Diagnostic Imaging of Exotic Pets

Birds · Small Mammals · Reptiles

With the cooperation of

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English translation

Teresa J. Gatesman

schlütersche
# Contents

<table>
<thead>
<tr>
<th>Authors</th>
<th>IX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviations</td>
<td>XI</td>
</tr>
<tr>
<td>Preface</td>
<td>XIII</td>
</tr>
</tbody>
</table>

## 1 Birds

### General principles

<table>
<thead>
<tr>
<th>1.1 Radiographic investigation</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1 Equipment</td>
<td>2</td>
</tr>
<tr>
<td>1.1.1.1 Radiography unit</td>
<td>2</td>
</tr>
<tr>
<td>1.1.1.2 Screens and films</td>
<td>2</td>
</tr>
<tr>
<td>1.1.1.3 Radiation safety</td>
<td>3</td>
</tr>
<tr>
<td>1.1.2 Positioning and projections</td>
<td>3</td>
</tr>
<tr>
<td>1.1.2.1 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.1.2.2 Positioning for imaging the body</td>
<td>4</td>
</tr>
<tr>
<td>1.1.2.3 Positioning for imaging the head</td>
<td>5</td>
</tr>
<tr>
<td>1.1.2.4 Positioning for imaging the wing</td>
<td>10</td>
</tr>
<tr>
<td>1.1.2.5 Positioning for imaging the hindlimb</td>
<td>10</td>
</tr>
<tr>
<td>1.1.3 Anatomical-physiological representation</td>
<td>12</td>
</tr>
<tr>
<td>1.1.3.1 Skeletal system</td>
<td>12</td>
</tr>
<tr>
<td>1.1.3.2 Cardiovascular system</td>
<td>20</td>
</tr>
<tr>
<td>1.1.3.3 Respiratory tract</td>
<td>20</td>
</tr>
<tr>
<td>1.1.3.4 Liver</td>
<td>22</td>
</tr>
<tr>
<td>1.1.3.5 Spleen</td>
<td>22</td>
</tr>
<tr>
<td>1.1.3.6 Gastrointestinal tract</td>
<td>24</td>
</tr>
<tr>
<td>1.1.3.7 Urinary tract</td>
<td>26</td>
</tr>
<tr>
<td>1.1.3.8 Genital tract</td>
<td>26</td>
</tr>
<tr>
<td>1.1.4 Contrast studies</td>
<td>28</td>
</tr>
<tr>
<td>1.1.4.1 Introduction</td>
<td>28</td>
</tr>
<tr>
<td>1.1.4.2 Contrast studies of the gastrointestinal tract</td>
<td>28</td>
</tr>
<tr>
<td>Further reading</td>
<td>30</td>
</tr>
<tr>
<td>1.1.4.3 Contrast investigation of the excretory organs (urography)</td>
<td>32</td>
</tr>
<tr>
<td>1.1.4.4 Contrast investigation of the infraorbital sinus and diverticula (sinography, rhinosinography)</td>
<td>32</td>
</tr>
<tr>
<td>1.1.4.5 Contrast studies of the cardiovascular system (angiocardiology)</td>
<td>32</td>
</tr>
<tr>
<td>1.1.4.6 Myelography</td>
<td>34</td>
</tr>
<tr>
<td>Further reading</td>
<td>34</td>
</tr>
</tbody>
</table>

### 1.2 Ultrasonographic examination

| 1.2.1 Technical requirements | 36 |
| 1.2.2 Preparation of the patient, coupling sites | 38 |
| 1.2.3 Procedure | 38 |
| 1.2.4 Additional coupling sites | 40 |
| 1.2.5 Biopsy | 40 |
| 1.2.6 Contrast studies | 42 |
| 1.2.7 Ultrasonographic imaging of normal structures | 42 |
| 1.2.7.1 Skeletal system | 42 |
| 1.2.7.2 Cardiovascular system | 42 |
| 1.2.7.3 Respiratory tract | 46 |
| 1.2.7.4 Liver | 46 |
| 1.2.7.5 Spleen | 48 |
| 1.2.7.6 Gastrointestinal tract and pancreas | 48 |
| 1.2.7.7 Urinary tract | 48 |
| 1.2.7.8 Genital tract | 52 |
| 1.2.7.9 Eye | 52 |
| Further reading | 52 |

### 1.3 Computed tomography (CT)

| 1.3.1 Equipment | 54 |
| 1.3.2 Preparation, positioning and planes | 54 |
| 1.3.3 Assessment of the organs | 54 |
| 1.3.3.1 Skeletal system | 56 |
| 1.3.3.2 Respiratory tract | 56 |
| 1.3.3.3 Other organs | 58 |
| Further reading | 58 |

### 1.4 Magnetic resonance imaging (MRI)

| 1.4.1 Equipment and uses | 64 |
| 1.4.2 Preparation | 64 |
| 1.4.3 Investigatory procedure | 66 |
| 1.4.4 Imaging of the organs | 66 |
| Further reading | 66 |

### Special diagnostics, pathological findings

<table>
<thead>
<tr>
<th>1.5 Skeletal system</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5.1 Cranium</td>
<td>71</td>
</tr>
<tr>
<td>1.5.2 Axial skeleton</td>
<td>71</td>
</tr>
<tr>
<td>1.5.3 Forelimbs</td>
<td>71</td>
</tr>
<tr>
<td>1.5.4 Hindlimbs</td>
<td>71</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.6 Cardiovascular system</th>
<th>84</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6.1 Heart</td>
<td>84</td>
</tr>
<tr>
<td>1.6.2 Blood vessels</td>
<td>85</td>
</tr>
</tbody>
</table>
2.1.3.4 Contrast studies of the spinal cord (myelography) ... 156

2.2 Radioanatomy ... 158

2.2.1 Skeletal system ... 158
  2.2.1.1 Cranium with teeth ... 158
  2.2.1.2 Spine, thorax ... 164
  2.2.1.3 Limbs ... 164
  2.2.2 Cervical soft tissues ... 168
  2.2.3 Thorax ... 168
  2.2.3.1 Esophagus ... 168
  2.2.3.2 Trachea ... 168
  2.2.3.3 Thymus ... 168
  2.2.3.4 Lungs ... 168
  2.2.3.5 Heart ... 170
  Further reading ... 172
  2.2.4 Abdomen ... 176
  2.2.4.1 Gastrointestinal tract ... 176
  2.2.4.2 Liver ... 180
  2.2.4.3 Pancreas ... 180
  2.2.4.4 Spleen ... 180
  2.2.4.5 Urinary tract ... 180
  2.2.4.6 Genital organs ... 182
  2.2.4.7 Adrenals ... 182

2.3 Ultrasonography ... 184

2.3.1 Equipment ... 184
  2.3.2 Positioning and fixation ... 184
  2.3.3 Preparation of the patient ... 186
  2.3.4 Investigation protocol ... 186
  2.3.5 Documentation of the results ... 186

2.4 Sonoanatomy ... 188

2.4.1 Cervical soft tissues ... 188
  2.4.2 Thorax: echocardiography ... 188
  2.4.2.1 Equipment ... 188
  2.4.2.2 Preparation and positioning ... 190
  2.4.2.3 Standard planes ... 190
  2.4.2.4 Two-dimensional echocardiography ... 192
  2.4.2.5 One-dimensional echocardiography – M-mode ... 200
  2.4.2.6 Doppler echocardiography ... 204
  2.4.2.7 Measurements and reference values ... 204
  2.4.2.8 Measurements in the M-mode and
two-dimensional echocardiography ... 210
  2.4.2.9 Measurements using PW and CW Doppler ... 210
  2.4.2.10 Special measurements and investigations ... 210
  Further reading ... 223
  2.4.3 Abdomen ... 224
    2.4.3.1 Gastrointestinal tract ... 224
    2.4.3.2 Liver ... 226
    2.4.3.3 Pancreas ... 226
    2.4.3.4 Spleen ... 226
    2.4.3.5 Urinary tract ... 230
    2.4.3.6 Female genital tract ... 232
    2.4.3.7 Male genital tract ... 236
    2.4.3.8 Adrenals ... 236
  2.4.4 Miscellaneous ... 238
    2.4.4.1 Eye ... 238
2.5 Computed tomography (CT) and magnetic resonance imaging (MRI) ................................................. 242

Communications, pathological findings

2.6 Skeletal system ................................................. 244

2.6.1 Cranium and teeth ........................................... 244
2.6.2 Spine, thorax .................................................. 246
2.6.3 Limbs .......................................................... 246

2.7 Cervical soft tissues ............................................ 247

2.8 Thorax ............................................................ 256

2.8.1 Pleural cavity .................................................. 256
2.8.2 Trachea ........................................................ 256
2.8.3 Esophagus ..................................................... 256
2.8.4 Lungs ......................................................... 257
2.8.5 Heart .......................................................... 257
2.8.5.1 Radiographic findings ................................. 257
2.8.5.2 Echocardiographic findings ......................... 258

Further reading ...................................................... 260

2.9 Abdomen .......................................................... 280

2.9.1 Stomach ....................................................... 280
2.9.2 Small intestines ............................................. 281
2.9.3 Appendix and large intestines ......................... 281
2.9.4 Liver .......................................................... 281
2.9.5 Pancreas ..................................................... 282
2.9.6 Spleen ........................................................ 282
2.9.7 Urinary tract ................................................ 282
2.9.7.1 Kidneys ..................................................... 282
2.9.7.2 Ureter ....................................................... 283
2.9.7.3 Urinary bladder ......................................... 283
2.9.8 Female genital tract ....................................... 283
2.9.8.1 Vagina ....................................................... 283
2.9.8.2 Cervix ...................................................... 284
2.9.8.3 Uterus ...................................................... 284
2.9.8.4 Ovaries ..................................................... 284
2.9.9 Male genital tract .......................................... 285
2.9.9.1 Testicles ................................................... 285
2.9.9.2 Accessory sex glands ................................. 285
2.9.10 Adrenal glands ............................................ 285

2.10 Miscellaneous ................................................. 298

2.10.1 Eye .......................................................... 298
2.10.1.1 Cornea ...................................................... 298
2.10.1.2 Ciliary body ............................................. 298
2.10.1.3 Lens ....................................................... 298
2.10.1.4 Peribulbar swelling ..................................... 298
2.10.1.5 Exophthalmos .......................................... 299
2.10.1.6 Trauma ................................................... 299
2.10.1.7 Congenital eye anomalies ......................... 299
2.10.1.8 Neoplasia within the globe ......................... 299

3 Reptiles

Introduction ......................................................... 309

General principles

3.1 Radiographic investigation .................................. 310

3.1.1 Equipment .................................................. 310
3.1.2 Positioning and projections ............................. 310
3.1.2.1 Radiography of lizards ............................... 311
3.1.2.2 Radiography of snakes ............................... 312
3.1.2.3 Radiography of chelomians ......................... 314
3.1.3 Contrast studies ........................................... 316
3.1.4 Assessment of radiographs in reptiles .................. 316
3.1.4.1 Radiograph quality (exposure, contrast, positioning) ............................................. 316
3.1.4.2 Assessment of the skeleton and musculoskeletal system ........................................ 318
3.1.4.3 General assessment of the internal organs ....... 318
3.1.4.4 Evaluation of the individual organ systems ....... 318
3.1.4.5 Standard radioanatomy ............................... 320

