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Magnetic resonance imaging-based tennis player wrist joints injury diagnosis

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ABSTRACT

With tennis players' increasing requirements of performance, training intensity has been gradually increasing, and lots of players have appeared wrist joints injury to different extents. Based on this, the paper applies magnetic resonance imaging into tennis player wrist joints diagnosis, with an aim to help to cure wrist joints sports injury. Firstly analyze magnetic resonance imaging principle, and magnetic resonance signal detection and image reconstruction, and then combine with computer technology, it takes pictures and analyzes magnetic resonance imaging with many tennis players that have wrist joints injury, by obtained MRI pictures, it can clearly understand players' wrist joints injury status. Finally take model test and know that MRI pictures analysis results are basically the same as players' reflected wrist joints injury severities, which shows magnetic resonance imaging, can better apply to wrist joints injury diagnosis and other similar sports injury diagnosis.

KEYWORDS

Magnetic resonance imaging;
Signal detecting;
Image reconstruction;
Wrist joints injury;
Biomechanics.

INTRODUCTION

Full name of magnetic resonance imaging is nuclear magnetic resonance imaging. In order to remove people's fear of "nuclear", so it calls magnetic resonance imaging for short, magnetic resonance imaging is related to magnetic nuclear inside organism, so magnetic resonance imaging is closely related to human body that is common used in medical field, and MRI image that is obtained by magnetic resonance imaging is very clearly, and the technology has small side effects on human body, therefore it greatly improves doctors' diagnosis efficiency, is preferred by doctors and patients. The paper applies magnetic resonance imaging into wrist joints diagnosis, with an aim to reduce tennis players' wrist joints sports injury.

For magnetic resonance imaging, lots of predecessors have made efforts, and got lots of valuable conclusions, which impels magnetic resonance imaging development. Among them, Zhu Yue-Huan (2013) in the article "Functional magnetic resonance imaging-based image cognitive research", she introduced functional magnetic resonance imaging experiment designing methods, data collecting, data processing and analyzing relative steps and relative methods, and by magnetic resonance imaging, she achieved results in human brain shape, vein and color sensing field positioning study fields[1];Jiang Ying-Ping (2007) in the article " Explore central mechanism of acupuncturing at Zusanli from functional magnetic resonance imaging", she made analysis and comparison of traditional theories understanding on Zusanli acupoint efficiency and functional magnetic resonance imaging results, got magnetic resonance imaging superiorities and let magnetic resonance imaging to be promoted[2]; Zhang Ping-Yin (2005)explored magnetic resonance imaging, introduced magnetic resonance all kinds of imaging principles and clinical applications, which showed current magnetic resonance imaging development level. He pointed out RMI was the field with development value in medical images, ideal RMI could get more information in the shortest time that high speed resolution rate collected anatomy and physiological functions information, and made specific evaluation on one organ lesions shapes, pathology and functions[3].

The paper based on predecessors researches on magnetic resonance imaging, moves magnetic resonance imaging principle to wrist joints sports injury diagnosis, the paper firstly introduces magnetic resonance imaging principle, and magnetic resonance signal detection and image reconstruction, and then carries out magnetic resonance imaging shooting analysis of many players' that have wrist joints injury, which makes contribution to tennis players' wrist joints sports injury treatment.

MAGNETIC RESONANCE IMAGING PRINCIPLE

From the perspective of physics, magnetic resonance imaging is caused by nuclear magnetic resonance phenomenon. "Nuclear magnetism" in nuclear magnetic resonance respectively refers to atomic nucleus and electromagnetic wave with magnetic moment. Research on nuclear magnetic resonance is researching on static magnetic field atomic nucleus and electromagnetic wave interaction that possess magnetic moment.

Atomic nucleus spinning and magnetic moment

Everything in the world is composing of molecules, and elemental particle that constitutes molecules is atom. Atom is composing of atomic nucleus and extranuclear electron; extranuclear electron takes endless high speed irregular spinning motion around atomic nucleus. Atomic nucleus is composing of proton and neutron, proton and neutron have spinning. Spinning refers to feature that microscopic particle high speed spins around one fixed point, is the inherent attribute of microscopic particle. As Figure 1 show.

