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High resolution 3D magnetic resonance imaging of the visceral organs in chicken (*Gallus domesticus*) by 3 Tesla MR unit and 15-channel transmit coil

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Summary: Imaging studies conducted on the modern imaging techniques for birds are limited and probably insufficient for the clinicians. As in mammals, magnetic resonance (MR) imaging (MRI) can be used as a convenient method for the diagnosis and treatment of the avian diseases. In this study, the whole bodies of 2 male and 2 female chickens were imaged by a 3 Tesla superconductive magnet and 15-channel transmit-receive birdcage coil. After acquisition of three dimensional (3D) T1, T2 and proton density weighted (W) MR images; bodies were frozen in same position with the one in imaging process and sliced from matching sections with original and reformatted MR images. Anatomic structures were identified and labeled in both MR images and cadaver sections. After that, 3D multiplanar reconstruction was performed on the MR images. On T1W images, it was observed that the anatomical details were superior due to the high geometric resolution. On T2W images, the tissue contrast differences and fluid filled ducts were clearly detected. On three orthogonal and oblique planes reformatted and maximum intensity projection (MIP) colored images, the anatomic details were more clearly determined and the tissues were more easily distinguished from each other with high geometric and contrast resolution. The aim of this study was to define MRI features of the tissues, and to provide an overview of MRI anatomy of the avian body structures. Besides, the most convenient sequences for the avian MRI were also designated.

Keywords: 3 Tesla, 15 channel transmit-receive coil, anatomy, chicken, magnetic resonance imaging, three dimensional.

Tavukta (*Gallus domesticus*) visseral organların 3 Tesla manyetik rezonans ünitesi ve 15-kanallı coil ile yüksek rezolüsyonlu 3B görüntülenmesi

Özet: Kuşlarda modern görüntüleme teknikleri üzerine yürütülmüş çalışmalar kısıtlıdır ve özellikle klinisyenler için yetersiz kalmaktadır. Manyetik rezonans (MR) görüntüleme (MRG), memelilerde olduğu gibi kanatlı hastalıklarının tanı ve tedavisi için de elverişli bir yöntemdir. Bu çalışmada; 2 horoz ve 2 tavuğun vücudu 3 Tesla MRG cihazı ile T1, T2 ve proton-dansite ağırlıklı (A) sekanslar ve 15-kanallı alıcı-verici koyil kullanılarak, 3 boyutlu (3B) olarak değerlendirildi. MRG işlemi sonrasında; görüntüleme işlemindeki pozisyonu ile aynı konumda dondurulmuş vücutlar, MR görüntüleri ile eşleşen bölümlerden dilimlendi. Anatomik yapılar, MR görüntüleri ve kadavra bölümlerinde tespit edildi ve işaretlendi. Daha sonra, MR görüntülerine 3B multiplanar rekonstrüksiyon uygulandı. T1A görüntülerde, anatomik detaylar yüksek geometrik çözünürlük nedeniyle daha iyi gözlendi. T2A görüntülerde, doku kontrastı farkları ve sıvı içerikli yapılar açıkça tespit edildi. 3B sekanslardan elde edilen oblik planlı ve maksimum yoğunluk gösteren renkli reformat görüntülerde, anatomik ayrıntılar daha net bir şekilde belirlendi ve dokular yüksek çözünürlük ile birbirinden daha kolay bir şekilde ayırt edildi. Bu çalışmadaki amaç; dokuların görüntüleme özelliklerini tanımlamak ve kuşların vücut yapılarının MRG'deki anatomisine genel bir bakış sağlamaktı. Bunların yanı sıra, kanatlılarda MRG için en uygun sekanslarda tayin edildi.

Anahtar sözcükler: 3 Tesla, 15 kanal alıcı-verici coil, anatomi, manyetik rezonans görüntüleme, tavuk, üç boyutlu.

Introduction

Similar to mammals', magnetic resonance imaging (MRI) has been a quite efficient method to understand some physiological functions related with the anatomical formation of birds and to evaluate the diagnosis and treatment of the avian diseases. However, studies, either clinical or experimental, focused on the modern imaging techniques for birds seem to be insufficient. Not only magnetic resonance (MR) studies but also computed tomography (CT) or micro CT researches were also very limited and most of these were based on osteology or osteological modeling (6, 12, 23, 24, 25).