3.2 Ultrasonography .............................................. 334

3.2.1 Equipment .................................................. 334
3.2.2 Coupling sites ............................................. 334
3.2.3 Approaches .................................................. 336
3.2.3.1 Approaches in snakes ............................... 336
3.2.3.2 Approaches in lizards ............................... 336
3.2.3.3 Approaches in chelomians ......................... 338
3.2.4 Ultrasonographically controlled aspiration and biopsying ................................................. 340
3.2.4.1 Biopsy of the liver in snakes ......................... 340
3.2.5 Assessment of the organs ................................ 342
3.2.5.1 Liver ....................................................... 342
3.2.5.2 Cardiovascular system ............................... 342
3.2.5.3 Urinary tract ............................................ 348
3.2.5.4 Genital tract ............................................ 348
3.2.5.5 Gastrintestinal tract ................................... 354
3.2.5.6 Fat bodies ................................................. 354
3.2.5.7 Fluid ....................................................... 354
3.2.5.8 Tumors ................................................... 354
3.2.5.9 Eye ........................................................ 354

3.3 Computed tomography (CT) ................................ 358

3.3.1 Equipment .................................................. 358
3.3.2 Preparation, positioning, and scanning plans ............. 358
3.3.3 Assessment of the organs ................................ 358
3.3.3.1 Skeletal system ....................................... 358
3.3.3.2 Respiratory tract ....................................... 360
3.3.3.3 Gastrintestinal tract and the liver ................. 360
3.3.3.4 Urogenital tract ........................................ 366
3.3.3.5 Other organs ............................................ 366

Further reading ...................................................... 366

Contents
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4</td>
<td>Magnetic resonance imaging (MRI)</td>
<td>368</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Equipment</td>
<td>368</td>
</tr>
<tr>
<td>3.4.2</td>
<td>Preparation, positioning, and scanning planes</td>
<td>368</td>
</tr>
<tr>
<td>3.4.3</td>
<td>Assessment of the organs</td>
<td>368</td>
</tr>
<tr>
<td>3.4.3.1</td>
<td>Fat bodies and musculature</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.2</td>
<td>Respiratory tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.3</td>
<td>Liver</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.4</td>
<td>Gastrointestinal tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.5</td>
<td>Urinary tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.6</td>
<td>Genital tract</td>
<td>372</td>
</tr>
<tr>
<td>3.4.3.7</td>
<td>Other Organs</td>
<td>372</td>
</tr>
<tr>
<td></td>
<td>Further reading</td>
<td>372</td>
</tr>
<tr>
<td>3.4.3.8</td>
<td>Assessment of the organs</td>
<td>368</td>
</tr>
<tr>
<td>3.4.3.9</td>
<td>Fat bodies and musculature</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.10</td>
<td>Respiratory tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.11</td>
<td>Liver</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.12</td>
<td>Gastrointestinal tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.13</td>
<td>Urinary tract</td>
<td>370</td>
</tr>
<tr>
<td>3.4.3.14</td>
<td>Genital tract</td>
<td>372</td>
</tr>
<tr>
<td>3.4.3.15</td>
<td>Other Organs</td>
<td>372</td>
</tr>
<tr>
<td>3.4.3.16</td>
<td>Further reading</td>
<td>372</td>
</tr>
<tr>
<td>3.5</td>
<td>Skeletal system</td>
<td>378</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Fractures</td>
<td>378</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Metabolic bone disease</td>
<td>379</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Skeletal deformities and fusion</td>
<td>379</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Luxations</td>
<td>379</td>
</tr>
<tr>
<td>3.5.5</td>
<td>Bone and joint infections</td>
<td>379</td>
</tr>
<tr>
<td>3.5.6</td>
<td>Gout</td>
<td>380</td>
</tr>
<tr>
<td>3.5.7</td>
<td>Neoplasia</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>Further reading</td>
<td>394</td>
</tr>
<tr>
<td>3.6</td>
<td>Respiratory Tract</td>
<td>394</td>
</tr>
<tr>
<td>3.7</td>
<td>Gastrointestinal tract</td>
<td>398</td>
</tr>
<tr>
<td>3.7.1</td>
<td>Excessive emptying of the gastrointestinal tract</td>
<td>398</td>
</tr>
<tr>
<td>3.7.2</td>
<td>Foreign bodies</td>
<td>398</td>
</tr>
<tr>
<td>3.7.3</td>
<td>Disturbances in emptying</td>
<td>398</td>
</tr>
<tr>
<td>3.7.4</td>
<td>Infections</td>
<td>399</td>
</tr>
<tr>
<td>3.8</td>
<td>Liver</td>
<td>408</td>
</tr>
<tr>
<td>3.9</td>
<td>Urinary tract</td>
<td>414</td>
</tr>
<tr>
<td>3.9.1</td>
<td>Kidneys</td>
<td>414</td>
</tr>
<tr>
<td>3.9.2</td>
<td>Allantois</td>
<td>414</td>
</tr>
<tr>
<td>3.10</td>
<td>Genital tract</td>
<td>420</td>
</tr>
<tr>
<td>3.10.1</td>
<td>Ovary</td>
<td>420</td>
</tr>
<tr>
<td>3.10.2</td>
<td>Oviduct and eggs</td>
<td>420</td>
</tr>
<tr>
<td>3.11</td>
<td>Other organ systems, space-occupying lesions</td>
<td>430</td>
</tr>
<tr>
<td>3.11.1</td>
<td>Heart</td>
<td>430</td>
</tr>
<tr>
<td>3.11.2</td>
<td>Eye</td>
<td>430</td>
</tr>
<tr>
<td>3.11.3</td>
<td>Space-occupying lesions</td>
<td>431</td>
</tr>
<tr>
<td>3.11.4</td>
<td>Photograph credits</td>
<td>440</td>
</tr>
<tr>
<td>3.12</td>
<td>Subject Index</td>
<td>441</td>
</tr>
</tbody>
</table>
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### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>µCT</td>
<td>micro-computed tomography</td>
</tr>
<tr>
<td>µm</td>
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</tr>
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<td>2D</td>
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</tr>
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</tr>
<tr>
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<td>late diastolic inflow during atrial contraction</td>
</tr>
<tr>
<td>BaSO₄</td>
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</tr>
<tr>
<td>bwt</td>
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</tr>
<tr>
<td>CaCr</td>
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<td>CFM</td>
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<td>cm</td>
<td>centimeter</td>
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<td>CNS</td>
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<td>craniocaudal</td>
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<tr>
<td>CSF</td>
<td>cerebrospinal fluid</td>
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<td>CT</td>
<td>computed tomography</td>
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<td>continuous wave</td>
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<td>dilatative cardiomyopathy</td>
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<td><em>Escherichia coli</em></td>
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<td>FSH</td>
<td>follicle stimulating hormone</td>
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<td>F-K</td>
<td>follicle-kidney unit</td>
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<td>gonadotropin releasing hormone</td>
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<td>IVS</td>
<td>systolic thickness of the interventricular septum</td>
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<td>level (CT)</td>
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<td>diameter of the left ventricle</td>
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<td>left ventricular myocardium</td>
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<td>left ventricular volume</td>
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<td>milliampere</td>
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<td>milliampere second</td>
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<td>Megahertz</td>
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<td>millimeter mercury</td>
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<td>MRI</td>
<td>magnetic resonance imaging</td>
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<td>n. k.</td>
<td>not known</td>
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<tr>
<td>n. s.</td>
<td>not specified</td>
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<tr>
<td>NAD</td>
<td>nothing abnormal diagnosed</td>
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<tr>
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<td>penetration depth</td>
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<td>PDD</td>
<td>proventricular dilatation disease</td>
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<td>proton-density weighted</td>
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<td>maximum velocity</td>
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<td>ventricular septal defect</td>
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<td>tricuspid valve</td>
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Preface

The idea to compile an atlas for imaging techniques that includes diagnostic information for birds, small pet mammals and reptiles requests by colleagues for a complete reference text on this subject. The proposed book was to include companion exotic animal species that are most often treated in veterinary practices with an emphasis on common presented problems.

In the last 20 years arguably no other area of veterinary medicine has evolved as much as exotic pet medicine and surgery. Many diagnostic tests that, until recently, were not considered for these animals are now available and routinely used. In particular diagnostic imaging methods have achieved a pivotal significance for companion exotic animal patients. Despite the advantages and the availability of improved diagnostic imaging techniques they are still not being used or rarely accessed in many veterinary practices. The various reasons for why veterinarians under utilize the available diagnostic imaging technologies include the uncertainty in handling companion exotic animals (i.e. beginning with capture and suitable fixation) and the uncertainties associated with performing the proper investigations and the interpretation of those images.

With this atlas, the practicing veterinarian is provided information regarding the most important investigation techniques and interpretation aids, so that these valuable diagnostic methods can be used on a daily basis. Two diagnostic imaging modalities (computed tomography [CT] and magnetic resonance imaging [MRI]) are also described which, in most cases, are only available in specialized clinics. The respective indications for the use of CT and MRI on companion exotic animals are explained so that an attending clinician can determine if one of these advanced imaging tests is required for their patient.

The production of such a comprehensive book on imaging diagnostics for companion avian and exotic animals would not have been possible without the competent support of the coauthors. Our heartfelt thanks are therefore extended to our colleagues T. Bartels (Leipzig), M. Fehr (Hanover), M. Gumpenberger (Vienna), J. Hein (Munich), I. Hoffmann (Nuremberg), I. Kiefer (Leipzig), V. Kostka (Hamburg), J. G. Kresken (Duisburg), E. Ludewig (Leipzig), C. Poulsen Nautrup (Munich), S. Schlieter (Freiburg in Breisgau), V. Schmidt (Leipzig), S. Schroff (Leipzig) and J. Spennes (Duisburg). In addition, we wish to thank all our colleagues who provided us with visual materials for the book.

The German-US American cooperation in the compilation of the visual materials and the composition of the chapters has ensured the depiction of a broad spectrum of species that play a special role in both the North American and European regions. The publication of the book in both German and English is welcomed by the publisher as is enables a transfer and understanding of knowledge between colleagues throughout the world.

Leipzig, Munich and Baton Rouge

Summer 2010

Maria-Elisabeth Krautwald-Junghanns
Michael Pees
Sven Reese
Thomas Tully

The authors have tried to ensure that the text, pictures, and drawings are correct and didactically suitable. For their valuable aid in the production of the positioning photographs in the bird radiography section, we wish to especially thank Ms. Fester and the Institute of Veterinary Anatomy, Leipzig, and Ms. Merseburger from the Small Animal Clinic, Leipzig, for their support in the undertaking of the CT and MRI investigations. Many former and current PhD students and veterinarians working at the Institute of Animal Anatomy in Munich and the clinics in both Leipzig and Munich have participated in obtaining the images published in this text. In addition, many unnamed helpers have contributed by voluntarily undertaking additional work, thereby enabling the authors to carry out the time-consuming and often difficult work involving the texts and visual materials.

