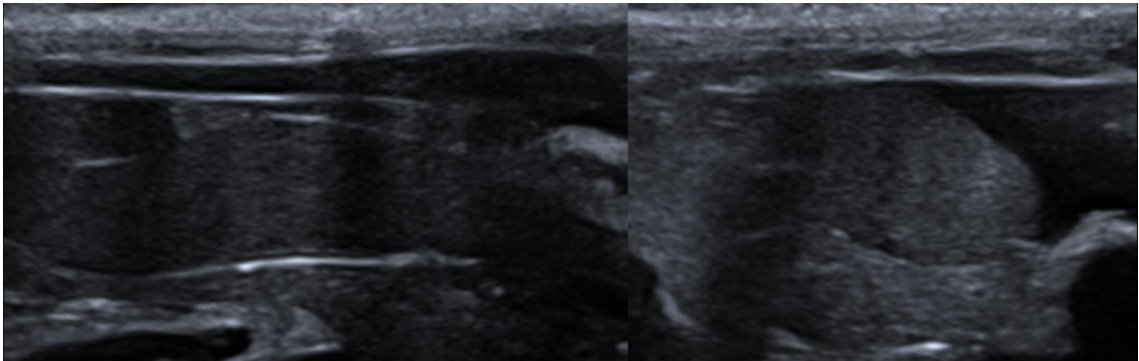


Figure 13. Ultrasonographic images in the longitudinal view (a) and transverse view (b) of the seminal glands of a healthy guinea pig. The seminal glands are elongated, with regular, well-defined contours, a thin hyperechoic layer, and echogenic parenchyma with a granular, homogeneous echotexture.

The testes, located in the caudal portion of the abdominal cavity, exhibited a hyperechoic outer layer corresponding to the tunica albuginea, and a homogeneous parenchyma that was hyperechoic relative to the liver and hypoechoic relative to the renal cortex. The testicular mediastinal line was observed as a well-defined, central, linear hyperechoic structure (Figure 14).

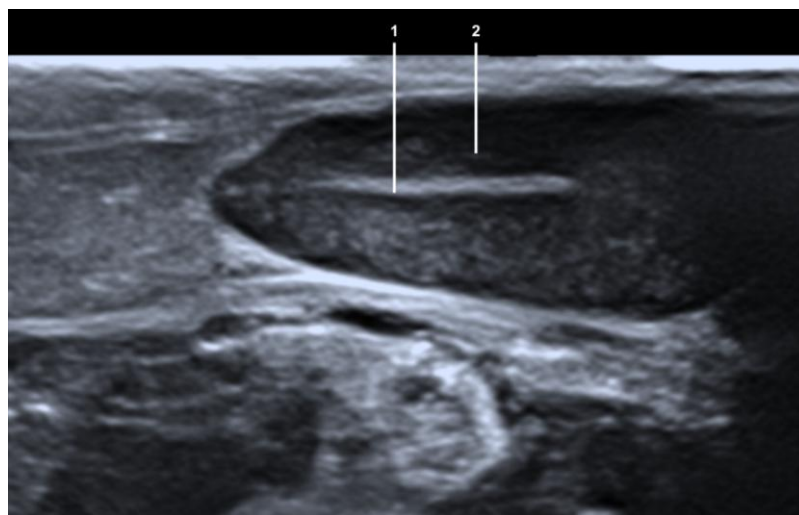


Figure 14. Ultrasonographic image in the longitudinal view of the testicle of a healthy guinea pig.
1. Well-defined hyperechoic mediastinal line; 2. Parenchyma, hypoechoic relative to the outer layer and the mediastinal line, with granular and homogeneous echotexture.

The mean values and standard deviations obtained for the major abdominal structures are presented in Table 1.