Although MRI distinguishes from CT as high resolution and radiation free technique (1, 10, 18, 19, 20), the MR studies on avian are mostly focused on the clinical cases (8, 14, 21, 26). Some of the researches has been carried out to calculate the different tissue densities such as fat or water ratios in the body by using MR techniques (9, 29). Especially tissues which have high fat and water ratio can be readily visualized and quantified in virtual slices with T1-weighted (W) MR sequences, and then summed across slices to calculate body composition (9). MRI gives us the opportunity to investigate the avian body parts from a three-dimensional (3D) capturing (22, 27, 28). MR can also provide important data about the egg composition or the embryonic development of the birds (4, 7, 13).

Dissimilarly to the domestic mammals (11), the thorax and the abdomen appear to one single cavity in most of the birds due to the rudimentary diaphragm. Considering about the abdominal organs, for instance, kidneys embedded into the lumbosacral bone, in males, testicles take a large space inside the body cavity, and the gaster consists of two different parts as is known (15, 17). Although current MR studies based on the anatomy or physiology of domestic birds were available (2, 5, 20, 22, 27), an anatomic evaluation for the abdominal organs comparing the MR images with the cadaver slices on birds might be useful for the researchers working on avian. With this study we tried to prepare an anatomical reference which combines and compares the data on the organic cross-sections and the MR images. We preferred the species *Gallus domesticus* for its economic value and it was thought that it could be an efficient animal model for a comparative anatomic study.

Materials and Methods

In this study, the whole bodies of 2 male and 2 female chickens were investigated. For the induction, an intramuscular application of 50 mg/kg ketamine hydrochloride was used to the birds. The anaesthetized birds were placed in “prone” position and were imaged by 3T superconductive magnet (Siemens Magnetom Trio, Erlangen, Germany) with using 15-channel receiver and transmitter birdcage coil. T1W and T2W 3D data were obtained with the optimized sequences (Table 1). Multiplanar reformatted, maximum-minimum intensity projection, and volume rendered images were achieved using Leonardo Workstation software and 3D data. An intravenous administration of 150 mg/kg thiopental sodium was injected to the birds for euthanasia. After MRI process, bodies were frozen to -25°C for 3 days. Then bodies were sliced from same levels with the matching MR image sections (Figure 1.A.1,2,3,4). Macroscopic segments were acquired using 3 mm slice thickness on frozen body. Afterwards, anatomic structures of the chicken were identified and labeled in both MR sections and cadaver slices. Nomina Anatomica Avium (3) was used for nomenclature.

Table 1: MRI protocol of the authors.
3D: three dimensional; W: weighted; NA: not applicable; FOV: field of view; 3D-SPACE: 3D sampling perfection with application-optimized contrasts by using different flip angle evolutions; 3D-MPRAGE: 3D magnetization-prepared rapid gradient-echo.
Tablo 1: Yazarların MRG protokolü
3D: three dimensional; W: weighted; NA: not applicable; FOV: field of view; 3D-SPACE: 3D sampling perfection with application-optimized contrasts by using different flip angle evolutions; 3D-MPRAGE: 3D magnetization-prepared rapid gradient-echo.

Sequence Parameters	T1W 3D-MPRAGE	T2W 3D-SPACE
TR (ms)	2130	3000
TE (ms)	3.86	430
FOV (mm)	120x100	174x100
Average	1	1
Slice thickness (mm)	0.47	0.68
Fat saturation	+	-
Distance (gap)	-	-
Voxel size (mm)	0.47x0.47x0.47	0.68x0.68x0.68
Number of slabs	1	1
Flip angle	12^0	Variant
Inversion time (ms)	1100 ms	NA
Number of slices	192	192
Phase oversampling	10%	50%

Results

On T1W images, it was observed that the anatomical data were superior due to the high geometric resolution (Figure 1.B.1,2,3,4). Fat containing tissues were appeared bright (hyperintense) on T1W images. Also aqueous structures had lower intensity (hypointense) on T1W images. The most hyperintense solid abdominal organ was liver (Figure 1.B.1,2,3,4) but muscular tissues such as muscular stomach and myocardium of the heart (Figure 1.B.1,2,3,4) were also appeared hyperintense on T1W images.

On T2W images, the tissue contrast differences and fluid filled spaces were more clearly detected. Testicles (Figure 1.C.1,3,4), cerebrospinal liquid, and also preen gland (Figure 1.C.2,4) were observed as hyperintense on these images (Figure 1.C.1,2,3,4). Fatty tissues were appeared bright (hyperintense) on T2W images but these tissues had the lower signal intensity compared to T1W images.

The lumen of the hollow organs such as intestines, stomach, and lungs (Figure 1.B.C) were prominent hypointense (very dark) on all sequences. On colored reconstructed and volume-rendered T1W images, the morphological details were more clearly determined (Figure 1.D.1,2,3,4, Figure 2) and the tissues were easily distinguished from each other due to high signal-to-noise and contrast-to-noise ratios.