In microscopic particle spinning, its motion state is described by angular momentum, set particle angular momentum as J, magnetic moment as μ, and then

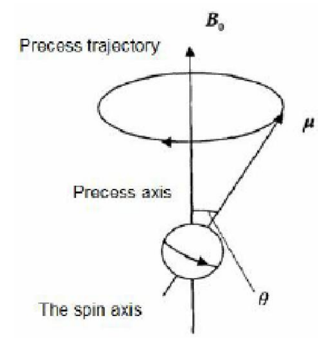

Figure 1: Hydrogen nucleus spinning in magnetic field

magnetic moment can be expressed by formula (1) :

$$\vec{\mu} = \gamma \vec{J} \quad (1)$$

Among them, γ is magnetogyric ratio, its size is up to particle attribute.

In order to research on nuclear magnetic moment macroscopic property, the paper introduces nuclear magnetization intensity vector $\overrightarrow{M}$, which expresses assigned unit nuclear magnetic moment vectors sum as formula (2)show:

$$\overrightarrow{M} = \sum_{i=1}^{n} \overrightarrow{\mu_i} \quad (2)$$

Hydrogen nucleus motion in magnetic field

Due to hydrogen nucleus spinning will generate magnetic moment, according to electromagnetic principle, it can regard hydrogen nucleus as ring current, and so it generates moment T as formula (3) show:

$$\vec{T} = \vec{\mu} \times \overrightarrow{B_0} \quad (3)$$

Among them, B_0 is static magnetic field's magnetic field intensity. Moment $\vec{T}$ is acting on hydrogen nucleus, it surely will lead to its $\vec{J}$ to change, its variation equation is:

$$\vec{T} = \frac{d\vec{J}}{dt} = \vec{\mu} \times \overrightarrow{B_0} \quad (4)$$

Multiply both sides of formula (4) by magnetogyric ratio γ, it can get:

$$\gamma \frac{d\vec{J}}{dt} = \gamma \left[\vec{\mu} \times \overrightarrow{B_0}\right] \quad (5)$$

Combined formula (1) (5), it can get:

$$\frac{d\vec{\mu}}{dt} = \gamma\left[\vec{\mu} \times \vec{B_0}\right] = \gamma\begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \mu_x & \mu_y & \mu_z \\ B_x & B_y & B_z \end{vmatrix} \quad (6)$$

That:

$$\frac{d\mu_x}{dt} = \gamma(\mu_y B_z - \mu_z B_y) \quad (7)$$

$$\frac{d\mu_y}{dt} = \gamma(\mu_z B_x - \mu_x B_z) \quad (8)$$

$$\frac{d\mu_z}{dt} = \gamma(\mu_x B_y - \mu_y B_x) \quad (9)$$

Establish space rectangular coordinate system, it lets z axis direction to be same as static magnetic field $\overrightarrow{B_0}$, set $\vec{\mu}$ and $\overrightarrow{B_0}$ directions included angle is θ, then nuclear magnetic moment each component motion is as Figure 2 show.

In initial state, $B_z = B_0$, $B_x = B_y = 0$, therefore it can get:

$$\frac{d\mu_x}{dt} = \gamma\mu_y B_0 \quad (10)$$

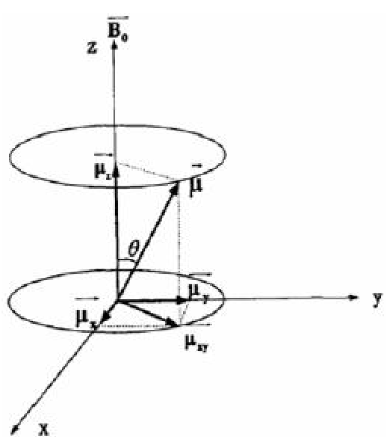

Figure 2 : Nuclear magnetic moment each component motion

$$\frac{d\mu_y}{dt} = \gamma\mu_x B_0 \quad (11)$$

$$\frac{d\vec{\mu_z}}{dt} = 0 \quad (12)$$

Combine formula (7)(8) and solve, it can get:

$$\begin{cases} \mu_x = A\cos(\gamma B_0 t + \varphi) \\ \mu_y = -A\sin(\gamma B_0 t + \varphi) \end{cases} \quad (13)$$

Let $\omega_0 = \gamma B_0$, it can get:

$$\begin{cases} \mu_x = A\cos(\omega_0 t + \varphi) \\ \mu_y = -A\sin(\omega_0 t + \varphi) \end{cases} \quad (14)$$

It is clear under static magnetic field, magnetic moment will produce procession in x direction and y direction, its procession frequency is $\omega_0 = \gamma B_0$, which is called Larmor frequency.