We wish to thank everyone who participated in the development of this book, especially the coworkers at the Clinic for Birds and Reptiles in Leipzig and all the coworkers in the Department of Small Pets in the Small Animal Medical Clinic in Munich.

The work on such a comprehensive book requires many years of planning and coordination therefore places great challenges on both the publisher and the authors. Due to the opportunity of simultaneously publishing this book in English-speaking countries, the necessary resources were made available. We would like to particularly thank Dr. Oslage and Ms. Sodemann for their engagement and their professional supervision during both the book’s planning and execution phases.

The authors wish to request that all readers of this book inform them of any suggestions, desired corrections or revisions. Thank you.
Introduction

MARIA-ELISABETH KRAUTWALD-JUNGHANNS

The role of imaging techniques is becoming increasingly important in pet, zoo and wild birds medicine. While conventional radiography has been established as an important veterinary diagnostic test for many years, an increasing number of scientific studies on the routine use of ultrasonographic and computed tomographic methods have become available in recent years. As a result, these newer imaging modalities, especially ultrasonography, has found its place in veterinary practices and is predominantly used to diagnose internal disorders of companion avian species maintained indoors. Conversely in wild and free-flying pet birds, imaging diagnostics are used frequently in the surgical/orthopedic fields.

Radiography is being used with increasing frequency to obtain a diagnosis in avian medicine. Many diagnostic test results have limited interpretive value in avian patients (e.g., percussion, body temperature, the collection of adequate amounts of blood from birds with a body weight under 40 g, etc.) and avian patients can often hide their clinical disease signs for a long period of time. Therefore, when many birds first present to a veterinary hospital they are severely ill and require a rapid health assessment to determine an underlying disease etiology. Using different imaging modalities can often aid in rapidly determining an underlying disease etiology for the presenting avian patient that requires life-saving treatment.

While the size of many birds with a body weight of under 40 g may be a limiting factor (especially with digital radiography systems due to the current limited detail rendition of this method), the cost of this method has decreased for small inexpensive birds. On the other hand, undertaking a radiographic investigation is often easy due to the small size of the bird: a bird’s whole body can generally be imaged using one exposure. In addition, the danger of personnel being exposed to radiation is not a problem when conventional radiography or CT investigation performed using published health and safety guidelines and the patient is restrained with a Plexiglas plate. Moreover, the interpretation of a radiograph of a bird is easy for an experienced radiologist as the avian air sac system acts as a negative contrast to the organs. However, the air sac system makes an ultrasonographic investigation more difficult. Despite the adverse effect of the air sac system on the interpretation of ultrasonographic images, ultrasonographic investigation in unsedated birds is an easy noninvasive diagnostic method, especially when examining the heart, liver and urogenital tract. Ultrasonography often provides important supplementary information about disease subsequent to an unclear radiographic result. Advanced imaging modalities (CT, MRI) are increasingly being used to achieve more precise imaging detail, especially in larger avian patients. Currently CT is preferred over MRI due to the shorter time period required to perform the examination.
1.1 Radiographic investigation

MARIA-ELISABETH KRAUTWALD-JUNGHANNS, SANDRA SCHROFF, THOMAS BARTELS

1.1.1 Equipment

1.1.1.1 Radiography unit

Highly detailed radiographic images are a basic requirement to successfully achieve a radiographic diagnosis on an avian patient. Highly detailed radiographs are advantageous because the anatomic details are superior, allowing for expert interpretation and recognition of pathological changes. Moreover, the anatomic differences between avian groups are also enhanced by detailed radiographic images, which is of greater importance in birds because of the relatively small size of many avian patients. To obtain high-quality images, it is not only necessary to have the proper radiographic equipment (e.g., x-ray apparatus, film-screen combination, developing system), but the technical support staff performing the procedure must be experienced handling avian patients. A comprehensive discussion regarding basic radiology technical parameters and a full explanation of the radiation protection requirements would exceed the scope of this book. As a consequence, only the technical aspects that have a particular importance for avian radiography will be described below.

Basically, the radiographic interpretation of a bird requires similar equipment to that used in small animal radiography. Although, or especially because, such interpretations usually involve relatively small patients, high-power X-ray machines are particularly useful. In addition to the anatomical differences in avian patients, motion blur due to the high respiratory rate, even in anesthetized birds, adversely affects image quality. As a consequence, short exposure times (maximum 0.015–0.05 s, if possible even lower) should be used. Increasing the anode voltage enables the exposure time to be reduced; however, this can lead to an extreme reduction in contrast. The anode voltage should be maintained as low as possible (45–55 kV) to achieve radiographic images with a high degree of contrast and a wide grey scale range.

To decrease the dose of radiation, the film-focus distance can be reduced by placing the patient as close to the film as possible. The radiation dose that a particular area of the body receives can be reduced by 25% if the distance between the radiation source and the object is doubled (Inverse square law). Accordingly, by halving the film-focus distance, the amount of radiation needed to produce a radiograph can be reduced by a quarter. However, in practice, certain minimum values must be taken into consideration; otherwise the image quality is reduced. This is especially true to the body areas located further away from the film, which may appear larger and out of focus. In addition, low-power machines have a larger focal spot (ca. 2 mm × 2 mm) than units that are highly powered (focal spot 0.6 mm × 0.6 mm to 1.2 mm × 1.2 mm), which causes a reduction in image sharpness when low-powered machines are used. This effect is intensified if the film-focus distance is increased. A reduction of the film-focus distance to 60–70 cm is acceptable as long as a fine film-screen combination is used.

1.1.1.2 Screens and films

In order to achieve diagnostic radiographs of birds, fine film-screen combinations should be used. With fine film-screen combinations, the film must correspond to the screen with respect to both its sensitivity and degree of fineness. The use of more highly intensifying screens is not beneficial because with increasing intensification there is an associated loss of image sharpness and consequently, detail. An optimal system for the radiographic investigation of the internal organs of birds is the combination of rare earth screens and suitable films. Mammography screens are used for the radiographic investigation of the avian skeleton, although the usual increase in exposure time is not implemented. The radiographic images reproduced in this chapter were principally taken with the following screens and films:

Screens
- Kodak Lanex Medium Screens, Kodak X-OMAT cassette (soft tissues)
- Kodak MIN-R 2000 screen/windowless, Kodak MIN-R 2 cassette (bones)
Due to the relatively small body size of many birds, a whole body radiograph, which includes proximal regions of the fore and hindlimbs, can be taken.

Under normal conditions, the following structures are observed in the lateral projection:

- spine
- heart/major blood vessels
- lung structure/main bronchus
- caudal walls of the air sacs (if pathologically changed)
- spleen
- kidneys/gonads
- crop/esophagus, proventriculus and gizzard
- intestines and cloaca.

In comparison, VD radiographs are suitable for assessing the following:

- variations in symmetry of the relative positions of the organs
- pectoral girdle/pelvis
- hip and femur
- heart and liver shadows
- axillary diverticula/caudal air sacs

Since the wing is depicted in the mediolateral plane of both the ventrodorsal and lateral positions, a caudocranial radiograph is needed for another plane of assessment of the forelimbs (= second projection; see Figs. 1-2 and 1-18).

In weak or fractious birds, the clinician can attempt to take an exploratory radiographic image(s) of an unsecured patient. For example, if it is suspected that the bird has ingested heavy metal particles, a survey radiographic image will identify the toxic material thereby allowing for immediate initiation of a proper treatment protocol. To take exploratory radiographic images on an unsecured patient, 2 views may be taken, 1) (using a vertical beam) DV projection, with the bird being placed in a radiolucent container on the x-ray cassette; 2) (using a horizontal beam) bird held as perpendicular as possible, on the x-ray table and as close to the cassette as possible (Fig. 1-3).

The latter position is also useful for the diagnosis of ascites as the level of fluid can be identified in the standing animal.

In most cases, avian patients require fixed positioning to produce diagnostic radiographic images. Various methods can be used, but the method of choice is the use of restraint board fixation. The bird is tethered to a Plexiglas® avian restraint board (Figs. 1-4A, B, 1-5 and 1-6) in the positions desired for imaging. With many avian patients sedation is not necessary. The board should not be thicker than 5 mm, as the sharpness of the radiographic image is adversely affected as the board’s thickness increases. To secure the head, exchangeable neck pieces are needed, adapted to the size of the patient’s cervical area. The limbs should be tied with laces or leather bands that are at least 3–5 mm wide, as narrower bands can lead to cutting injuries. With board fixation, the bird has a greater chance of moving which will lead to motion blur thereby causing a greater loss in detail than that noted with handheld patients. While the bird may move while in the restraint board, the personnel involved with obtaining the images are not exposed to radiation and the board method does not appear to have any disadvantages for the

Films
- Kodak T-MAT PLUS DG Film (soft tissues)
- Kodak MIN-R L Film (bones)

1.1.2 Positioning and projections

1.1.2.1 Introduction

The radiographic anatomy of healthy birds often displays a certain degree of variability depending on the bird’s age, gender, reproductive status, and environmental conditions in which they live. Therefore, for one to correctly assess a radiographic image, it is necessary to have a thorough knowledge of avian anatomy and physiology.

Each radiographic interpretation should always involve images taken in at least two projections (Fig. 1-2). In general, both VD and lateral projections are taken for imaging the body. Correct positioning is imperative for the radiographic results to be properly assessed. However, this is often not considered in practice due to the clinician’s uncertainty in positioning the avian patient (see Fig. 1-1).

For the lateral projection, the bird is placed in standard right lateral recumbency. Special care should be taken when positioning birds in lateral recumbency if they are suffering from respiratory depression. The extension of the patient’s wing(s), as required when a bird is placed in lateral recumbency, often results in respiratory compromise.

Positioning and projections

1.1.3 Radiation safety

Avian radiodiagnostics often involves positioning small patients that are difficult or impossible to manipulate when wearing protective clothing. Despite this, the basic principles of radiation safety may not be ignored (Fig. 1-1). Protective clothing should be worn to protect technical personnel from scatter radiation produced while the radiographic images are being taken. The primary radiation beam will even penetrate the material incorporated in lead gloves. As a consequence, the avian patient should be positioned so they do not have to be held by hand when the images are taken. The bird should be sedated/anesthetized then placed in the appropriate position by taping or using a restraint board (see Chap. 1.1.2). The radiographic format should be adapted to the size of the patient or the area of the body being investigated by using a suitable cassette or by having the beam adequately collimated. If a bird has to be held when the radiographic images are taken, the person(s) holding the bird should hold their hands outside of the primary beam and have them covered with radiopaque material (e.g. lead gloves) to protect them from the scatter radiation.

In weak or fractious birds, the clinician can attempt to take an exploratory radiographic image(s) of an unsecured patient. For example, if it is suspected that the bird has ingested heavy metal particles, a survey radiographic image will identify the toxic material thereby allowing for immediate initiation of a proper treatment protocol. To take exploratory radiographic images on an unsecured patient, 2 views may be taken, 1) (using a vertical beam) DV projection, with the bird being placed in a radiolucent container on the x-ray cassette; 2) (using a horizontal beam) bird held as perpendicular as possible, on the x-ray table and as close to the cassette as possible (Fig. 1-3).