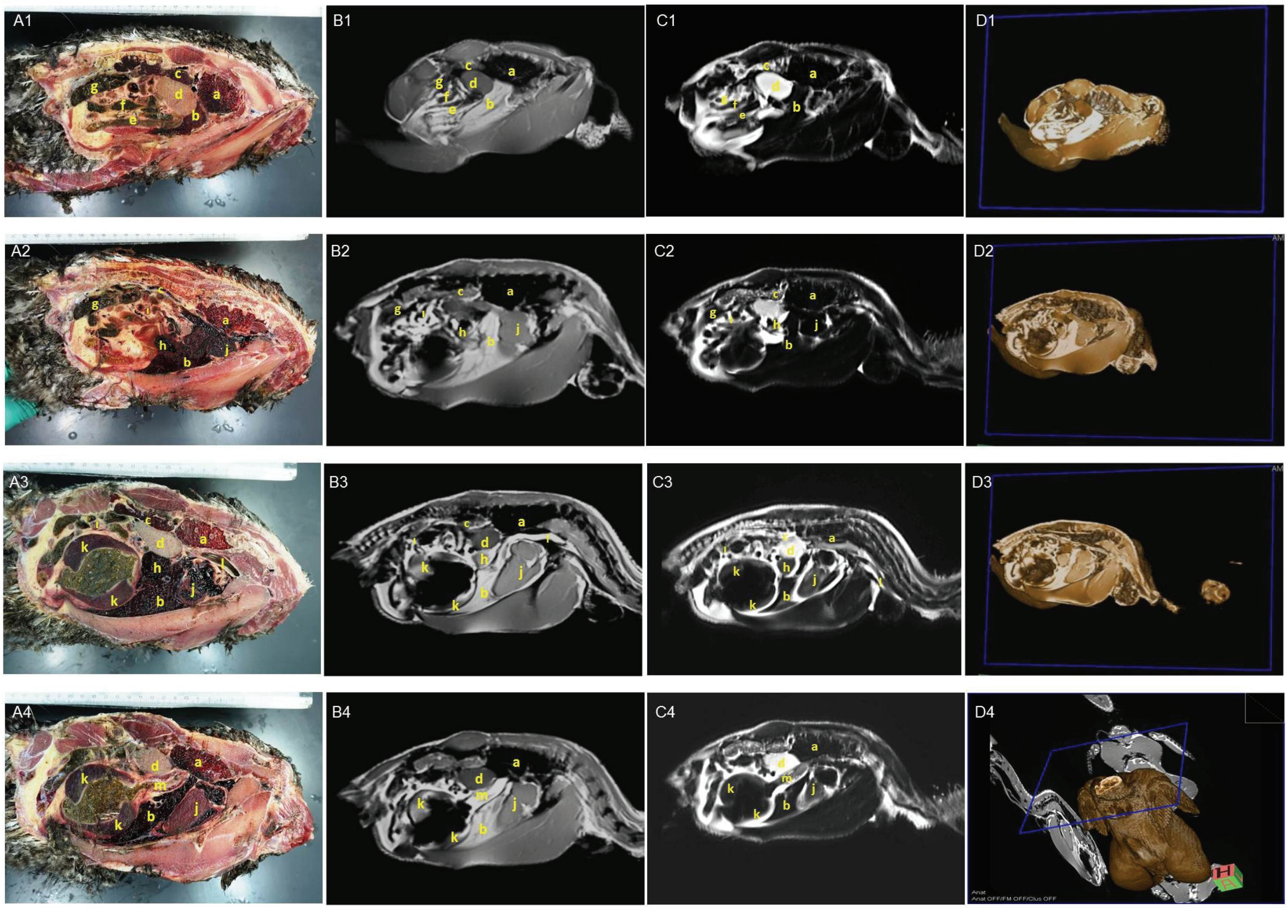

Figure 1: Comparing of the anatomic structures in cadaver body slices and the MR images.
A/ 1,2,3,4; The sagittal slices of the body cavity obtained from specimens.
B/ 1,2,3,4; T1-weighted sagittal images obtained from the same level with cadaver slices.
C/ 1,2,3,4; T2-weighted sagittal images obtained from the same level with cadaver slices.
D/ 1,2,3,4; Reformatted, colored, and volume rendered 3D T1-weighted images from the same level with cadaver slices.
a: lung (pulmo), b; liver (hepar), c; kidney (ren), d; testicle (testis), e; left caecum, f; right caecum, g; colon, h; spleen (lien), ı; jejenum, j; heart (cor), k; muscular stomach (ventriculus muscularis), l; trachea, m; glandular stomach (ventriculus glandularis).