	Mean	SD
Urinary bladder wall thickness	0.03	0.02
Left Kidney length (cm)	1.75	0.19
Left Kidney width (cm)	1.24	0.19
Right Kidney length (cm)	2.15	0.24
Right Kidney width (cm)	1.19	0.14
Left Testicle length (cm)	1.53	0.30
Left Testicle width (cm)	0.77	0.06
Right Testicle length (cm)	1.67	0.34
Right Testicle width (cm)	0.79	0.10
Seminal glands length (cm)	2.02	0.36
Seminal glands width (cm)	0.54	0.22
Seminal glands thickness (cm)	0.43	0.09
Stomach wall thickness (cm)	0.13	0.03
Descending Duodenum wall thickness (cm)	0.10	0.01
Jejunum wall thickness (cm)	0.08	0.01
Cecum wall thickness (cm)	0.05	0.01
Ileum wall thickness (cm)	0.11	0.02
Descending Colon wall thickness (cm)	0.06	0.01
Gallbladder wall thickness (cm)	0.06	0.03
Right Adrenal Gland length (cm)	0.92	0.14
Right Adrenal Gland cranial pole thickness (cm)	0.33	0.07
Right Adrenal Gland caudal pole thickness (cm)	0.35	0.05
Left Adrenal Gland length (cm)	0.92	0.24
Left Adrenal Gland cranial pole thickness (cm)	0.41	0.11
Left Adrenal Gland caudal pole thickness (cm)	0.34	0.04
Pancreas width (cm)	0.26	0.05

Table 1. Means and standard deviations (SD) in centimeters (cm) obtained from the evaluated abdominal structures.

4. DISCUSSION

All evaluated animals showed moderate bladder distension, with floating and sedimented echogenic material. This characteristic is physiological in guinea pigs and rabbits, as these species excrete calcium predominantly through the urine, in which calcium elimination occurs mainly

through the gastrointestinal tract (Hargaden & Singer, 2012).

The urinary bladder wall was identified in all individuals, with the three classic echographic layers properly characterized, as previously described in *Cavia porcellus* and rabbits (Krautwald-Junghanns et al., 2011; Penninck & D'anjou, 2015; Martin et al., 2024). It is reported that, in cases of high bladder distension, layer differentiation may be limited, and the degree of distension directly influences wall thickness and homogeneity (Hecht & Henry, 2011; Banzato et al., 2014; Martin et al., 2024).

The seminal glands were identified as elongated structures located dorsolateral to the urinary bladder, a finding consistent with descriptions in rodents (Banzato et al., 2014). These glands show significant development in both species; however, in rabbits, their echogenicity, similar to that of adjacent tissues, may hinder visualization (Banzato et al., 2015). In rats, they have an ovoid shape with echogenic parenchyma and are easily identified (Banzato et al., 2014). The prostate was not identified in any animal, as expected given the gland's small size, an observation also reported in rabbits, rats, and felines (Aksoy et al., 2009; Banzato et al., 2015; Trautwein & Martins, 2021).

The testes exhibited a hyperechoic testicular mediastinum and homogeneous parenchyma, which was hypoechoic relative to the mediastinal line, a pattern similar to that described for rabbits (Aksoy et al., 2009; Penninck & D'anjou, 2015; Trautwein & Martins, 2021). They differ from rats, which did not exhibit a defined mediastinal line, as reported by Banzato et al. (2014).

Corticomedullary distinction varied across species. Rats demonstrated differentiation only in transverse scans (Banzato et al., 2014), while rabbits showed clear distinction in both longitudinal and transverse planes (Banzato et al., 2015). Guinea pigs exhibited a pattern similar to rabbits, with corticomedullary differentiation evident in longitudinal scans showing distinct medullary zonation, and a hyperechoic appearance of the internal medulla compared to the cortical region (Banzato et al., 2015). The renal pelvis was not identified, which is common in examinations of healthy individuals (Penninck & D'anjou, 2015).

Renal size was consistent with that previously described in guinea

pigs (Beregi et al., 2001; Martin et al., 2024). The ureters were not visualized, a finding similar to that reported in other species (Penninck & D'anjou, 2015).