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Board restraint is contraindicated in critically ill birds or those suffering from circulatory and/or respiratory depression. Board restraint can be used contraindicated in critically ill birds because the clinicians do not have any direct contact with the bird during the procedure, therefore they are unlikely to recognize deterioration in the patient's condition at that time. In addition, with manual restraint a bird can be brought quickly into an upright position if needed, whereas with board fixation the bird will have to be released first. High-risk patients should be manually restrained for a radiographic investigation. Manual restraint is also suitable for raptors with a body weight of more than 1000 g as these birds can be held with lead gloves without difficulty.

It is very hard to properly hold small birds (i.e. with a body weight of less than 40 g) in a desired position when one is wearing lead gloves. Only in extreme circumstances should manual restraint be used by placing the bird in the correct position with unprotected hands. An assistant must then cover the investigator’s hands completely with either lead gloves or lead plates (Figs. 1-9A–C, 1-13, 1-14). The horny tissue can be cleansed using soapy water before being taped to ensure that the adhesive adheres better and can the patient be positioned tautly enough to the cassette to prevent motion artifact. Adhesive tape (e.g. adhesive film, crepe) can be used successfully for the horny parts of the body (e.g. beak, leg, foot, Figs. 1-9A–C, 1-13, 1-14). The horny tissue can be cleansed using soapy water before being taped to ensure that the adhesive adheres better.

Although larger birds can be placed in a proper position manually while using lead gloves, this is not possible in birds with a body weight of less than 40 g. If small birds (i.e. < 40 g) have to be manually positioned, this should initially be performed as described above with unprotected hands. Once the beam has been focused properly, the hands holding the bird should be covered with radiopaque material (e.g. lead gloves, lead plates). The assistant’s hands must be kept out of the primary beam at all times (Fig. 1-7)!

In extremely rare cases, sedated small birds can be fixed to the x-ray table using adhesive tape. The neck, the wings at the level of the primary feathers, and the legs in the region of the tibiotarsal joints are fixed into position with tape. If necessary, additional tape can be placed over the chest to minimize motion blur. Loss of feathers from such regions due to the tape removal cannot be avoided.

If an avian restraint board is available, the bird should be positioned to the board as described above. Care should always be taken in patients with long tail feathers (macaws, pheasants, etc.) so that the tail lies in a straight line to the spine ensuring that a symmetrical image can be taken.

The central beam should be directed vertically to the cassette targeting the bird medially, roughly at the level of the caudal costal arch.

### Lateral radiographs

For a lateral projection, the patient must be placed on its right side. With manual restraint, the head of the bird is held with the thumb and index finger of one hand holding the jaws together and the other hand should hold the feet stretched of the caudally as much as possible. This is important to prevent superimposition images difficult at best (Fig. 1-10). The wings should be pulled over the back of the bird and kept in place by the forearm of the person holding the bird (Fig. 1-8). To prevent superimposition, the right wing should be positioned slightly lower and in front of the left wing and the right leg in front of the left leg. To prevent the bird’s body from being twisted, a radiolucent object (e.g. cellulose wadding, pillows) with a suitable width should be placed between the wings. This enables a torsion-free radiograph to be made of a hand-held patient (Fig. 1-6).

If due to the size of the bird (i.e. but < 40 g), positioning of the patient is not feasible when wearing lead gloves, then the bird should be put into position using bare hands which are then covered with radiopaque material (Fig. 1-8).

Small birds with a body weight of less than 40 g should only be fixed with adhesive tape in rare cases for a lateral radiograph and only after being sedated. The bird should be placed on its right side on the x-ray table and placed into position using adhesive tape over the neck, the dorsally stretched wings, and the caudally stretched legs. An additional piece of tape can be placed over the breast to help reduce motion artifact with unsettled birds.
The method of choice for proper positioning is an avian restraint board, whereby the bird is placed in the lateral position as described above. Once the head has been secured by a suitably sized neck piece (Figs. 1-4A, B, 1-6), the wings are placed in their proper position. To ensure that there is no twisting, a radiolucent spacer of suitable width should be situated between the wings. The legs should be stretched out as far as possible then secured using the ties attached to the board (Fig. 1-6). The position of the bird can be additionally stabilized by placing weights on the feet. Transferring the bird from supine to lateral recumbency can be done without releasing the bird’s head from the board – the neck pieces used to secure the head usually provide enough room for the bird to be able to turn its head.

The central beam is directed vertically to the table and should be aimed at the longitudinal axis of the body, roughly at the caudal part of the costal arch. If the body has been positioned correctly, the hips are superimposed in the lateral projection.

1.1.2.3 Positioning for imaging the head

For radiologic images of the head, the standard projections are DV, VD and lateral. With these views, it is possible to diagnose the radiographically depicted anomalies with a satisfactory degree of confidence. In addition, further images can be obtained from the rostrocaudal projection at angles of 30° or 75° (Fig. 1-9). Principally, radiography of the head can be performed with either manual positioning of the patient or by using an avian restraint board. However, as exact positioning is a prerequisite for diagnosis of diseases involving the head, sedation of the bird is required. Without the use of a board to restrain the bird, it is usually necessary, in the majority of cases, to heavily sedate the patient to prevent the occurrence of motion artifact. If an avian restraint board is available, then light sedation is usually all that is needed. One disadvantage of the avian restraint board is the neck piece, which causes a reduction in image quality by attenuating the beam as its radiographic shadow superimposes on the back of the head and/or the cranial cervical vertebra (Fig. 1-17). As a consequence, one should consider the benefits of leaving the neck piece off versus the risk of placing the patient under a deeper level of sedation.
1.1 Radiographic investigation

Fig. 1-1: Radiograph referred for assessment of a beak fracture (and subsequent repair with a cerclage wire) in a small parakeet. The image quality, aiming of the central beam, correct positioning of the patient, and radiation protection measures are often neglected in small avian patients, often resulting in the radiographic image being uninterpretable.

Fig. 1-2: Radiographic images of a barn owl (Tyto alba) wing showing the ventrodorsal (A) and caudocranial (B) projections. The luxation of the metacarpal joint is only visible in the caudocranial projection (arrow) due to the different planes of the skeletal structures in the two projections. This underlines the need to always take radiographs in at least two planes.

Fig. 1-3: Radiographic examination of a canary placed in a radiolucent container (behind the box is the cassette) to rule out the ingestion of heavy metal particles. The x-ray tube is to the right of the picture.
Fig. 1-4A: Plexiglas® avian restraint board (1) with various head pieces (2) used for the fixation of birds. The head piece needs to be locked into the fastener (yellow arrows). Additional device (3) for the fixation of the hindlegs with shoe laces or similar cord (red arrows: direction of tightening). The film cassette is lying under the restraint board.

Fig. 1-4B: Schematic drawing and dimensions of the plexiglas® avian restraint board from Fig. 1-4A.

Fig. 1-5: African grey parrot (Psittacus erithacus): Board fixation for a ventrodorsal radiograph.

Fig. 1-6: African grey parrot (Psittacus erithacus): Board fixation for a lateral radiograph.

Positioning and projections
Fig. 1-7: Cockatiel (Nymphicus hollandicus): Manual fixation for a ventrodorsal radiograph.
A: Without any radiation protection.
B: With radiopaque shielding of the hands.

Fig. 1-8: Cockatiel (Nymphicus hollandicus): Manual fixation for a lateral radiograph.
A: Without any radiation protection.
B: With radiopaque shielding of the hands.
Positioning and projections

Fig. 1-10: Radiographic image of a common buzzard’s (*Buteo buteo*) body using a lateral projection. The internal organs cannot be assessed because the legs have not been completely extended in a caudal position.

Fig. 1-9: Blue-fronted Amazon (*Amazona aestiva*): Positioning of the head for (A) dorsoventral, (B) lateral, (C) ventrodorsal, and (D) rostrocaudal radiographs following isoflurane induction for short-term sedation.
1.1 Radiographic investigation

Dorsoventral radiographs

For a DV radiograph, the sedated bird is placed in ventral recumbancy (prone). The tip of the upper beak is cleansed and secured with extremely tacky adhesive tape. The extremities of the patient can be held either manually or with an avian restraint board using ties and adhesive tape. The neck of the bird is stretched and held in position using the tape on its beak. When done correctly, the head now lies symmetrically with both lower jaws flat on the cassette or restraint board (Fig. 1-9A).

Ventrodorsal radiographs

A VD radiograph can be taken in a similar manner. The sedated patient is placed in dorsal recumbancy and fixed. It is important to ensure that the positioning is symmetrical. By pulling on the adhesive tape attached to the bird’s beak, the neck is stretched and fixed without twisting. With exact positioning, both the lower jaws lie parallel to the cassette (Fig. 1-9C).

Lateral radiographs

If the head needs to be radiographed on its side, the patient is placed in right lateral recumbancy and restrained either manually or using an avian restraint board. The neck of the bird is stretched as far as possible and secured in this position using a tape attached to its upper beak. It is important when interpreting the radiographic images that the positioning is exactly symmetrical, especially in this projection, since assessment of the radiographs can be adversely affected by asymmetry (Fig. 1-9B).

Rostrocaudal, caudorostral, and oblique radiographs

For rostrocaudal radiographs, the bird is laid on its back with its body and limbs secured. The head of the bird is laid at an angle of 90° to the cassette with its beak closed or slightly opened. The head is held in this position by a piece of adhesive tape placed on the base of its neck. For this projection, the central beam is directed vertically towards the cassette and is aimed at the tip of the beak (Fig. 1-9D).

If the head needs to be radiographed in the caudorostral projection, the bird is placed and secured in a similar position but this time in ventral recumbency.

For oblique radiographs, the head of the x-ray machine is placed at the required angle (i.e. 30° or 75° are most often used) and the central beam is aimed at the middle of the parietal bone (back of the head).

1.1.2.4 Positioning for imaging the wing

When the bird is positioned for radiographs of the body in dorsal or lateral recumbency, the wings are always viewed in the mediolateral plane. For radiographic images of the wing, the patient is usually positioned in dorsal recumbency and secured as described above. The wing is stretched as far as possible before being held in place (Fig. 1-11).

To position the bird for the second projection of the wing (caudocranial), it is necessary to place the bird on the edge of the table with its head lying down (the cassette is placed on the edge of the table). The feet and tail are held with one hand, while the head is held at the base of the beak with the thumb and index finger of the other hand. A second person should stretch the wing to be radiographed as far as possible away from the bird’s body, with the front of the wing lying on the cassette parallel to the edge of the cassette (Fig. 1-12). The central beam is aimed at a 90° angle to the cassette, focusing on the elbow joint.

1.1.2.5 Positioning for imaging the hindlimb

A dorsoplantar radiograph of the hindlimbs is performed with the bird positioned in dorsal recumbency as described above for the VD radiograph of the body (Fig. 1-13).

