Practical Applications of Ultrasonography for Nonhuman Primates

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Overview of NHP Ultrasonography

- Diagnostic ultrasonography in NHP medicine
- Review of NHP anatomy and physiology
- Clinical uses of ultrasonography
- Abdominal ultrasonography
- Echocardiography
- NHP clinical cases
Perspectives on NHP Ultrasonography

- History of the NHP Workshops
- There are few publications on normal values
- Studies performed are limited in selection of species and animal numbers
- Limited number of case reports
- Need to develop standards or best practices
- Need for clinical diagnostic training
- Few research models
- THIS IS A TECHNOLOGY WITH LOTS OF POTENTIAL AND CONSTANT IMPROVEMENT
Challenges with Access to NHP Ultrasound Information and Training

- No formal NHP organization
- Equipment Improvement
- Technology constantly changes
- Access to species
- Regulatory creep
- Scientific validity
- Lack of funding for development of resources
- Infectious diseases
Clinical Uses of Ultrasound Imaging

- Evaluate Symptoms
- Examine Internal Organs
- Evaluate Pregnancy
- Check Blood Flow
- Determine Abnormalities
- Guided Procedures
Diagnostic Ultrasound Machines
<table>
<thead>
<tr>
<th>Ultrasound Modes</th>
<th>Type</th>
<th>Applications</th>
</tr>
</thead>
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<tr>
<td>A- Amplitude Mode</td>
<td>Therapeutic, Echocardiogram</td>
<td>Lithotripsy, Tumors</td>
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<tr>
<td>Pulse-echo</td>
<td></td>
<td></td>
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<tr>
<td>B-Brightness Mode</td>
<td>Real-time</td>
<td>Abdominal organs</td>
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<tr>
<td>Pulse Echo</td>
<td>Two-Dimensional</td>
<td>Obstetrics</td>
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<tr>
<td></td>
<td>Linear Array</td>
<td>Echo</td>
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<tr>
<td></td>
<td>Three-Dimensional</td>
<td>Small parts</td>
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<td></td>
<td></td>
<td>TEE</td>
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<tr>
<td></td>
<td></td>
<td>Biopsies</td>
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<tr>
<td></td>
<td></td>
<td>Musculoskeletal</td>
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<td></td>
<td></td>
<td>Contrast</td>
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<tr>
<td>C - Mode</td>
<td>B- mode plane</td>
<td>Specific Depth Focus</td>
</tr>
<tr>
<td>Doppler Mode</td>
<td>Color Flow – Velocity</td>
<td>Measuring and</td>
</tr>
<tr>
<td></td>
<td>Continuous – All velocities</td>
<td>Visualizing blood flow</td>
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<tr>
<td></td>
<td>Pulse Wave – Small volumes</td>
<td>Valvular Regurgitation</td>
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<td></td>
<td>Duplex – Combination of 2D imaging and PW</td>
<td>Stenosis</td>
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<tr>
<td></td>
<td>doppler</td>
<td>Abnormal flow</td>
</tr>
<tr>
<td></td>
<td>Spectral – Continuous + PW</td>
<td>Fetal heart beat</td>
</tr>
<tr>
<td></td>
<td>Triplex – Color plus duplex</td>
<td></td>
</tr>
<tr>
<td>Motion - Mode</td>
<td>B- Mode pulses to produce a video</td>
<td>Velocity of organs</td>
</tr>
</tbody>
</table>
Abdominal Ultrasonography

- Tool to manage NHP breeding colonies
- Evaluate organ or GI pathology
- Complementary to MRI, X-Ray/Contrast studies
- No radiation from x-rays
- Faster, cheaper and more diagnostic than radiographs
- Needle-guided biopsies or paracentesis
- Diagnostic examples: cholelithiasis, cysts, obstruction, tumors, abscesses, ascites
Estimating Gestational Age - BPD