Compared to rabbits, the spleen exhibited a smaller relative size while maintaining similar ovoid morphology (Banzato et al., 2015). Its echogenicity, lower than that of the liver, is consistent with findings in rabbits, whereas in rats, the spleen is generally more echogenic than the liver (Banzato et al., 2014; Banzato et al., 2015; Penninck & D'anjou, 2015). The observed hyperechoic splenic capsule and homogeneous parenchyma are compatible with reports for small mammals (Banzato et al., 2014; Banzato et al., 2015; Penninck & D'anjou, 2015). The splenic hilus was not identified, as also described in rabbits (Banzato et al., 2015).

The liver demonstrated higher echogenicity than the spleen, consistent with the pattern described in rabbits but opposite to that observed in rats (Banzato et al., 2014; Banzato et al., 2015). Ultrasonographic lobar delineation was absent, reflecting the anatomical absence of connective tissue separation between hepatic lobes characteristic of small mammals (Hargaden & Singer, 2012; Banzato et al., 2014; Banzato et al., 2015).

The gallbladder was located in a medial and slightly right-sided position, similar to the pattern observed in rabbits and is absent in rats (Banzato et al., 2014; Banzato et al., 2015; Martin et al., 2024). The wall appeared regular, consistent with that described for other species (Banzato et al., 2015; Penninck & D'anjou, 2015).

The pancreas of *Cavia porcellus* can be divided into three irregular lobes: right (duodenal), body, and left (splenic), with the left lobe being thicker and longer (Al-Saffar & Nasif, 2020). In the present study, the right lobe was identified, positioned between the descending and ascending duodenum. Other authors describe the evaluation of the left lobe, located cranioventrally to the spleen and caudal to the stomach (Martin et al., 2024). The measurements obtained were similar to those described by Martin et al. (2024), regardless of the lobe evaluated. Pancreatic hyperechogenicity relative to the liver was comparable to that of rabbits and rats (Dimitrov et al., 2013; Penninck & D'anjou, 2015).

The adrenal glands were visualized craniomedially to the kidneys, as described in guinea pigs. The cortex and medulla were distinguishable, with

a pattern similar to that reported by Martin et al. (2024) and Sainato et al. (2024). Studies report correlations between body weight and adrenal dimensions across species, particularly in the length and thickness of the poles (Melián et al., 2021; Perez-Lopez et al., 2021; Sainato et al., 2024).

Ultrasonographic visualization of gastrointestinal wall layers was achieved in all examined animals, with the four characteristic layers identifiable throughout the digestive tract. An additional challenge in small mammals is the difficulty in distinguishing the hypoechoic mucosa due to its reduced thickness, as reported in both rabbits and guinea pigs (Krautwald-Junghanns et al., 2011; Banzato et al., 2015; Martin et al., 2024).

Notably, intestinal segments devoid of luminal content allowed for clearer layer identification and more precise wall thickness measurements, highlighting the impact of luminal filling on image quality. The imaging challenges documented likely resulted from the absence of bowel preparation protocols, which are routinely employed in canine and feline ultrasonography to enhance image quality (Penninck & D'anjou, 2015).

Variable degrees of gastrointestinal luminal content were observed despite the standardized four-hour fasting period implemented prior to examination. The heterogeneous distribution pattern observed across different intestinal segments reflects individual variations in gastric emptying rates and digestive transit time. The cecum exhibited marked distension in most animals, consistent with the species. These findings suggest that while a four-hour fasting period reduces gastric content and minimizes gas artifacts, it does not completely standardize intestinal filling patterns across all gastrointestinal segments.

The stomach of guinea pigs, similar to that of rabbits and chinchillas, does not present anatomical sulci (Krautwald-Junghanns et al., 2011; AL-Rhman, 2016). The thickness of the gastric and intestinal walls varied with filling status, as described in other species (Penninck & D'anjou, 2015).

Comparative analysis with measurements reported by Martin et al. (2024) revealed segment-specific variations. The stomach and duodenum demonstrated greater mean wall thickness in the present study, whereas cecum and colon measurements were comparable between studies. Jejunal and ileal wall thicknesses, not measured by Martin et al. (2024). The

observed differences in gastric and duodenal wall thickness are likely attributable to variations in luminal content between studies, as the absence of intraluminal material facilitates more accurate wall measurements and enhances layer distinction due to reduced distension and improved acoustic window.