The patient is radiographed in lateral recumbency for mediolateral radiographs. Depending on the disease condition being evaluated, the animal is placed on its right or left side, so that the extremity to be radiographed is placed as close to the cassette as possible. The central beam is aimed vertically at the cassette and focused on the intertarsal joint. If the toes need to be radiographed, it is recommended to position each individually to the table or cassette using adhesive tape (Fig. 1-14).
Fig. 1-11: Common buzzard (Buteo buteo): Positioning of the wing for a mediolateral radiograph. The bird has been fixed on a plexiglas® avian restraint board.
A: side projection.
B: projection from above.

Fig. 1-12: Common buzzard (Buteo buteo): Positioning and fixation of the wing for a caudocranial radiograph.

Fig. 1-13: Blue-fronted Amazon (Amazona aestiva): Positioning of the legs for a dorsiplantar radiograph.

Fig. 1-14: Blue-fronted Amazon (Amazona aestiva): Positioning of the legs for a mediolateral radiograph.
1.1.3 Anatomical-physiological representation

1.1.3.1 Skeletal system

Cranium and axial skeleton

There is significant anatomical variation of the beak between avian species along with breed-specific differences within a species (e.g. domestic pigeons). The owls (strigiforms), primarily a nocturnal avian group, have voluminous eyeballs set in large orbits. The two eyes are only separated by a thin, slightly radiopaque wall. A radiopaque structure that is distinctive to the avian eye is the ossified scleral ring. The bones of the cranium are pneumatic (filled with air), with the extent of air within this area dependent on the species examined (Figs. 1-15 and 1-16). The air spaces within the cranial bones are in direct contact to the infraorbital sinus through connections called diverticula.

The cervical and parts of the thoracic vertebral bones are also pneumatized. In contrast to mammals, the number of vertebrae within the class Aves is not constant but is variable depending on the species (e.g. domestic chicken 16, mute swan 25). In many avian species, there is a fusion of the free thoracic vertebrae forming the notarium. When the caudal thoracic vertebra, lumbar vertebrae, and sacrum, as well as, some of the cranial coccygeal vertebrae fuse, this forms a structure called the synsacrum (the dorsal wall of the pelvic girdle) (Fig. 1-22). The last free thoracic vertebra before the synsacrum is often movable and this area of the spine is predisposed to fractures.

Indications

- trauma, beak injuries, fractures of the jaw or hyoid apparatus, suspicion of spinal fracture
- swelling or increased size of the head (e.g. chronic sinusitis)
- suspicion of tumor formation (e.g. retrobulbar tumors)
- injuries of the cervical air sac

Possible clinical signs

- external injuries, hemorrhages
- paralysis, with injuries of the spine often in combination with difficulties in defecation
- CNS abnormalities
- abnormal stance, torticollis
- swellings
- chronic respiratory problems, nasal discharge
- therapy-resistant subcutaneous emphysema
- problems with food uptake, weight loss of unknown cause

Trunk and limb skeleton

To aid in the reduction of their body weight, the skeletal system of flighted birds is characterized by a high degree of pneumatization, primarily involving bones of the proximal skeleton. Bones within the proximal skeleton that contain air include the humerus and coracoid, but also the thorax (i.e. parts of the ribs and especially the sternum, including the sternal ridge), the pelvic girdle, and femur. Typical radiographic images of pneumatized bones show thin radiopaque cortices surrounding a loose system of fine three-dimensionally connected bony trabeculae. In contrast, the distal parts of the wing and leg skeleton do not have any air-filled spaces.

The ulna appears more prominent in the avian forewing skeleton (Fig. 1-18) than the radius. Both the wing and foot skeletal structures are characterized by reductions and fusions of the bones. The distal carpal and metacarpal bones fuse to form the carpometacarpus, while the tibia and proximal parts of the tarsus form the tibiotarsus. In the foot, the tarsal bones are fused with the metatarsal bones forming the tarsometatarsus (Fig. 1-19).

The increase of circulating blood estrogen when female birds are reproductively active leads to an increased radiopacity of the medullary cavity within the long bones of female birds. This increase in radiopacity within the long bones is due to an increased thickness of the compact bone and the laying down of calcium deposits in the form of so-called medullary bone tissue within the medullary cavity (Fig. 1-21).

The radiographic assessment of the pectoral girdle and the pelvic region is hindered by the superimposition of the well-formed wing and leg musculature. There is superimposition of the coxoid and scapula in the VD projection of the pectoral girdle (Fig. 1-23). If there is suspicion of changes in this area, then asymmetrical positioning is needed; by slightly tilting the patient off center, both parts of the pectoral girdle can be assessed. In addition, the imaging of the cranial air sac system can also be impaired due to the superimposition of the well-developed pectoral musculature.

Indications

- fractures, fissures, investigations to control the course of healing
- malpositioning of the extremities, luxations
- infections that also involves the skeletal structures (e.g. pododermatitis [Bumblefoot], tuberculosis, etc.)
- metabolic disturbances, nutritional deficiency (e.g. rickets in young birds)
- suspicion of a foreign body (e.g. gunshot in wild or imported birds)

Possible clinical signs

- reduced resistance of the hindlimbs
- reduction or loss of ability to fly, abnormal posture of one or both wings
- abnormal posture, skeletal deformation
- neoplasia or osteophyte production on the skeleton
- swellings, inflammation
- cachexia of unknown etiology
- abdominal hernia (in connection with bony changes associated with pathological hyperostosis)
Normal variations

The diagnostic capability of radiographic imaging of young birds is poor due to the lack of radiodense skeletal structures (Fig. 1-20). Only with increasing calcification can the bones be adequately radiodense for optimum evaluation.

In contrast to mammals, the epiphyses of growing birds exhibit no epiphyseal zones of ossification, with one exception, the intertarsal joint. During the maturation of the intertarsal joint, each of the tarsal bones develops separately. In birds the proximal row of the tarsal bones fuse with the tibia to form the tibiotarsus, while the tarsometatarsus develops from the fusion of the distal tarsal bones with the metatarsus.

The air sac diverticuli that grow into the humerus are at first not very large and attain their final size by successive pneumatization of the medullary cavity. Due to the lack of age-related scientific investigations, neither the degree of humeral pneumatization nor the state of calcification of the skeleton can be used for age determination in pet birds.

During reproductive activity, female birds have a higher degree of bone density due to their hormonal status. This increased bone density affects the femurs and other long bones and should be considered as being normal. Starting in the endosteum, medullary bony tissue is formed in reproductively active females thereby acting as a calcium reserve for producing egg shells (Fig. 1-21).
1.1 Radiographic investigation

Fig. 1-15: Radiographic images of a goshawk’s (Accipiter gentilis) head showing the (A) lateral and (B) ventrodorsal projections.

1: upper beak
2: lower beak
3: quadrate bone
4: dorsal arch of the atlas
5: cervical vertebrae
6: scleral ring
7: brain
8: trachea
9: hyoid bone
10: vomer
Fig. 1-16: Radiograph images of a blue-fronted Amazon parrot’s (Amazona aestiva) head showing the (A) lateral, (C) rostrocaudal, (E) ventrodorsal projections, each with the respective projection of the cranium (B, D, F).

1: horny sheath of the upper beak
2: bony nares
3: craniofacial fissure
4: parts of the infraorbital sinus
5: orbit
6: palatine bone
7: quadrate bone
8: palatine bone
9: jugal bar
10: horny sheath of the lower beak
11: hyoid bone
12: trachea
13: pterygoid process of sphenoid bone
14: vomer
15: dorsal arch of the atlas

Anatomical-physiological representation
1.1 Radiographic investigation

Fig. 1-17: Radiographic image of the craniocervical region of a gyrfalcon (Falco rusticolus) showing a lateral projection. A bone is lying in the esophagus. The bird was sedated using an inhalational anesthetic administered with a face mask and positioned on a plexiglass® avian restraint board.

Fig. 1-18: Radiographic images of a blue-fronted Amazon's (Amazona aestiva) wing showing the (A) ventrodorsal and (B) caudocranial projections.

Fig. 1-19: Radiographic images of a blue-fronted Amazon parrot’s (Amazona aestiva) leg showing the (A) mediolateral and (B) dorsoplantar projections.

1: humerus
2: ulna
3: radius
4: carpometacarpus
5: alula (thumb)
6: metacarpal bone
7: proximal phalanx
8: distal phalanx

1: femur
2: tibiotarsus
3: tarsometatarsus
4: metatarsus
5, 6, 7: digit with phalanges
Anatomical-physiological representation

Fig. 1-21: Total body radiographic image of a budgerigar (Melopsittacus undulatus) showing the ventrodorsal projection. Formation of medullary bone can be observed in the pectoral girdle, humerus (arrows), femur (arrows), and tibiotarsus. Egg formation in the abdomen has led to the compression of the air sacs, displacement of the gizzard and changes in the silhouette of the heart and liver.

Fig. 1-20: Total body radiographic image of an emu (Dromaius novaehollandiae) showing the lateral projection. Young birds, such as this, have wide joint cavities because their bones lack ossification; this condition is especially prominent in the ankle. The emu’s stomach and intestines have a voluminous silhouette, which is typical for young birds.
1: sternum
2: coracoid
3: clavicle
4: scapula
5: femur
6: tibiotarsus
7: cervical vertebrae
8: thoracic vertebrae, notarium
9: synsacrum
10, 11: tail vertebrae, pygostyle
12: rib
13: humerus
14: trachea with syrinx
15: lung with the thoracic and abdominal air sacs (**)
16: heart with the brachiocephalic trunk (*)
17: crop
18: proventriculus
19: ventriculus with grit
20: loop of intestine
21: liver
22: spleen
23: kidney
24: gonad

**Fig. 1-22:** Total body radiographic images of a blue-and-yellow macaw (Ara ararauna) showing the lateral projection.
Fig. 1-23: Total body radiographic images of a blue-and-yellow macaw (Ara ararauna) showing the ventrodorsal projection.

Anatomical-physiological representation

1: humerus
2: coracoid
3: clavicle
4: scapula
5: sternal carina, superimposed by the spine
6: femur
7: tibiotarsus
8: fibula
9: rib
10: pelvis
11: tail vertebrae, pygostyle
12: trachea with syrinx
13: lung
14: thoracic and abdominal air sacs
15: diverticuli of the clavicular air sacs
16: heart with major blood vessels
17: liver
18: ventriculus with grit
19: loop of intestine
20: cloaca
1.1.3.2 Cardiovascular system

The heart is situated in the VD projection roughly between the 2nd and 5th–6th ribs. The base of the heart is directed craniocaudally, while the apex lies close to the sternum in the radiographic shadow of the liver. Typically in granivores, an hourglass shape is formed by the shadows of the heart and liver (Figs. 1-23 and 1-26). Only in cockatoos can the apex of the normal heart be differentiated when viewing the lateral projection due to the position of the air sacs.

A slight dorsal bending over of the left atrium may be observed radiographically in a number of avian species. In macaws, there is a characteristically obvious ventrally directed bend between the heart and liver shadows in the lateral projection.