Using Acoustic Imaging to detect SQ Norplants
Obstetrical Ultrasonography

- Confirmation of pregnancy
- Presence of ectopic pregnancy, # of fetuses
- Position of fetus(es)
- Placenta (previa)

- Evaluation of fetal growth, gestational age.
- Evaluation of amniotic fluid volume.
- Structural / congenital abnormalities of the fetus.
- Amniocentesis.
Gynecological Ultrasonography

- **Uterus** - size, shape, presence of masses
  - Fibroids
  - Neoplasms
- **Ovary** - presence of masses
  - Cysts
  - Neoplasms
- **Fallopian Tubes** -
  - Hydrosalpinx or pyosalpinx
  - Ectopic pregnancy
Uterine Fibroid Tumor

Fibroid
Renal Sonography

Normal Kidney

Polycystic Kidney
Urinary Bladder

Normal

Mass
Liver

Gall stones

US Guided Biopsy
Spleenic Ultrasonography

Infarct

Throbosis
Vascular and Small Parts Imaging

Femoral Vein Thrombosis

Testicular Mass
Use of Echocardiography in Nonhuman Primate Species
Thorasic Echocardiography

- Valvular defects, chamber size
- Structural abnormalities - patent ductus, atrial and ventricular septal defects
- Pleural effusion, cardiac tamponade
- Pleural effusion, cardiac tamponade
- Color imaging can detect flow – laminar vs. turbulent
- Some changes in coronary flow
- ECG sometimes done simultaneously
Echocardiography Basics

- Ultrasound provides a substantial amount of structural and functional information about the heart
- Still frames provide anatomical detail
- Dynamic images tell us about physiological function
- The quality of an echo depends on the experience and skill of the operator
Limitations of Echocardiography in NHP’s

- Few references available for echocardiography in NHP’s
- Inconsistent techniques used
- Methods for analysis
- Standardization is not established
Valves of the Heart

Sagital View Apical Position

Transverse View - Subcostal
Systole

Diastole
The Clinical Modalities of Echocardiography

Conventional Echo
- B-Mode (2-D echo)
- M-mode echo

Doppler Echo
- Continuous wave (CW) Doppler
- Pulsed wave (PW) Doppler
- Color flow (CF) Doppler
Transducer Positioning

“Echo Windows”
Human vs. NHP Anatomy
Parasternal Short Axis View (PSAX)

Transducer position: left sternal edge, 2\textsuperscript{nd} – 4\textsuperscript{th} intercostal space

Marker dot direction: points towards left shoulder (90° clockwise from PLAX view)

By tilting transducer on an axis between the left hip and right shoulder, short axis views are obtained at different levels, from the aorta to the LV apex.

Many structures seen
Suprasternal View
Papillary Muscle (PM) Level

PSAX at the level of the papillary muscles showing how the respective LV segments are identified, usually for the purposes of describing abnormal LV wall motion.

LV wall thickness can also be assessed.
Parasternal Long-Axis View (PLAX)

Transducer position: left sternal edge; 2\textsuperscript{nd} – 4\textsuperscript{th} intercostal space

Marker dot direction: points towards right shoulder

Some echo studies begin with this view

It sets the stage for subsequent echo views

Many structures seen from this view
Apical 4-Chamber View (AP4CH)

Transducer position: apex of heart

Marker dot direction: points towards left shoulder

The AP5CH view is obtained from this view by slight anterior angulation of the transducer towards the chest wall. The LVOT can then be visualised.
Apical 2-Chamber View (AP2CH)

Transducer position: apex of the heart

Marker dot direction: points towards left side of neck (45° anticlockwise from AP4CH view)

Good for assessment of

LV anterior wall
LV inferior wall
Sub-Costal 4 Chamber View (SC4CH)

Transducer position: under the sternum
Marker dot position: points towards left shoulder
The animal is in supine position
Better images are obtained during inspiration
# Normal Macaque Echo Values

