Surface Image of Normal Intervertebral Disc on 3 Dimensional CT

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Purpose: To evaluate surface configuration of intervertebral disc on three dimensional CT.

Materials and Methods: Three dimensional surface images reconstructed from CT scans (1 mm thick) of 20 discs in 14 healthy adults were reviewed.

Disc surface was classified into peripheral and central zones in contact with consecutive peripheral ring and central endplate. Local irregularity incidence, pattern in radial, concentric, or mixed form, size, location, and extension were observed. Incidence and severity ranges in 4 grades of general irregularity, and peripheral width relative to central radius were evaluated.

Results: Normal disc mostly showed smooth surface with few display of small local irregularity (6/20) which was mainly radial in pattern (4/5), posterolaterally located (4/6), and confined within peripheral zone (5/6).

General irregularity displayed (5/20) was all grade I and peripheral width was 0.82 of central radius.

Conclusion: Normal disc shows smooth surface but few may display small local irregularity maybe due to very early degenerative change.

Index Words: Spine, Intervertebral disks
Spine, CT
Computed tomography (CT), three-dimensional

INTRODUCTION

The components of the intervertebral disc serve two functions. Circumferential rings of fibrocartilage (outer anulus) contain central hydrophilic matrix (inner anulus and nucleus pulposus) which, in turn, acts as a cushion between the vertebral bodies and endplates (1).

The vertebral endplate, which acts as a major supporting and attachment structure, also maintains disc nutrition with the consequent important implication for disc structure and function (2).

The vertebral body, which is consisted of the compact and the weightbearing cancellous bone, supports the vertebral endplate and the disc (3–4).

Thus, intervertebral disc, vertebral body, and vertebral endplate are closely interrelated both functionally and structurally. Time-related changes with the progressive dehydration of the disc, remodelling of the vertebral body, and thinning of the vertebral endplate would accompany decrease in the functional roles and interdependant changes in the configurations (2–6).

Therefore, the surface configuration of the disc would be representative of interrelated condition of the disc, vertebral endplate and bone.

This study is performed to demonstrate the surface configuration of normal disc which would serve as the reference in the evaluation of the surface configuration of various disc abnormalities leading to a new dimension in the diagnosis of pathologic discs in addition to discographic CT or MR.

MATERIALS and METHODS

The study subjects included 4 male and 10 female healthy adults without clinical evidence of intervertebral disc diseases. The subject age ranged from 19 to 45 years with the mean of 28 years. Two disc levels (L3–4 and L4–5) were evaluated in 6 subjects and 1
a. Central  b. Peripheral

Fig. 1. 2 Zones of Disc Surface

Fig. 2. Patterns of Local Irregularity

Fig. 3. Three dimensional(3D) image of L4-5 intervertebral disc shows no evidence of local or general surface irregularities in(a) superior and(b) oblique views.(c) Axial reconstructed view shows the normal disc.(d) Coronal and(e) sagittal views show no sign of cartilaginous endplate erosions as does the(f) axial scan of the L4 inferior endplate. The findings of the 3D and the reconstructed images are an example of normal disc without an evidence of early degenerative change.
level (L2–3 in 3 subjects, L3–4 in 5) in 8 subjects with the total of 20 discs evaluated. Discography was performed with 1:12 solution of 61 g% iopamidol (Bracco, Milan). One mm thick contiguous scans were done on a spiral CT unit (GE HighSpeed Advantage, Milwaukee, WI) and three dimensional images were reconstructed with a software (GE Advantage Window, Milwaukee, WI) using Surface Rendering Mode.

Disc surface was classified into 2 zones: peripheral in contact with the peripheral fibrocartilaginous ring and central in contact with the central hyaline cartilaginous endplate (Fig. 1). Surface irregularity was categorized into 2 types: local and general.

Local irregularity incidence, pattern in radial, concentric, or mixed form (Fig. 2), size in small (subtle) or large (definite) magnitude, and location in anterior, lateral, posterolateral, or posterocentral position was noted. Extension of local irregularity from peripheral zone to disc margin or to central zone was investigated.

General irregularity incidence was evaluated and its degree categorized into 4 grades: 0, negative; 1, subtle; 2, moderate; 3, severe. Peripheral zone width was measured relative to midline anterior radius of central zone.

Discs were divided into 2 groups: 1, without local irregularity; 2, with local irregularity. Surface irregularity was compared between the two groups and was correlated with endplate erosion in two dimensionally (2D) reconstructed images and with discographic findings.

RESULTS

Normal disc mostly showed smooth surface (Fig. 3a, Fig. 4a) as only 6 out of 20 cases displayed local irregularity (Fig. 5b) which was confined within peripheral zone except for 1 extension to disc margin and was small in size. The local irregularity was mainly located posterolaterally in radial pattern (Table 1) and was not correlated in discography which was normal in all discs. However, it was well correlated with endplate erosion in 2D images.

General irregularity was not the usual finding of normal disc as only 5 out of 20 cases showed the irregularity (Fig. 5b) all of which in grade 1 (Table 2). Its incidence rate was higher in the group with the local irregularity. However, peripheral width was not signifi-
cantly different between the two groups (t = 0.16, d.f. = 18, p > 0.05).

**DISCUSSION**

Rationale for three dimensional surface imaging of disc include two basic fundamentals: one, surface irregularity can depict the earliest change brought on by degeneration. The patterns and locations of local irregularity are listed in Table 1. The general irregularity in normal disc is shown in Table 2.