Both in the DV and lateral radiographic views, the major blood vessels can be identified as round or cord-like structures. These circulatory structures are readily apparent in many older avian patients because of increased calcification of the major blood vessel walls (Figs. 1-22 to 1-24, and 1-37).

Indications
- diseases characterized by changes in the position, size, and form of the heart
- infectious processes that may lead to secondary changes in the heart (e.g. pericarditis after generalized infection)
- non-infectious disease (e.g. space-occupying lesions, rare genetric defects, neoplasia)

Possible clinical signs
- numerous clinical signs are possible as the changes in the heart observed radiographically are often secondary and the clinical signs are influenced by the primary disease
- cardiovascular insufficiency, bluish discolouration of the skin (especially around the eyes) and mucous membranes, incoordination, disequilibrium, tendency to develop shock, etc.
- depression
- respiratory distress
- reduced ability to fly
- seizure activity

Normal variations

The large blood vessels in older birds can be clearly observed on radiographs due to the higher degree of calcification of the vessel walls (Fig. 1-37). It is not always possible to make a clear distinction between a physiological and pathological (arteriosclerosis) degree of calcification.

1.1.3.3 Respiratory tract

The avian respiratory tract exhibits only a few radiographic variations. The trachea can be easily observed on a radiographic image due to its cartilaginous or bony supporting rings. The syrinx (voice organ in birds) lies in the area where the trachea branches into the two main bronchi. The syrinx is not clearly visible due to superimposition of other anatomic structures in the area and is best observed on lateral radiographic images. The lungs are relatively nonelastic structures embedded within the ribs and are evident in lateral radiographs due to their honeycomb-like shadowing.

In contrast to other animals, the lung volume is constant in birds because they lack a diaphragm. With avian patients, taking radiographic images during maximum inspiration is not usually possible due to their high respiratory rate. Characteristic of all birds is their extensive, radiographically variable, but easily observed air sac system. The avian air sac system usually consists of nine air sacs, whose diverticuli extend in part, into individual bones. Normal air sac walls cannot be imaged using standard radiographic techniques. There are group-specific differences (e.g. raptors) with respect to the extent of the air sac system and the dimensions of the different air sacs (Figs. 1-22 to 1-25, 1-28, 1-29). An example of these group-specific differences involves accipitriforms and falconiforms which have extensive clavicular air sacs.

Indications
- suspicion of infections, especially mycoses (e.g. aspergillosis), bacterial infections
- air sac rupture, chronic overextension of an air sac
- suspicion of a foreign body in the upper respiratory tract, other types of stenosis
- suspicion of aspiration pneumonia

Possible clinical signs
- respiratory sounds
- cardiovascular insufficiency, seizure activity, ataxia
- »cheek blowing«
- tail bobbing
- loss of voice
- nasal discharge, conjunctivitis, coating in the throat
- apathy, increased »yawning«
- reduced flight ability, lack of endurance
- chronic subcutaneous emphysema
- nonspecific symptoms such as diarrhea, cachexia, anorexia, retching, vomiting (especially associated with mycoses)

Normal variations

The tracheal rings are, at first, laid down as cartilage in young birds and become ossified with age. The length of the trachea varies greatly according to the avian species being examined. In cranes, swans, and flamingos, the trachea can be longer than the body length. In some birds the trachea can even lie in loops underneath the sternum (Fig. 1-30), while in other birds the trachea lies in a special cavity within the sternum. Mynas have a typical bend in the trachea that occurs proximal to the thoracic inlet. In penguins, the trachea appears to be divided due to a bifurcation of the structure located in cervical area.
Anatomical-physiological representation

Fig. 1-24: Total body radiographic image of an orange-winged Amazon (Amazona amazonica) showing the lateral projection.

1: trachea
2: syrinx
3: lung with connecting thoracic and abdominal air sacs (*)
4: crop
5: proventriculus
6: ventriculus with grit
7: loop of intestine
8: heart
9: liver
10: kidney
11: spleen
12: gonad

Anatomical-physiological representation
The bronchi are highly ossified in older great crested grebe males (Fig. 1-31). An ossified protrusion of the trachea lying close to the syrinx is typically found in drakes of many duck species, the so-called bulla ( tympaniformis ) syringealis (Fig. 1-27).

The diverticuli of the clavicular air sac which penetrate into the humerus are at first small and reach their final size as the bird ages (Fig. 1-23).

1.1.3.4 Liver

The radiographic shadow of the liver can vary greatly with respect to its form and size. The differences in the radiographic shadow are partly species specific, but also depend on the nutritional status of the bird (compare Figs. 1-22 and 1-23 with Fig. 1-26). Under physiological conditions, the outlines of the liver on a VD radiograph do not extend beyond a line formed between the coracoid and acetabulum. In parrots and other gra- nivores, the typical hourglass shape formed by the soft-tissue shadows of the heart and liver is influenced on the left side by the degree of filling of the proventriculus (Figs. 1-23 and 1-25). In the lateral projection, the liver cannot be differentiated from the gastrointestinal tract without the use of a contrast agent.

The gallbladder cannot be radiographically differentiated and is often not present many species of pigeons or parrots.

Indications

- neoplasia (especially in budgerigars)
- metabolic disturbances (e.g. hemosiderosis in mynas, fatty liver degeneration in obese birds)
- infectious processes (liver swelling in many virus infections, e.g. Pacheco’s disease [parrot herpesvirus], leucosis, PMV-1 infection; in psittacosis often in association with swelling of the spleen)

Possible clinical signs

- abdominal swelling
- icterus (rare)
- diarrhea with a yellowish discoloration of the urates
- abnormal feathering with discoloration of the feathers (chronic hepatitis) and pruritis
- nonspecific symptoms such as cachexia, anorexia, apathy, general malaise
- vomiting
- obesity, respiratory distress (e.g. with fatty liver)
- paralysis of the hindlimbs (e.g. liver tumor in budgerigars)

Normal variations

The size of the liver can vary considerably depending on the avian species being examined. The size of the liver also depends on the nutritional status of the bird as hepatomegaly or fatty liver is often observed in obese birds (Fig. 1-26).

1.1.3.5 Spleen

A normal spleen is observed on lateral radiographs as a spherical, at times egg or bean-shaped, soft-tissue shadow dorsal to the proventriculus (Figs. 1-22 and 1-24). The splenic shadow cannot be differentiated from the surrounding tissues on VD radiographs in birds. The size of the spleen in budgerigars is ca. 1 mm and in the larger parrots (e.g. grey parrots or Amazons), ca. 6 mm. The spleen can only be seen satisfactorily in roughly 30% of radiographic images taken of large parrots. In pigeons the spleen cannot be clearly differentiated from the surrounding tissue because it is usually embedded in fat.

Indications

- infectious processes [swelling of the spleen, tuberculosis, psittacosis (with massive swelling of the spleen in connection with the clinical disease signs it is possible to make a quick tentative diagnosis of this disease)]
- neoplasia (especially in budgerigars, tends to be rare in other avian species)

Possible clinical signs

- nonspecific clinical signs (e.g. cachexia, anorexia, apathy)
- changes in the feces (diarrhea, black-green inanition feces, etc.)
- conjunctivitis, rhinitis (psittacosis)
- rare signs of paralysis of the hindlimbs (splenic tumor)

Normal variations

The size of the spleen may vary considerably depending on the avian species being examined.
Fig. 1-25: Total body radiographic image of an orange-winged Amazon (Amazona amazonica) showing the ventrodorsal projection. The same bird as in Fig. 1-24. Representation of an unchanged heart (1) and liver (2) silhouette. Measurement of the cardiac shadow width (4) should be undertaken on a ventrodorsal radiograph with complete symmetrical positioning. It should be compared to the maximal width of the thorax (5). In medium-sized parrots (body weight 200–500 g), the width of the heart on a radiograph should be ca. 51–61% of the maximal width of the thorax.

Fig. 1-26: Total body radiographic images of a blue-fronted Amazon (Amazona aestiva) showing the (A) ventrodorsal and (B) lateral projections. Obesity (arrows: fat deposits). The heart-liver silhouette is enlarged.

Fig. 1-27: Total body radiographic image of a red-breasted merganser (Mergus serrator) showing the ventrodorsal projection. Bulla syringealis (arrows).
In many birds, the cervical part of the esophagus widens to form a crop. Particularly voluminous crops or esophageal diverticuli can be found in granivorous, carnivorous, and carrion-feeding birds (Fig. 1-17). In pigeons the crop divides into two lateral sacs. With granivorous species, the caudal esophagus, proventriculus, and ventriculus can be well differentiated on a lateral radiographic image. Additionally, radiopaque particles, which may be noted as a »normal finding,« can be identified in the ventriculus due to the presence of grit. In fructivorous, nectarivorous, and carnivorous species, the proventriculus and ventriculus cannot be differentiated from each other radiographically, especially after the patient has ingested a large meal. With fructivorous, nectarivorous, and carnivorous birds the ventriculus is more distendable than in granivorous species. In raptors, owls, and other avian carnivorous, piscivorous, or molluscivorous species, calcified parts of the diet (e.g. bone or even complete prey, mollusk, or snail shells) can be seen as radiopaque structures in the gastrointestinal tract (Figs. 1-17, 1-29).

The gastrointestinal tract can only be radiographically examined through the administration of a suitable contrast agent (Figs. 1-36 A–F). Without any contrast agent and only on rare occasions is it possible to observe a loop of intestine on the right side of the abdomen and the cloacal region.

The cecum is often observed as a double organ that can achieve a rather a large size in game birds (grouse), ducks, geese, and owls. In some species (e.g. herons, loons), the ceca is reduced. In many avian species maintained as pets (e.g. parrots, pigeons, mynas), the two ceca are only rudimentary or are completely absent.

Indications
- suspicion of a foreign body (primarily heavy metals which can be diagnosed radiographically)
- mechanical or paralytic ileus (e.g. neoplasia, engorgement with food)
- abdominal hernia
- cloacal prolapse
- infectious gastrointestinal disease (e.g. parasitic infections: tentative diagnosis in the prepatent period is possible; viral infections: e.g. proventriculus dilatation disease – important possibility of confirming a tentative diagnosis in the live bird)

In order to properly differentiate the gastrointestinal tract, after taking a survey radiographic image, gastrography using a contrast agent is indicated (Fig. 1-36).

Possible clinical signs
- vomiting, retching
- cachexia, anorexia
- swelling of the abdomen
- cloacal prolapse
- adhesions in the cloaca, changes in the cloacal mucosa
- no defecation or difficulties in defecation, changes in the feces (e.g. undigested grain in candidiasis, proventriculus dilatation disease, etc.; hematochezia with heavy metal poisoning)
- polydipsia, polyuria
- discoloration of the feces and/or urates
- changes in the amount of feces (e.g. pancreatic insufficiency)
- CNS disturbances with cachexia and a negative parasitological investigation

Normal variations
The gastrointestinal tract can differ radiographically according to the nutritional requirements and normal diet of the bird. In granivorous birds, radiopaque particles (grit) are normally identified in the ventriculus. In pigeon chicks or nestlings of granivorous species, the gastrointestinal tract appears to be very voluminous in the first few weeks of life due to the consistency of the food fed to the young by adults (e.g. crop milk, food mash). Parts of prey skeleton (bone, mollusk shells) can be found in the radiographic images of carnivorous birds (e.g. Fig. 1-17).
Anatomical-physiological representation

Fig. 1-28: Total body radiographic image of a pigeon (Columba livia f. domestica) showing the (A) ventrodorsal and (B) lateral projections. Grit is not only present in the ventriculus, but also in the crop, just cranial to the thoracic inlet, and within the intestinal lumen.