MAGNETIC RESONANCE SIGNAL DETECTION AND IMAGE RECONSTRUCTION

Relaxation and relaxation time

When RF magnetic field disappear, hydrogen nuclear magnetic moment shifts from excited state to equilibrium state, the process is called relaxation. Relaxation divides into vertical relaxation and horizontal relaxation. Vertical relaxation refers to vertical magnetization intensity vector recovery process, its relaxation process is as Figure 3-A show, vertical magnetization intensity M_Z can be expressed as formula (15):

$$M_Z = M_0\left[1 + (\cos\theta - 1)e^{-t/T_1}\right] \quad (15)$$

In formula, M_0 is vertical magnetization intensity under steady state, θ is deflection angle under ratio frequency driving, T_1 is vertical relaxation time.

Horizontal relaxation is also called spinning-spinning relaxation, its process is as Figure 3-B show, and horizontal magnetization intensity can be expressed as formula (16):

$$M_{xy} = M_0 \sin\theta e^{-t/T_2} \quad (16)$$

In formula, T_2 is horizontal relaxation time.

Therefore, the whole magnetic resonance process can be divided into two steps: resonance excitation and relaxation. Bloch got by researching that these two steps were simultaneously proceeding, and given Bloch equation:

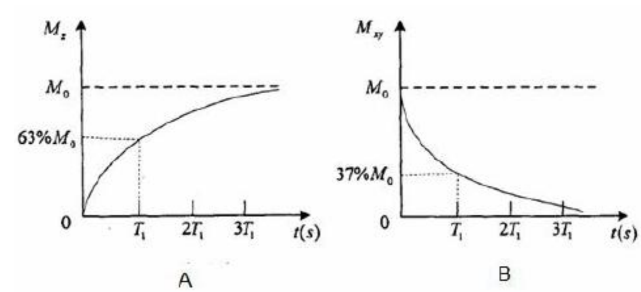

Figure 3: Vertical relaxation and horizontal relaxation curve

FULL PAPER

$$\begin{cases} \frac{dM_x}{dt} = \gamma\left(M_y B_0 + M_z B_1 \sin\omega t\right) - \frac{M_x}{T_2} \\ \frac{dM_y}{dt} = \gamma\left(M_Z B_1 \cos\omega t - M_x B_0\right) - \frac{M_y}{T_2} \\ \frac{dM_z}{dt} = \gamma\left(M_x B_1 \sin\omega t - M_y B_1 \cos\omega t\right) - \frac{M_z - M_0}{T_1} \end{cases} \quad (17)$$

Free induction decay signal and signal detecting

Free procession refers to magnetization intensity component $\overline{M}$ procession procedures after ratio frequency field stopping, and free induction decay signal refers to decay signal that is obtained in free procession procedure induction foil, magnetic resonance signal detecting principle is as Figure 4 show.

By Bloch equation (formula 17), it can get free procession procedure horizontal magnetization component M_{xy} is:

$$M_{xy} = M_0 e^{-i\left(\omega_0 t - \frac{\pi}{2}\right)} \cdot e^{-\frac{1-\tau}{T_2}} \quad (18)$$

By the induction, it can get FID signal as Figure 5

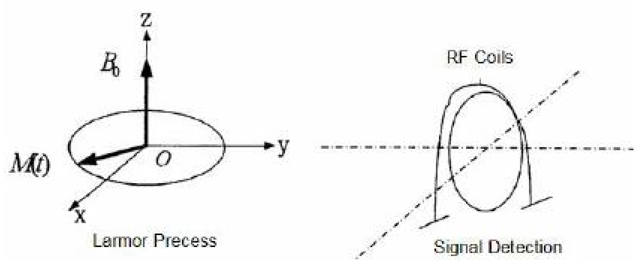

Figure 4: Magnetic resonance signal detecting principle

show.

In the following, use circulate coil, it can collect FID signal, and detect variation magnetic field intensity signals, convert them into corresponding electrical signals. Until now, it fulfills magnetic resonance signals collecting.

