NMR Microscopy for the Relaxation Phenomena of Skin Layers

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ABSTRACT

In-vivo and in-vitro NMR Microscopy has been performed to investigate the histological and/or pathological difference between the normal and the abnormal skin layers. The acquired images in the present study were able to provide the information of both the relaxation changes and the histological changes due to skin abnormality. The present study is also intended to show the possibility of NMR Microscopy application to both the noninvasive investigation of skin pathology and the helpful use in the development of cosmetics.

Introduction

Skin abnormality often results in a multitude of biochemical changes together with the histological variations in the skin layers. This kind of biochemical and histological changes is important from the standpoint of both the skin pathology and the development of cosmetics. The visualization of the changes, therefore, may provide the useful information relating with skin pathology. Especially, the noninvasively performed visualization can produce more valuable information of the skin abnormality than the conventional visualization of the excised skin tissues can. Over the past few decades, MRI(Magnetic Resonance Imaging) has long been utilized as one of the important noninvasive diagnostic techniques in the Medical society. In comparing with the other diagnostic tools such as X-ray CT and Ultrasound techniques, MRI is far superior in respect of the noninvasiveness as well as the spatial resolution. Moreover, MRI has many imaging parameters such as relaxation times, molecular diffusion, flow, etc by which valuable biochemical information can be extracted to study human pathology noninvasively. Unfortunately, human skin is composed of very thin layers that are hardly discriminated by the conventional MRI technique. The reason is that the conventional MRI has not achieved the high enough resolution to distinguish the thin skin layers whose thickness is thin enough to reach up to sub-mm. Among the skin layers, the epidermis is very important from the cosmetic point of view due to its initial contact with cosmetics. Since its thickness is on the order of sub-mm, the epidermis layer has been hardly visible on the conventionally acquired MR images. Although the ultrasound technique has been widely utilized to study skin layers because of its valuable properties including noninvasiveness, this technique often lags of visualizing the morphological changes in skin layers due to its low spatial resolution.[1]

NMR Microscopy is one of the important MRI applications and holds the same properties of the conventional MRI such as the noninvasiveness and the nucleus selectivity. On top of the properties, NMR Microscopy provides more highly resolved images than the conventional MRI does.[2] In the present study, two dimensional images were acquired by the dermal NMR Microscopy to obtain the morphological changes, the relaxation variations, and the different diffusion behavior occurring from both the normal and the abnormal skin layers. Also, the feasibility study for in-vivo NMR Microscopy was implemented for the thin skin layers of both humans and animals that include hairless mice and guinea pigs.

Materials and Methods

Preparation of specimens: For the animal

in-vivo experiment, hairless mice and guinea pigs were anesthetized before positioned in the rf (radio-frequency) coil. Hair was removed from the imaging regions for guinea pigs. Abnormal skin was generated to produce erythema by the irradiation of 200mJ/cm2 of UV-B using a solar simulator (Solar Light Co. USA). Each skin tissue for the in-vitro experiment has been prepared from a guinea pig. In the in-vitro experiment, each excised skin tissue was positioned in a 6mm (i.d.) acryl tube filled with glycerol to reduce the swelling effect as well as the susceptibility imaging artifact. The subcutaneous fat layer of each tissue was attached on the inner wall of a tube so that its epidermis layer was directly contacted with glycerol.

Hardware: For the in-vivo experiment, a 1.5cm diameter surface coil was utilized as a rf coil along with both a 13cm diameter gradient coil (for guinea pigs) and a 6cm diameter gradient coil (for hairless mice). Both gradient coils were constructed as a modified Golay type. The surface coil was positioned directly on top of the imaging area of an animal. For imaging in-vitro specimens, a shielded solenoid coil (i.d. of 4, 9, and 19mm) was used and positioned in a 6cm diameter high gradient coil that was capable of producing up-to 100G/cm. Each rf coil along with a gradient coil was located in a 2.0T whole body MRI system operating at 85.3 MHz.