Fig. 1-29: Total body radiographic image of a gyrfalcon (Falco rusticolus) showing the lateral projection: Tube-like proventriculus and gizzard (arrows). There are bones from prey the bird ate in the ventriculus.

Fig. 1-30: Total body radiographic image of a mute swan (Cygnus olor) showing the lateral projection: Long convoluted trachea (arrows).

Fig. 1-31: Total body radiographic image of a great crested grebe (Podiceps cristatus) showing the lateral projection: Calcified main bronchi (arrows).

1: trachea
arrows: main bronchi
1.1.3.7 Urinary tract

Birds have a pair of kidneys that are embedded retroperitoneally on either side of the vertebral column in a depression in the ventral surface of the synsacrum. Each one of the kidneys has a three-part structure. In lateral radiographs, the cranial end of the kidney is superimposed by the gonad, although the degree of superimposition depends on the bird’s reproductive status as the genital tract can be very enlarged during the breeding season (Figs. 1-22, 1-24, 1-32, 1-33A, B). In VD radiographs, the kidneys are often not visible or are indistinct. The kidney of the domestic chicken is ca. 7–9 cm long, whereas in the African grey parrot it is ca. 3 cm. The typical structural and functional divisions (i.e. external renal cortex and internal renal medulla with a renal pelvis) found in mammalian kidney are missing in the avian renal organs. The most significant radiographic feature is the renal portal vein system, as this allows for a rapid excretion of contrast during urographic investigations. Neither a urinary bladder nor a urethra is present in birds. The excrement is discharged directly from the ureters into the cloaca via the urodeum. Both these structures can become radiopaque under certain disease conditions (e.g. urate congestion, nephrolithiasis; see Chap. 1.10).

Indications

- infectious processes (renal swelling e.g. psittacosis, nephrocalcinosis often associated with bacterial nephritis)
- neoplasia (especially in budgerigars)
- metabolic disturbances (e.g. vitamin A deficiency, nephrocalcinosis)
- other noninfectious processes which affect the kidney (e.g. chronic lead poisoning – with respect to the prognosis, severe dehydratation)

Possible clinical signs

- polydipsia
- polyuria, discoloration of the urates
- vomiting
- dehydratation
- crooked posture, severe general malaise
- paralysis of the hindlimbs
- disturbances in feather growth and skin changes without pruritis, hyperkeratosis
- abnormal blood values, e.g. increased urate concentration

1.1.3.8 Genital tract

The pair of testicles in male birds lies cranioventral to the cranial aspect of the kidneys. The size of the avian testicle depends on the reproductive status of the bird. The testicles of sexually active males in passeriform species can be up to 500 times larger than those in the same birds when not reproductively active. Testicles enlarged due to reproductively active males should not be confused with renal tumors (Figs. 1-32 and 1-33A).

In female birds, only the left ovary is functional in most cases. The right ovary is formed during the embryonic stage but does not really grow and usually degenerates. In raptors, such as the goshawk (Accipter gentilis) and sparrow hawk (various Accipter spp.), the right ovary can undergo cystic development, which in rare cases is completely functional. When the female is sexually active, the ovary appears as a structured soft-tissue shadow with different degrees of radiodensity (Fig. 1-33B). The oviduct is visible in the abdomen as a soft-tissue shadow.

Indications

- egg binding
- formation of a laminated egg, changes in the form and/or surface of the egg
- suspicion of ovarian cysts
- abdominal hernia (often in female birds in association with increased bone density)
- neoplasia (testicular tumors, especially in budgerigars)
- infectious processes (e.g. salpingitis)

Possible clinical signs

- difficulties in defecation
- increased amount of urates in the feces
- sitting with legs far apart, pressing on the cloaca
- soft or hard palpable masses in the abdomen with swelling of the abdomen
- infertility
- cachexia, changes in cere coloration, varying degrees of lameness of the hindlimbs (neoplasia, budgerigars)

Normal variations

The functional left ovary may be observed as an irregularly radiopaque, furrowed soft-tissue shadow at the cranial pole of the kidney in the female bird when she is reproductively active (Fig. 1-33B).

Due to its position between the liver, kidneys, and intestines, the oviduct should not be misinterpreted as radiographic evidence of hepatomegaly. Normal eggs that are fully developed can be easily identified due to their radiopaque shell. Radiographically, eggs that are fully developed may displace the gastrointestinal tract (Fig. 1-21).
Anatomical-physiological representation

Fig. 1-32: Total body radiographic images of a budgerigar (Melopsittacus undulatus) showing the (A) ventrodorsal and (B) lateral projections: Active testicle (arrows).

Fig. 1-33A: Total body radiographic image of a red kite (Milvus milvus) showing a lateral projection: Active testicle (arrows).

Fig. 1-33B: Caudal body (section) radiographic image of a blue-fronted Amazon (Amazona aestiva) showing the lateral projection: Active ovary (arrows).
1.1.4 Contrast studies

1.1.4.1 Introduction

Principally, contrast agents are differentiated into positive and negative forms, whereby the latter only plays a minor role in avian radiodiagnostics. The more clinically relevant contrast agents are those which increase the radiopacity of organs or blood vessels. To achieve this, substances are used whose radiopacity is increased due to their content of elements with a high atomic number, in particular barium and iodine.

Barium sulfate can only be used for investigations of the gastrointestinal tract. With the synthesis of tri-iodinated benzoc acid, it was possible to design radiopaque substances that could be used within the blood vessels. As a rule, water-soluble iodine compounds are utilized. Generally, in radiography, there is a differentiation between ionic and non-ionic iodine compounds, whereby the non-ionic compounds, such as ioxidanol and iotorlan, are preferred due to their better tolerance by the patient and less toxic side effects. Organic iodine compounds are primarily given intravenously, in rare cases orally, or in sinography studies, locally administered. However, iodine-based contrast agents are hypertonic and should only be used intravenously in dehydrated patients after adequate rehydration.

1.1.4.2 Contrast studies of the gastrointestinal tract

The indications for a contrast study of the gastrointestinal tract are varied. They include all of the pathological conditions which are characterized by morphological changes in the gastrointestinal tract as a whole (e.g. dilatation of the proventriculus or proventriculus dilatation disease, displacement of intestinal loops in abdominal hernia) or of its walls (e.g. thickening in vitamin A deficiency, chronic candidiasis). In addition, the administration of a contrast agent can be used to differentiate the gastrointestinal tract from its neighboring organs (e.g. liver, spleen, gonads, kidney) which may be affected by neoplastic (Fig. 1-34) or inflammatory processes. The administration of a contrast agent in food also allows the functionality of the gastrointestinal tract to be assessed, as the transit of the intestinal contents in ileus is extremely slow or even nonexistent, while accelerated intestinal transit times can be identified when the patient is suffering from an acute gastrointestinal infection. If there is suspicion that the bird has ingested a foreign body, a contrast study enables one to determine the position of the foreign body after a survey radiograph is of no diagnostic aid because the foreign body is radiolucent.

A survey radiograph should always be taken prior to the administration of contrast material. If there is a suspected perforation of the proventriculus, ventriculus, or intestine only those contrast agents which will not induce tissue damage may be used. Only contrast agents that do not contain barium sulfate, can be resorbed by the body.
**Fig. 1-35a–e:** Sequence showing the passage of a barium-based contrast agent in a bird with an empty crop after the administration of 20 ml/kg body weight of 25% barium sulfate suspension.

Figure reproduced from Krautwald-Junghanns et al. 1992 with kind permission.

1: crop  
2: proventriculus  
3: loop of intestine

**Fig. 1-34:** Total body radiographic images of a budgerigar (*Melopsittacus undulatus*) 45 min after the administration of 1 ml barium sulfate in the crop showing the (A) ventrodorsal and (B) lateral projections. A renal tumor is ventrally displacing the intestines.

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Tissue section partially/filled with contrast during emptying or filling

Tissue section completely filled with contrast

**Fig. 1-35a–e:** Sequence showing the passage of a barium-based contrast agent in a bird with an empty crop after the administration of 20 ml/kg body weight of 25% barium sulfate suspension. Figure reproduced from Krautwald-Junghanns et al. 1992 with kind permission.
Standard barium sulfate suspensions are often used as contrast agents when doing contrast studies of the gastrointestinal tract. Organic iodine compounds are only used for gastrography in rare cases, because they usually do not have good image quality and have a much faster transit time.

Barium-based contrast agents are always administered as a suspension using a tube or a ball-tipped gavage needle. A 25-45% barium sulfate suspension (ca. 20 ml/kg body weight) is the recommended concentration and dose for avian contrast studies of the gastrointestinal tract.

The quantity of barium sulfate in the suspension should be adjusted to the patient’s condition and clinical signs associated with the presenting complaint. A weaker suspension should be administered to differentiate the gastrointestinal tract from its neighboring tissues, while a more viscous suspension is better suited for diagnosing changes in the gastrointestinal tract itself. Alternatively, when there is suspicion of perforation, non-ionic iodine-based contrast agents should be administered orally at a dosage of 10 ml/kg body weight (iodine content of the suspension: 250 mg iodine/ml).

To prevent regurgitation of the contrast material and to reduce the possibility of aspiration pneumonia, the bird should be held for a short time in the upright position after orally administering the contrast agent. Gastrography should not be performed on anesthetized or sedated birds, as intestinal function can be reduced by the effects of the narcotics or sedatives used.

Only approximate values can be given for the transit time of contrast agents in the avian gastrointestinal tract, because these factors vary greatly between species and individuals (Figs. 1-34 to 1-36). The transit time depends not only on the bird’s required diet (e.g. granivore, fructivore, carnivore) which may reflect an associated variability in gut length, but also the size, nutritional condition, and age of the patient, as well as the consistency of the contrast suspension. There can be a relatively rapid transit time observed in birds that eat soft foods and in cachectic or stressed birds, whereas the contrast agent tends to have a longer passage time in the gastrointestinal tract of large granivores. The transit time is also slower in young, obese, or richly fed birds, as well as in patients that have been anesthetized or sedated. If the bird has been subjected to a prolonged period of fasting before the administration of the contrast material, then initially the barium sulfate suspension is transported rapidly to the ventriculus; thereafter it only leaves the ventriculus after a delay.

There is always a danger with ingluvial (crop) administration of a contrast suspension of aspiration after regurgitation of the contrast agent. For this reason, it is recommended that the bird should be fasted prior to the contrast procedure. If the crop is filled with food, then one should wait until the crop has emptied before administering the contrast agent because it is nearly impossible to prevent regurgitation in these patients. The oral or cloacal administration of paraffin oil to increase the emptying of the gut should only be done in rare cases.