**Table 1. Patterns and Locations of Local Irregularity**

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Anterior</th>
<th>Lateral</th>
<th>Central</th>
<th>Lateral</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. General Irregularity in Normal Disc**

<table>
<thead>
<tr>
<th>Group</th>
<th>Grade</th>
<th>Peripheral width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(n=14)</td>
<td>0</td>
<td>0.81</td>
</tr>
<tr>
<td>2(n=6)</td>
<td>3, 2</td>
<td>0.83</td>
</tr>
<tr>
<td>(n=20)</td>
<td>15</td>
<td>Average 0.82</td>
</tr>
</tbody>
</table>

Fig. 5. (a) Surface image of L4–5 disc shows mixed (concentric and radial) form of peripheral superior surface irregularities anteriorly (arrow) and posteriorly. Width of the peripheral surface is 1.5 times that of central surface radius. (b) Oblique view shows the posterior lesion extending to posterior disc margin (thick arrow) and subtle general irregularity of central surface (thin arrow). (c) Axial reconstructed view shows the normal disc while (d) coronal and (e) sagittal views show endplate erosions (arrow) which are demonstrated more clearly in (f) axial scan of the L4 inferior endplate representative of early degenerative change.
by aging or traumatic event; two, it reflects the condition of the disc interrelated with the endplate and bone.

Evidence for the first fundamental includes various study results. In the study on the effect of torsional stress on disc change, Farfan et al(7) stated that the maximum stress was on posterolateral of the disc where the cohesion between the outermost lamina would be disrupted leading to successive deeper anulus compromise.

In the study on the effect of axial loading on disc change, Jayson et al(8) stated that axial loading to the point of failure results in bursting of the disc content into the vertebral body rather than disruption into the anulus fibrosus.

In the study on the stages of disc degeneration in discography, Adams et al(9) stated that most commonly, normal mature disc was that of lobular type the relative weakness and deformability of the endplate compared to the anulus explaining the largest pool located directly underneath the endplate.

In review of the above studies, the earliest sign of stress-related or traumatic change would occur where it is most vulnerable to usual axial and torsional stress of daily life that is, most outer posterior anulus adjacent to weak vertebral endplate which would be best viewed in the three dimensional surface images as the local irregularity the extent, size, and incidence of which reflecting the severity of involvement.

Evidence for the second fundamental includes the fact that the configuration and function of the intervertebral disc are, to a great extent, dictated by those of neighboring vertebral endplates and bodies(6) and that the various components of the disc change according to the stresses and strains of aging with the changes in the cartilaginous endplate and bone(10-11). Thus, disc surface change such as increased general irregularity reflects the age-related interdependant condition of the disc as does the peripheral width narrowing which is the manifestation of the central zone widening and peripheral cartilaginous ring narrowing known to occur in degeneration.(12)

The above are supported by the result of this study as most of the normal disc showed smooth surface. The surface irregularities in some of the normal discs with the unremarkable discographic findings suggest that these maybe the very early outer anulus and cartilaginous endplate changes before inner anulus and nucleus degeneration ensue.

Peripheral surface width of the discs with local irregularity being not significantly different from that without the irregularity may support this as nucleus degenerative change is known to widen the central zone (12) which would be reflected as decreased peripheral width described earlier.

Local irregularity being mostly radial in pattern with posterolateral location is congruous with the radiating type of anulus tear which is described by Hirsch and Schajowicz(13) to eventually to extend from the surface of the anulus to the nucleus and by Vernon-Roberts(2) for its particular affinity for posterolateral zone. Yu(14) suggested that it may be the primary event in disc degeneration similar to the implication of this study and the prerequisite condition for herniation.

Higher incidence rate of general irregularity among those with local irregularity suggest that the two types of the surface irregularity tend to occur simultaneously.

Normal disc displayed smooth surface with peripheral width of 0.82 relative to central radius. Peripherally confined small local irregularity in some discs maybe the very early degenerative change. Thus, the three dimensional surface configuration of normal disc would serve as the reference in the evaluation of various disc abnormalities leading to a new dimension in the diagnosis of pathologic discs in addition to discographic CT or MR.

REFERENCES

삼차원 CT를 이용한 정상 추간판의 표면영상

목적: 삼차원 CT상에서 정상 추간판의 표면형태를 평가하고자 하였다.

대상 및 방법: 14명의 건강한 젊은 성인 남녀 대상에서 총 20개의 척추판을 나선형 전산화 단층 촬영(1mm 두께)하여 삼차원적 표면 영상을 재구성하였다. 척추판 표면은 섬유판연글 고리와 접한 주변부와 유리연골 종판과 접한 중심부로 분류하였다. 국소적 불규칙성의 빈도, 방선형, 동축성, 환합형 등의 형태, 크기, 위치, 그리고 척추판으로의 이행을 관찰하였다. 전반적 불규칙성의 빈도와 정도 및 주변부의 두께등을 평가 하였다.

결 과: 정상 추간판 표면은 대부분 평활면이었다. 관찰된 6여의 국소적 불규칙성은 후방 주변부에 국한된 방선형이 많았고 연골고리 침식과 일치하였다. 전반적 불규칙성은 미세하였고 주변부의 두께는 중심부 반경의 0.82였다.

결 론: 대부분의 정상 추간판 표면은 평활면으로 이루워져 있으며 일부에서 보이는 불규칙성은 외판륜과 연골판 퇴행의 초기 단계를 반영한다고 사료된다.