Pulse sequence: The conventional 2-D spin echo sequence[3,4] has been utilized with different imaging parameters depending on the objective information. For the measurements of relaxation times (T_1: spin-lattice relaxation time, T_2: spin-spin relaxation time), TE(echo time) and TR(repetition time) values were varied to obtain T_1, T_2 and proton density weighted images in which image contrast is different depending upon the different relaxation effects within samples.

Results and Discussion

The relaxation phenomena were quantitatively studied to result in different behavior depending upon the biochemical changes occurred in skin layers. Two different information relating with both T_1 (spin-lattice relaxation time) and T_2 (spin-spin relaxation time) was obtained from both T_1 and T_2 weighted images using the following parameters: TR/TE = 1500, 900, 400, 200 / 30ms

for the T_1 weighted images and TR/TE = 1500 / 30, 50, 70, 100ms for the T_2 weighted images. All 2-D images were acquired using the following common parameters: FOV of 20mm, number of excitations of 4, slice thickness of 2mm and matrix size of 128*128. Skin tissues were prepared from both guinea pigs and hairless mice as both normal and abnormal skin tissues. Abnormal skin tissues were contained erythema generated by UV-B or croton oil. Both types of skin tissues were located in a same sample vial to acquire 2-D images. Then signal changes were quantitatively analyzed in the interested locations from the acquired skin images.
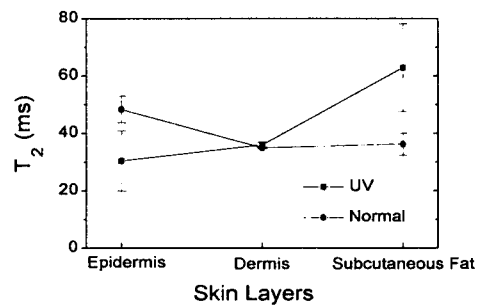
(a)
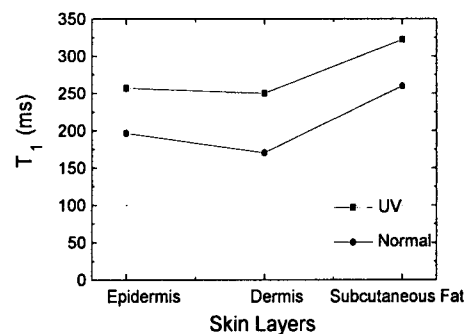
(b)

Figure 1. (a) Both Spin-lattice relaxation times (T1) and (b) spin-spin relaxation times (T2) for three different layers (epidermis, dermis and subcutaneous fat) of both normal and UV-B treated skin tissues of guinea pigs.

T_1 and T_2 values were measured as shown in the graphs of Figs. 1a and 1b, respectively, for the skin tissues excised from guinea pigs. It is found that the UV-B treated skin tissue produces the increased T_1 values in comparison with the T_1 values of the normal skin tissue. This is the reason that the swelling phenomena is induced due to the UV-B irradiation to result in the generation of erythema and the increased water content. On the contrary, T_2 values of the UV-B treated epidermis are decreased by half comparing with that of the normal epidermis. Although each skin layer of hairless mice is much thinner than that of guinea pigs, the skin layer of hairless produces the same relaxation phenomena. In the case of hairless mice, erythema was generated by treating croton oil instead of UV-B light. The croton oil treated epidermis of hairless mice provides the decreased T_2 values in comparison with the normal epidermis as shown in Fig.2.
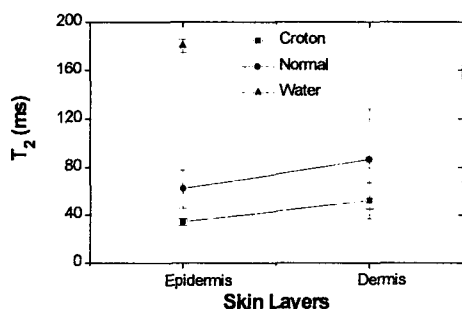

Figure 2. Spin-spin relaxation times (T2) for two different layers (epidermis and dermis) of both normal and croton oil treated skin tissues of hairless mice.