Figür 1: MR görüntüleri ile kadavra vücut kesitlerindeki anatomik yapıların karşılaştırılması.
A/ 1,2,3,4; Örneklerden elde edilen, vücut boşluğuna ait sagittal kesitler.
B/ 1,2,3,4; Kadavra kesitleri ile aynı düzeyden elden edilen T1A sagittal kesit görüntüleri.
C/ 1,2,3,4; Kadavra kesitleri ile aynı düzeyden elden edilen T2A sagittal kesit görüntüleri.
D/ 1,2,3,4; Kadavra kesitleri ile aynı düzeyden elden edilen T1A, reformat, renklendirilmiş, volumetrik 3B sagittal kesit görüntüleri.
a: akciğer (pulmo), b; karaciğer (hepar), c; böbrek (ren), d; testis, e; sol caecum, f; sağ caecum, g; colon, h; dalak (lien), ı; jejenum, j; kalp (cor), k; kaslı mide (ventriculus muscularis), l; trachea, m; bezli mide (ventriculus glandularis).

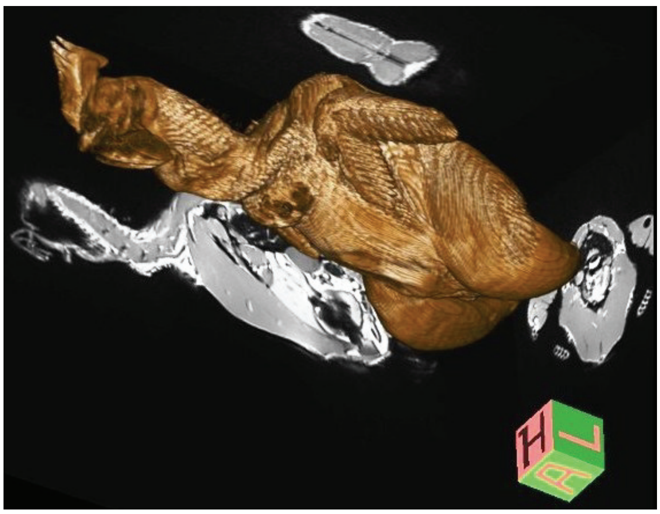

Figure 2. A 3D reconstructed, reformatted, colored, and volume rendered T1W image sample.
Figür 2. 3B rekonstrükte edilmiş, reformat, renklendirilmiş, volümetrik T1A görüntü örneği.

Discussion and Conclusion

As mentioned before, one of the purposes of this study was to define imaging features of tissues and to provide an overview of MRI anatomy of the avian abdominal structures and their natural positions. It can be said that MRI is quite efficient for the identification of anatomical structures and also can be used for diagnosis of pathological changes. The most convenient sequence that enables to delineate the anatomic details was also designated by this study. Wirestam et al. (29) had indicated that MRI could be used for the measurement of the variations in the spatial distributions of adipose tissue in small migratory birds. Our research supports this finding on domestic birds. Although MRI provides better anatomical detail due to its high resolution when compared to the CT, researches on the use of cross-sectional imaging in avian species have been limited. Ruffins et al. and Vellema et all. (22,27) have composed atlases in detail using MR images, but they examined prenatal and postnatal anatomic structures which are not exactly corresponds to our research. Therefore, data collected from our MR images can be used to create a comparative avian body atlas for anatomy education or avian researchers and clinicians in the future. However the number of subjects should be increased to prepare a detailed atlas.

On T1W images the clear displaying of organ boundaries made us think that T1W sequences were more efficient for anatomists. One to one correspondence between the slices obtained from the cadavers and the MR images couldn't be provided in all cross-sections. This mismatch might probably originate from the volumetric changes in specimens after freezing process and the positioning failures during the band saw process.

When compared with the previous MR researches, the most important superiority and difference of our study was to use of 3 Tesla MR device and 15-channel transmit-receive birdcage coil. With the usage of this coil in 3 Tesla MR unit, the 3D data which is composed from isotropic voxels smaller than 1 mm could be obtained with high signal-to-noise ratio. The quality and resolution of the multiplanar images obtained from this data was notably high. Because the all sequences that we've used, were composed from submilimetric isotropic voxels. The devices and the techniques we've mentioned above are generally used in cases that require high resolution such as human knee pathologies (16).

In conclusion, 3 Tesla MR unit with 15-channel coil and optimized 3D sequences provides significantly higher quality images compared to conventional 2D techniques, particularly for fluid and fat containing spaces, leading to improved diagnostic confidence in birds.

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