<table>
<thead>
<tr>
<th></th>
<th><em>M. nemestrina</em></th>
<th><em>M. mulatta</em></th>
<th><em>M. fasicularis</em> (male)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVFWd (cm)</td>
<td>0.64 (0.19)</td>
<td>0.47 (0.07)</td>
<td>0.39 (0.07)</td>
</tr>
<tr>
<td>LVIDd (cm)</td>
<td>1.71 (0.30)</td>
<td>2.23 (0.31)</td>
<td>1.50 (0.17)</td>
</tr>
<tr>
<td>LVIDs (cm)</td>
<td>1.11 (0.24)</td>
<td>1.41 (0.25)</td>
<td>0.92 (0.15)</td>
</tr>
<tr>
<td>IVSd (cm)</td>
<td>0.43 (0.11)</td>
<td>NA</td>
<td>0.40 (0.07)</td>
</tr>
<tr>
<td>LVId apical (cm)</td>
<td>2.37 (0.43)</td>
<td>3.57 (0.44)</td>
<td>NA</td>
</tr>
<tr>
<td>LVLs apical (cm)</td>
<td>1.84 (0.40)</td>
<td>2.99 (0.42)</td>
<td>NA</td>
</tr>
<tr>
<td>MV diam. (cm)</td>
<td>1.00 (0.15)</td>
<td>1.54 (0.15)</td>
<td>NA</td>
</tr>
<tr>
<td>LVOT diam. (cm)</td>
<td>0.75 (0.13)</td>
<td>0.94 (0.11)</td>
<td>NA</td>
</tr>
<tr>
<td>RVOT diam. (cm)</td>
<td>1.11 (0.20)</td>
<td>0.95 (0.12)</td>
<td>NA</td>
</tr>
<tr>
<td>LV FS (%)</td>
<td>34.3 (10.9)</td>
<td>37.3 (5.4)</td>
<td>39.2 (6.1)</td>
</tr>
<tr>
<td>PEP (sec)</td>
<td>0.036 (0.012)</td>
<td>NA</td>
<td>0.03 (0.01)</td>
</tr>
<tr>
<td>LVET (sec)</td>
<td>0.244 (0.026)</td>
<td>0.171 (0.024)</td>
<td>0.20 (0.03)</td>
</tr>
<tr>
<td>Ao SV (ml)</td>
<td>10.76 (4.26)</td>
<td>9.24 (2.57)</td>
<td>NA</td>
</tr>
<tr>
<td>Ao CO (L/min)</td>
<td>1.30 (0.61)</td>
<td>1.36 (0.41)</td>
<td>NA</td>
</tr>
<tr>
<td>PA SV (ml)</td>
<td>15.85 (7.47)</td>
<td>8.61 (2.52)</td>
<td>NA</td>
</tr>
<tr>
<td>PA CO (L/min)</td>
<td>1.82 (0.72)</td>
<td>1.23 (0.37)</td>
<td>NA</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>9.06 (2.58)</td>
<td>8.52 (2.26)</td>
<td>3.49 (0.71)</td>
</tr>
</tbody>
</table>
Transesophageal Echocardiography (TEE)
Transesophageal Echocardiography

- Generates an image unimpeded by the lungs and chest-wall structures
- Especially good visualization of the left atrium and aortic root
- Examples: infective endocarditis, aortic dissection, cardiac origin of an arterial embolus such as atrial fib. much better than TTE
- RISKS: bleeding, aspiration, perforation, arrhythmias
Types of 2D Measurements Using TEE

- Distance
  - LVID, LVL, RVOT, MV
- Area
  - RVA, RA Area
- Calculated volumes of chambers
  - LVV
- Calculated changes in distance or volume
  - FS, SV, CO
TEE Outflow Tracts