5. CONCLUSION

The obtained findings provide ultrasonographic parameters of normality and serve as an anatomical reference for diagnostic imaging and future research involving small mammals.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

6. REFERENCES

- Aksoy, M., Erdem, H., Hatipoğlu, F., Lehimcioğlu, N. C., Akman, O., & Ozkan, K. (2009). Ultrasonographic examination of the scrotal content in the rabbit. *Reproduction in domestic animals = Zuchthygiene*, 44(1), 156–160. <https://doi.org/10.1111/j.1439-0531.2007.01055.x>
- AL-Rhman, S. A. A. (2016). Morphological and histological study of the stomach in local rodent species (guinea pig) *Cavia porcellus*. *International Journal of Advanced Research*, 4(3), 141–155. [https://www.journalijar.com/article/8149/morphological-and-histological-study-of-the-stomach-in-local-rodent-species\(guinea-pig\)-cavia-porcellus/](https://www.journalijar.com/article/8149/morphological-and-histological-study-of-the-stomach-in-local-rodent-species(guinea-pig)-cavia-porcellus/)
- AL-Saffar, F. J., & Nasif, R. H. (2020). Morphological study of the pancreas and duodenum in adult guinea pigs (*Cavia porcellus*). *The Iraqi Journal of Veterinary Medicine*, 44(1), 1–9. <https://doi.org/10.30539/ijvm.v44i1.928>
- Avante, M. L., DA da Silva, P., Feliciano, M. A., Maronezi, M. C., Simões, A. R., Uscategui, R. A., & Canola, J. C. (2018). La ecografía del páncreas canino. *Revista MVZ Córdoba*, 23(1), 6552-6563. <https://doi.org/10.21897/rmvz.1249>
- Azevedo, L. S. B. (2024). *Doenças do trato urinário: Estudo ultrassonográfico retrospectivo em porquinhos-da-india (Cavia porcellus)* [Tese de doutoramento, Universidade de Cuiabá]. Repositório Digital Cogna. <https://repositorio.pgsscogna.com.br/bitstream/123456789/71371/1/Ludmila%20Silva%20Borges%20Azevedo.pdf>
- Banzato, T., Bellini, L., Contiero, B., Martin, A., Balikçi, S., & Zotti, A. (2014). Abdominal anatomic features and reference values determined by use of ultrasonography in healthy common rats (*Rattus norvegicus*). *American journal of veterinary research*, 75(1), 67–76. <https://doi.org/10.2460/ajvr.75.1.67>
- Banzato, T., Bellini, L., Contiero, B., Selleri, P., & Zotti, A. (2015). Abdominal ultrasound features and reference values in 21 healthy rabbits. *The Veterinary record*, 176(4), 101. <https://doi.org/10.1136/vr.102657>
- Beregi, A., Felkai, C., Börzsönyi, L., & Molnár, V. (2001). A preliminary study of the ultrasonographic determination of renal size in the guinea pig (*Cavia porcellus*). *Contemporary topics in laboratory animal science*, 40(5), 50–52. <https://pubmed.ncbi.nlm.nih.gov/11560406/>
- Brustolin, J. M., Weiller, M. A. A., Souza, C. L. de, Brito, H. F. V. de, Vogel, F. S. F., Botton, S. de A., & Sangioni, L. A. (2015). PIOMETRA EM PORQUINHO DA ÍNDIA (*Cavia porcellus*)-RELATO DE CASO. *Science and Animal Health*, 3(2), 169-180. <https://doi.org/10.15210/sah.v3i2.4862>
- Carabaño, R., Piquer, J., Menoyo, D., & Badiola, I. (2010). The digestive system of the rabbit. In C. de Blas & J. Wiseman (Eds.), *Nutrition of the rabbit* (2nd ed., pp. 1–18). CABI.

Coulson, J. D., & Lewis, N. (2008). The thoracic radiograph. In J. K. Kealy, H. McAllister, & J. P. Graham (Eds.), *Diagnostic radiology and ultrasonography of the dog and cat* (5th ed., pp. 37–63). Saunders Elsevier.