K space and two dimensional image reconstruction

K Space is constructed frequency domain space when magnetic resonance collects data; normally it takes square data space. Image reconstruction is the last step in magnetic resonance imaging, it usually adopts two dimensional Fourier transform to K space data, and further converts frequency domain information into temporal information, and gets magnetic resonance imaging. K Space is frequency data space that is constructed

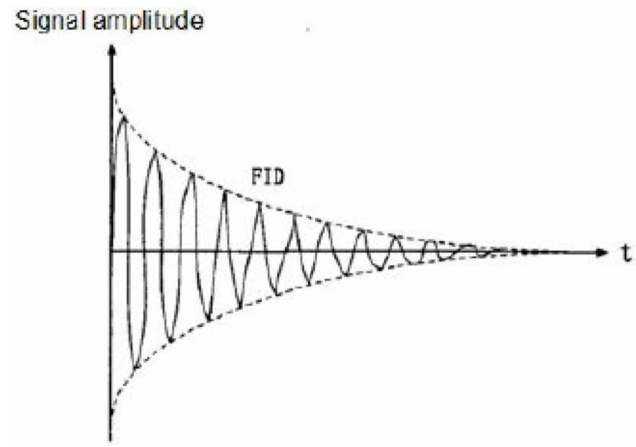

Figure 5 : Free induction decay signal

by collected magnetic resonance signal after phase encoding and frequency encoding, magnetic resonance K space three dimensional and two dimensional images are as Figure 6 show.

K space every point represents the point magnetic resonance signal intensity size, collected magnetic resonance signal $s(k_x, k_y)$ is as formula (19)show:

$$s(k_x, k_y) = \iint \rho(x, y) e^{-i \cdot 2\pi(xk_x + yk_y)} d_x d_y \quad (19)$$

In formula (19), $\rho(x, y)$ is hydrogen nuclear density distribution, then:

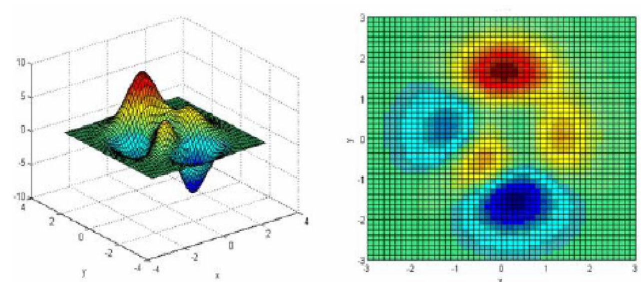

Figure 6: Magnetic resonance K space

$$k_x = \gamma \int_0^{l_x} G_x(t) dt \quad (20)$$

$$k_y = \gamma \int_0^{l_y} G_y(t) dt \quad (21)$$

By formula (20)(21), it is clear that k_x, k_y is up to frequency gradient t_x and phase gradient t_y.

After fulfilling filling in K space data, it starts to use image reconstruction algorithm to reconstruct it. To the way of uniform sampling filling in rectangular K space, directly use two dimensional Fourier inverse transformation to convert frequency domain information into image information. For Fourier transformation, formula is as following:

$$\rho(x,y)=\sum_{ky=1}^{N}\sum_{kx=1}^{N}s(k_x,k_y)\cdot e^{i\frac{2\pi(k_x x+k_y y)}{N}} \qquad (22)$$

In formula (22), $s(k_x,k_y)$ represents collected magnetic resonance signal, $\rho(x,y)$ represents the layer hydrogen nuclear density distribution function, which reflects as different grey values in image (Figure 7), therefore magnetic resonance obtained image actually is hydrogen nuclear distribution status figure.

Magnetic resonance imaging to tennis player wrist joints injury diagnosis

Carry out magnetic resonance shooting analysis of 38 cases' tennis players suffered wrist joints injury; it can get four kinds of basic information as Figure 7 show.

By MRI pictures, it can obviously see that wrist joints injury worsens successively from 7—1 to 7—4, Figure 7-1 coronal T2W1 image can show patchy high signal that is restricted in triangle cartilage disk, it is mild injury, Figure 7-2 coronal T2W1 image can show slanted bar high signal inside triangle cartilage disk but it doesn't arrive at edge, it is moderate injury, Figure 7-3, 7-4 are serious injury. Combine with statistics investigation results; it is clear that picture indicated conclusion is basically the same as injury severity that is reflected at ordinary times.

CONCLUSION

The paper firstly introduces magnetic resonance imaging principle, and uses hydrogen nuclear magnetic moment concept to state hydrogen nucleus procession and static magnetic field relations, and then analyzes Bloch equation, presents magnetic resonance signal detecting and collecting methods; collect signal and fill in K space, use two dimensional Fourier inverse transformation to convert frequency domain information into image information, obtained MRI picture actually is image that is hydrogen nuclear distribution status figure; carry out magnetic resonance shooting analysis of many tennis wrist joints injured players, it is clear that pictures indicated results are basically the same as players' injury severity, which shows magnetic resonance principle has good practical values, and can be further vigorously promoted to sports injury diagnosis treatment field.

Figure 7 : Player wrist joints MRI pictures

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