If a bird regurgitates the contrast material, the patient should immediately be held with its head in a downward position. Afterwards, the bird should be returned to its accustomed surround-

ings to reduce stress. If the patient aspirates a large amount of barium suspension, in rare cases, respiratory problems can occur due to the resulting cellular damage to the lung parenchyma. However, birds appear to be less sensitive to aspiration of barium suspension due to the anatomical differences of their lower respiratory tract when compared to mammals (i.e. no blind-ending alveoli as in mammals).

The danger of an ileus developing after the administration of a contrast suspension is particularly great in dehydrated birds due to the excessive dissicating properties of the contrast agent. Therefore, it is imperative that an adequate fluid supply (20 ml/kg body weight s.c.) is provided prior to the administration of the contrast agent and until it is evacuated from the gastrointestinal tract.

Due to their hygroscopic effects, ionic iodine-based contrast agents (e.g. Gastrografen®) should not be used. These ionic iodine-based contrast agents can cause the loss of body fluid into the lumen of the intestines thus diluting the contrast suspension, and thereby greatly reducing the diagnostic value of the gastrography. Newer non-ionic substances (e.g. Omnipaque®) are much better suited for gastrography as they are not hygroscopic.

The transit time of these contrast agents is usually twice as fast as with barium sulfate (Fig. 1-37).

A form of gastrography which is relatively rarely used in avian medicine is the double-contrast method in which both a positive and negative contrast agent (i.e. usually barium sulfate and air) are administered to the patient at the same time (Fig. 1-38). With this method, a fine layer of positive contrast material covers the walls of the gastrointestinal tract, whereby lesions or other anomalies in the intestinal wall (e.g. neoplasia, papillomatous changes in the rectum) can be identified. The gastrointestinal tract should be evaluated for contents that may affect the radiographic quality of the contrast study by taking a survey radiograph prior to administering the two contrast agents. The patient is prepared for the investigation as described above.

For double-contrast studies, the bird is given 10 ml/kg body weight of a 25% barium sulfate suspension orally or via the cloaca. Immediately after administration of the barium sulfate suspension, the bird is given air orally or via the cloaca as the negative contrast agent. The volume of air given should be roughly twice as much as the volume of positive contrast material (i.e. ca. 20 ml/kg body weight). Adequate distribution of the contrast agents can be achieved by the careful (!) back and forth movement of the bird.

Further reading

Fig. 1-36A–F: Total body radiographic images of a cockatiel (Nymphicus hollandicus) showing ventrodorsal and lateral projections, before (A and B), 30 min (C and D) and 120 min (E and F) after the administration of 2 ml barium sulfate into the crop. It should be noted that the transit time through a full crop is longer than with an empty crop (Fig. 1-35a–e).
1.1.4.3 Contrast investigation of the excretory organs (urography)

Urographic investigations have only a limited diagnostic value in the bird due to the anatomic and functional differences between that of the avian and mammalian excretory system (e.g. lack of a clear differentiation between renal medulla and cortex, lack of a renal pelvis, loss of bladder and urethra).

The indications for urography include dysfunction of the urinary tract (e.g. polyuria, polydipsia) or changes in the size and form of the kidneys (e.g. acute nephritis) where survey radiographs or ultrasonographic investigations have not provided a definite diagnosis. The administration of a contrast agent is also indicated to differentiate the kidney from the surrounding tissues or organs (e.g. ovarian cysts, tumors of the gonads), which is not possible when viewing a nonenhanced radiographic image.

If the kidney and/or ureter is only vaguely depicted or not observable, this is an indication that tumors or cysts may be present within the urinary tract. Normally, there is a rapid excretion of the contrast material due to the efficiency of the renal portal venous system in birds, whereas delayed contrast excretion occurs when the patient is suffering from renal insufficiency.

In addition, urography is also suitable for controlling the function of the ureters (i.e. after the surgical removal of uroliths). Urography is also indicated in special cases to help detect disease in other parenchymal organs through the concentration of contrast material in these structures.

The contrast agent (an organic iodine compound with an iodine content of 300–400 mg iodine/ml) must be warmed to body temperature for urography. It is then slowly administered intravenously (usually in the ulnar vein) to the sedated or anesthetized patient at a dosage of 2 ml/kg bwt. It is important that only highly concentrated compounds which are registered for use in urography are utilized for an avian urography procedure otherwise the results of the study will be nondiagnostic due to inadequate contrast of the desired anatomic structures.

The quality of the radiographic contrast is affected by both the iodine content of the contrast agent and the ability of the kidney to concentrate the preparation used. The heart, aorta, and lung arteries are already depicted 10 seconds after injection. After 30–60 seconds, the contrast reaches the kidneys and ureters (Fig. 1-39), and after 2–5 minutes, the rectum and cloaca.

A urographic investigation is, however, contraindicated in dehydrated birds unless the patient has been sufficiently rehydrated before the contrast agent is administered.

1.1.4.4 Contrast investigation of the infraorbital sinus and diverticula (sinography, rhinosinography)

To depict the nasal passages and sinuses, resorbable contrast agents (non-ionic iodine compounds) can be administered directly into the region of the head that is being investigated. However, the interpretation of sinographic radiographs is difficult due to the extensiveness and superimposition of the nasal (infraorbital) sinus. In the majority of cases, a CT investigation would provide a better diagnostic result (also at times with the administration of a contrast agent). If CT imaging cannot be used because it is either not available or is too expensive for the client’s budget, then disease diagnosis using contrast radiography of the infraorbital sinus and diverticula can be attempted using a conventional radiographic investigation. Sinography or rhinosinography can depict the presence of a blockage of the airways, especially when the disease condition is associated with chronic rhinitis and/or sinusitis, or if there is suspicion of an intranasal tumor or head trauma.

Delineation of the sinuses can be achieved by injecting 0.1–1 ml (dosage relative to the size of the bird) of an iodine-based preparation (iodine content of 200–250 mg iodine/ml) directly into the paranasal sinuses. A standardized method for avian sinography/rhinosinography has not been published at the present time.

The contrast agent should be immediately flushed out of the sinus with sterile saline solution once the investigation has been completed. Flushing of the contrast material from the respiratory system helps minimize the effects and reduce the potential of local tissue irritation, edema, and periorbital swelling (Fig. 1-40).

1.1.4.5 Contrast studies of the cardiovascular system (angiocardiology)

Angiography is the method of choice for investigating the avian cardiovascular system. Angiography is especially useful for the assessment of heart size and function in those cases which cannot be adequately diagnosed using echocardiography (e.g. congenital diseases of the vascular system, morphological changes of the heart). Aneurysms of the right avian coronary artery can also be depicted using angiography. Angiographic investigations are not considered a substitute for echocardiography, but they can have additional diagnostic value that the ultrasound evaluation does not provide (i.e. when details are unsatisfactorily depicted in a B-mode echocardiogram). Conversely, for practical reasons, angiography is indicated when no suitable coupling sites are available for the ultrasonographic transducer (i.e. in aquatic birds where it is difficult to pluck enough feathers from the area of the coupling site).

Angiography should always be done under general anesthesia. The iodine-based contrast agent (e.g. iopamidol; 380 mg iodine/ml) used at a dose of 2–4 mg/kg body weight should be slowly injected intravenously through a catheter which has been placed in either the jugular or basilic vein.
Fig. 1-37: Total body radiographic image of a peregrine falcon (Falco peregrinus) during a gastrography examination in the ventrodorsal projection, 30 min after the oral administration of 10 ml/kg bwt iohexol (250 mg iodine/ml solution). The tube-like proventriculus (1) can be clearly identified in the image. Cross-sections of the cardiac blood vessels can be clearly seen (arrows).

Fig. 1-38: Radiographic images of a pigeon’s (Columba livia f. domestica) crop showing ventrodorsal (A) and lateral (B) projections, after the administration of 10 ml/kg bwt barium sulphate and 20 ml/kg bwt air into the crop. The double-contrast method enables the depiction of the crop mucosa as well as the particles of grain within the organ.

1: kidney
2: cloaca
arrow: ureters

Fig. 1-39: Total body radiographic image of a pigeon (Columba livia f. domestica) during a urography procedure in the lateral projection, approximately 1 min after the intravenous administration of 2 ml/kg bwt iomeprol (300 mg iodine/ml solution).
1.1  Radiographic investigation

The avian dose, 2–4 mg/kg body weight is roughly twice the published amount for mammals. Subsequently, a series of radiographs are taken at a rate of several pictures per second either in the VD or lateral projection. Due to the rapid beating of the avian heart, an assessment of cardiac contractility is difficult; however, hypertrophy (ventricle), dilatation (ventricle, atria), stenosis (blood vessels, heart valves) and aneurysms (blood vessels) can be diagnosed with angiography (Fig. 1-41).

1.1.4.6  Myelography

Myelographic studies are indicated when there is suspicion of congenital vertebral deformation or a spinal injury that results in a narrowing of the spinal canal. However, at the present time, there has been only two scientific study, which was performed on chickens and pigeons (HARR et al. 1997, NAEINI et al. 2006). In practice, myelographic investigations are rarely attempted because of the high degree of risk associated with the procedure for the avian patient. Currently there is a better diagnostic method available to diagnose spinal injuries, MRI. Also, with many avian species, the spinal cord caudal to the lumbar glycogen body cannot be well imaged using myelography as the subarachnoid space is narrowed by the glycogen body which hinders the flow of contrast. Experience has shown that myelography in raptors and pigeons due to the better anatomical conditions in these species (i.e. injection cranial to the synsacrum or 2) an injection in the atlanto-occipital space lying over the cerebromedullary cistern (Fig. 1-42). The latter site is, however, risky as it is very small and is covered by a large plexus of veins. Furthermore, pressure necrosis can occur due to the injection of an excessive volume leading to myelography-induced trauma. Another risk in small birds is the inadvertent injection into the spinal cord instead of the subarachnoid space, which will result in life-threatening consequences (e.g. cardiac arrest, CNS disease).

Further reading


Contrast studies

Fig. 1-42: Total body radiographic image of a common buzzard (Buteo buteo) head during a myelography procedure in the rostrocaudal projection, approximately 1 min after the injection of 0.5 ml iopamidol (250 mg iodine/ml solution) into the right infraorbital sinus. The contrast has reached the contralateral side due to a communication between the two sinuses (arrow: nares, part of the infraorbital sinus).

1: left ventricle
2: right ventricle
3: ulnar vein

Fig. 1-41: Radiographic image of a red kite’s (Milvus milvus) body during an angiocardiographic procedure in the lateral projection, immediately after the intravenous administration of 2 ml/kg bw iopamidol (250 mg iodine/ml solution) into the cutaneous ulnar vein.

Fig. 1-40: Radiographic image of a blue-fronted Amazon’s (Amazona aestiva) head during a sinography procedure in the rostrocaudal projection, approximately 1 min after the injection of 0.5 ml iopamidol (250 mg iodine/ml solution) into the synsacrum of 1 ml/kg bw iopamidol (200 mg iodine/ml solution). The radiographic image clearly shows both the (1) cannula and spinal cord stained with contrast (arrows).

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