It is obvious that the main goal of the skin study should be the noninvasive characterization using in-vivo studies. Though valuable information can be expected from in-vitro studies of excised skin tissues, it is definitely true that more important information can be obtained if the skin tissues are within the living body. In-vivo images for hairless mice were acquired as shown in Fig.3a, 3b, and 3c. The epidermis of abnormal skins (Fig.3a, 3b) are somewhat thicker than that of normal skin (Fig.3c).
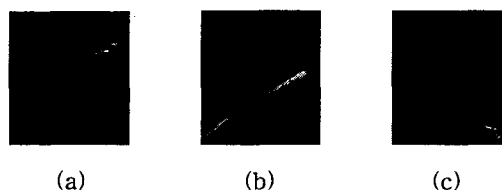

(a)   (b)   (c)

Figure 3. In-vivo skin images of hairless mice acquired for the UV-B treated skin (a), for the croton oil applied skin (b) and for the normal skin (c).

The abnormal skins were prepared to generate erythema on each epidermis by irradiating UV-B (Fig. 3a) or by applying croton oil.(Fig.3b) These images were obtained by the conventional spin echo imaging sequence with the following parameters: the FOV (field of view) of 10mm, matrix size of 128x128, slice thickness of 1mm, number of acquisitions of 14 and TR/TE=1500/30ms. The thickness of the normal epidermis was 85±10mm, while those of the abnormal epidermis were 164±10mm for the croton oil applied skin and 126±6mm for the UV-B treated skin. The thickness of the abnormal epidermis was increased by 1.5-2 times. This thickness increase may be due to a protection role against the UV-B irradiation or the croton oil treatment. As reported previously[5], the superficial layers (including the epidermis and the dermis) of the abnormal skin are swollen in comparison with those of the normal skin.

In-vivo study for human skin was performed by acquiring the 2-D images with both T_1 weighted and T_2 weighted contrasts. Figures 4a-4c and Figs. 5a-5c are the 2-D images of the human skin in-vivo with T_1 weighted and T_2 weighted contrasts, respectively. The same image set was obtained after applying a glycerin patch for 2 hours. T_2 variation along with water quantity changes was determined for the epidermis of the same location of a volunteer. T_2 was decreased from 120ms to 30ms with the application of the glycerin patch. The quantity of water was observed to be increased by about 40% after applying the patch.
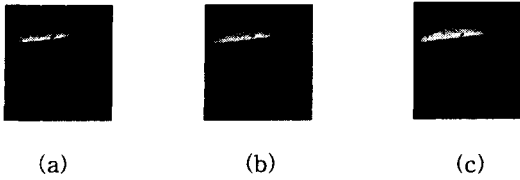
(a)   (b)   (c)

Figure 4. T_1 effect for the human in-vivo skin images with FOV of 30mm, a slice thickness of 2mm, matrix size of 128x128, and the number of acquisitions of 2: (a) TR/TE=300/30ms, (b) 600/30ms, (c) 1000/30ms.
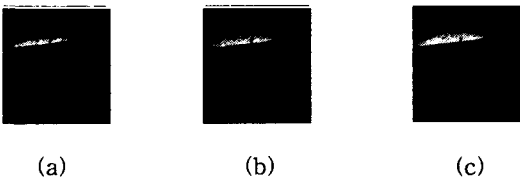

(a)   (b)   (c)

Figure 5. T_2 effect for the human in-vivo skin images with the same parameters in Fig.6 except the followings: (a) TR/TE=1000/30ms, (b) 1000/60ms, (c) 1000/100ms.

Conclusions

In the present study, NMR Microscopy for thin skin layers offers noninvasive visualization of skin pathology.   It is expected that NMR Microscopy of animal skin will be advantageous for testing new cosmetics before the application to the human skin.   In-vivo MR Microscopy is found very feasible for the study of skin.   More work relating noninvasive investigation of skin is currently in progress.

References

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