Primate TEE
S7-2omni
71Hz
8cm

2D
F5
Gn 42
232dB/C4
E/2/0

Pat. T: 37.0 °C
TEE T <37.0 °C

LVOT diam
Ao root diam (2D)
RVOT diam

0.562 cm
0.962 cm
1.07 cm
TEE (4-Chamber)
Atrial Measurements with TEE

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K06078 Washington National Primate Research

PRIMATE EC
S8-3
69Hz
8cm

2D F3
Gn 60
232dB/C5
C/3/0

LA dimension (2D) 1.78 cm
RA Area 2.03 cm²
RAL apical 1.37 cm
RA width 1.73 cm
Ventricular Measurements with TEE
TEE Ventricular (End Systolic)
Spectral Doppler Ultrasound

- Continuous wave (CW) Doppler
- Pulsed wave (PW) Doppler
- Color flow (CF) Doppler
Spectral Doppler - Mitral Valve
Spectral Doppler - Tricuspid Valve

PHILIPS K06078
K06078 Washington National Primate Research TIS 0.5 10:27:17 AM

PRIMATE EC
S8-3
8cm

2D
F3
Gn 60
232dB/C5
C/3/0

PW
3.0 MHz
Gn 50
3.3 cm
Angle 0

121 BPM

TV max PG 2.80 mmHg
TV mean vel 60.0 cm/s
TV VTI TIME 0.196 sec
TV E POINT 82.9 cm/s
TV A POINT 58.9 cm/s
TV DEC SLOPE 664 cm/s2
IVRT TV 0.054 sec
Spectral Doppler - Aorta
Spectral Doppler - LV Outflow Tract

PHILIPS K06078
K06078 Washington National Primate Research TIS 0.7 10:26:07 AM

PRIMATE EC
S8-3
8cm

2D
F3
Gn 60
232dB/C5
C/3/0

PW
3.0 MHz
Gn 50
3.8 cm
Angle 0

132 BPM

SV(LVOT) 3.56 ml
LV V1 max 100 cm/s
LV mean PG 1.67 mmHg
LV V1 VTI 14.3 cm
Doppler - Pulmonary Trunk

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MI 1.3 12/22/2010
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PRIMATE EC
S8-3
8cm

2D
F3
Gn 60
232dB/C5
C/3/0

PW
3.0 MHz
Gn 50
3.8 cm
Angle 0

108 BPM

PA V2 max 91.6 cm/s
PA max PG 3.36 mmHg
PA mean PG 1.71 mmHg
PA VTI TIME 0.270 sec
PA acc time 0.081 sec
PA P1/2t 68.3 msec
PA dec slope 512 cm/s2
PA dec time 0.189 sec
Spectral Doppler – Pulmonary Insufficiency

PHILIPS K06078
MI 1.3 12/22/2010
K06078 Washington National Primate Research TIS 0.7 10:28:57 AM

PRIMATE EC
S8-3
8cm

2D
F3
Gn 60
232db/C5
C/3/0

CW
3.0 MHz
Gn 50
3.8 cm
Angle 0

+ PI max vel
PI max PG 119 cm/s
5.69 mmHg

-1.2
-0.6
-0
-0.6
+ m/s -

+ P
G R
3.0 8.0
Continuous-Wave Doppler
Pulsed-Wave Doppler
Color Doppler (Tricuspid Valve)
Color Doppler (Aortic Valve)
Color Doppler (Pulmonic Valve)
NHP Echocardiography publications

- **Cynomolgus**
  - Right parasternal (long and short axis) and left apical views (Sleeper, 2008)
  - Right parasternal (long and short axis; Koie, 2005)
  - Apical (4-chamber and 2-chamber; Norol, 2007)
  - Apical (4-chamber; Izumi, 2009)

- **Rhesus**
  - Left parasternal (long and short axis), apical, and subcostal views (Korcarz, 1997)
  - Parasternal (long and short axis; Shannon, 2008)
  - Parasternal (long and short axis), apical (Lima, 1986)
  - Not described (Carvalho, 2003; Tang, 2007)