Debruyn, K., Haers, H., Combes, A., Duchateau, L., Peremans, K., Paepe, D., Daminet, S., & Saunders, J. H. (2012). Ultrasonography of the feline kidney: Technique, anatomy and changes associated with disease. *Journal of Feline Medicine and Surgery*, 14(11), 794–803. <https://doi.org/10.1177/1098612X12464461>

Dimitrov, R., Russenov, A., Stamatova-yovcheva, K., & Uzunova, K. (2013). Ultrasonographic Characteristics of Rabbit's Pancreas. *İstanbul Üniversitesi Veteriner Fakültesi Dergisi*, 39(2), 139–147. <https://doi.org/10.16988/iuvfd.00846>

Griffin S. (2019). Feline abdominal ultrasonography: What's normal? What's abnormal? The normal gastrointestinal tract. *Journal of feline medicine and surgery*, 21(11), 1039–1046. <https://doi.org/10.1177/1098612X19880433>

Hargaden, M., & Singer, L. (2012). Anatomy, physiology, and behavior. In M. A. Suckow, K. A. Stevens, & R. P. Wilson (Eds.), *The laboratory rabbit, guinea pig, hamster, and other rodents* (pp. 575–602). Academic Press.

Hecht, S. (2015). Diagnostic imaging of lower urinary tract disease. *Veterinary Clinics of North America: Small Animal Practice*, 45(4), 639–663. <https://doi.org/10.1016/j.cvsm.2015.02.002>

Keeble, E., & Heggie, H. (2012). Mammals: biology and husbandry. In M. Varga, R. Lumbis, & L. Gott (Eds.), *BSAVA manual of exotic pet and wildlife nursing* (pp. 34–57). British Small Animal Veterinary Association.

Krautwald-Junghanns, M.-E., Dziallas, P., & Reese, S. (2011). Diagnostic imaging in small mammals. In M.-E. Krautwald-Junghanns (Ed.), *Diagnostic imaging of exotic pets* (pp. 85–132). Schlütersche.

Martin, N.G., Miño, E.D., Carellán, A. G., & Solé, L.V. (2024). Abdominal ultrasound features and reference values in healthy guinea pigs (*Cavia porcellus*). *The Veterinary record*, 194(2), e3668. <https://doi.org/10.1002/vetr.3668>

Melián, C., Pérez-López, L., Saavedra, P., Ravelo-García, A. G., Santos, Y., & Jaber, J. R. (2021). Ultrasound evaluation of adrenal gland size in clinically healthy dogs and in dogs with hyperadrenocorticism. *The Veterinary record*, 188(8), e80. <https://doi.org/10.1002/vetr.80>

Penninck, D., & d'Anjou, M. A. (2015). *Atlas of small animal ultrasonography* (2nd ed.). Wiley-Blackwell.

Pérez-López, L., Wägner, A. M., Saavedra, P., Jaber, J. R., & Melián, C. (2021). Ultrasonographic evaluation of adrenal gland size in two body weight categories

of healthy adult cats. *Journal of feline medicine and surgery*, 23(8), 804–808.
<https://doi.org/10.1177/1098612X20974962>

Sainato, D., Pelligra, T., Puccinelli, C., Petrini, D., & Citi, S. (2024). Ultrasonographic measurements of the normal adrenal glands in guinea pigs (*Cavia porcellus*). *Veterinary Radiology & Ultrasound*, 65(4), 385–391.
<https://doi.org/10.1111/vru.13367>

Trautwein, L. G. C., & Martins, M. I. M. (2021). Ultrassonografia em modo B e Doppler para avaliação reprodutiva de cães e gatos. *Revista Brasileira de Reprodução Animal*, 45(4), 574–582. <https://doi.org/10.21451/1809-3000.RBRA2021.077>

Waugh, S., Andrie, K. M., Johnson, V., Biggo, M., Aboellail, T., & Sadar, M. J. (2021). Liver Lobe Torsion in a Guinea Pig (*Cavia porcellus*). *Topics in companion animal medicine*, 43, 100517.
<https://doi.org/10.1016/j.tcam.2021.100517>