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Measure-set Computed Tomography in the Diagnosis of Herniated Nucleus Pulposus

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The present study has been carried out to enhance the specificity of computed tomography (CT) in diagnosing herniated nucleus pulposus (HNP) of the lumbar spine by the application of measure-set (MS) technic. MSCT scans of 20 patients with proven diagnosis of HNP were reviewed prospectively to sort out features of diagnostic value. Eleven were men and 9 were women with the mean age being 40 years. MSCT scan revealed dislocation of the center of the nucleus pulposus (NP) in direction of herniation in 75%, "permeation" of the annulus fibrosus (AF) by HNP material and a clear disruption of the outermost layer of AF in all patients. The site and grade of the protrusion of HNP beyond the normal saliancy of AF could be easily evaluated in 90%. The present study revealed that MSCT can demonstrate four characteristic findings of HNP enabling one to directly and semiquantitatively assess the pathologic changes of NP.

Key Words: *Intervertebral disk, CT scan, Measure-set CT technic, Herniated nucleus pulposus.*

INTRODUCTION

Computed tomography (CT) has been widely used in the diagnosis of herniated nucleus pulposus (HNP) of the spine (Bahk and Lee, 1984; Bahk and Lee, 1988; Chafetz, 1982; Firooznia et al., 1984; Fries et al., 1982). However, due to infeasibility of the standard CT to clearly separate the nucleus pulposus (NP) from the annulus fibrosus (AF) of a disk, the CT diagnosis of HNP inevitably relies on the observation of the change of the posterior saliency of the disk and other associated indirect signs (Bahk and Lee, 1988; Fries et al., 1982). Recently, we found measure-set (or the narrowest window-width setting) computed tomography (MSCT) is useful to directly visualize NP and AF as two distinctive structures of the disk permitting its analytical study (Fig. 1) (Bahk and Lee, 1984; Bahk and Lee, 1988; Lee and Bahk, 1986).

The aim of the present communication is to report the results of MSCT analysis of HNP, with an emphasis on the specificity of findings and their usefulness in a semiquantitative assessment of changes occuring in NP.

MATERIALS AND METHODS

During the past 12 months, at the Department of Radiology, Catholic University Medical College, Seoul, we performed standard CT scan in 202 patients who were referred to us for evaluation of low-back and/or radiating pain. Of these, 71 patients having findings suggestive of HNP on standard CT were subjected to MSCT evaluation, and 20 of the 71 patients subsequently underwent disk surgery. Eleven were men and nine were women with the age ranging from 22 to 43 (mean 40) years.

CT scans were performed with a Somatom 2 scanner (Siemens) immediately after calibration. The tech-

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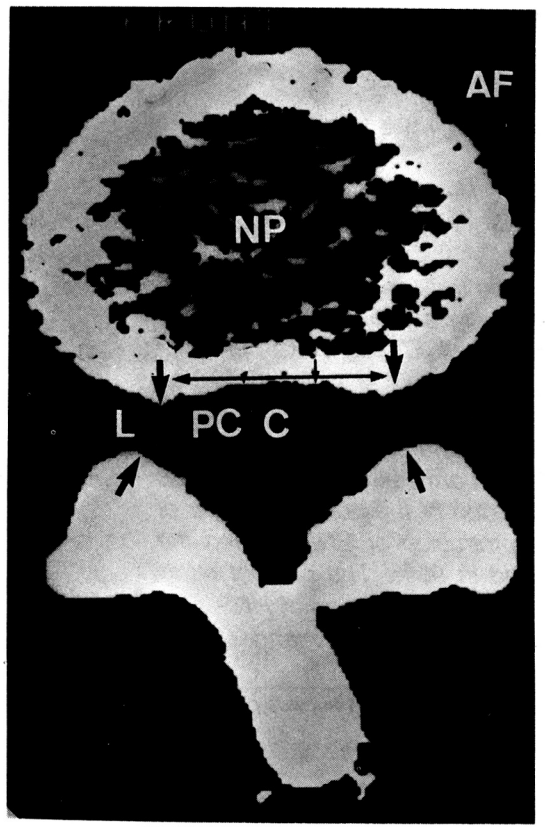

Fig. 1. MSCT scan of a normal L2/3 intervertebral disk showing the nucleus pulposus (NP) as a centrally placed large ovoid structure consisting mainly of "black dots" intermingled with some "white dots" and the annulus fibrosus (AF) as a white ring-like structure surrounding NP. The posterior segment of AF is defined as that portion of AF delimited bilaterally by the narrowest point of the intervertebral foramen (opposing arrows). The posterior segment is subdivided into the central (C) and both paracentral (PC) portions. The (far) latoral portion is the area iying laterally to the posterior segment (L).

nical factors were tube voltage 125 kVp, exposure time 10 seconds, tube current-second 460 mAs, matrix 256×256, and pixel size 0.4mm. After reviewing the orientational topograph, 2-mm-thick continuous slices of each disk were obtained in a plane parallel to the central transverse axial plane of a disk at 3-mm interval, from the lower margin of the upper vertebral body to the upper margin of the lower one. When necessary, additional slices were cut at 1-mm interval. Out of multiple slices of each disk, the one which had neither partial volume effect nor artifact

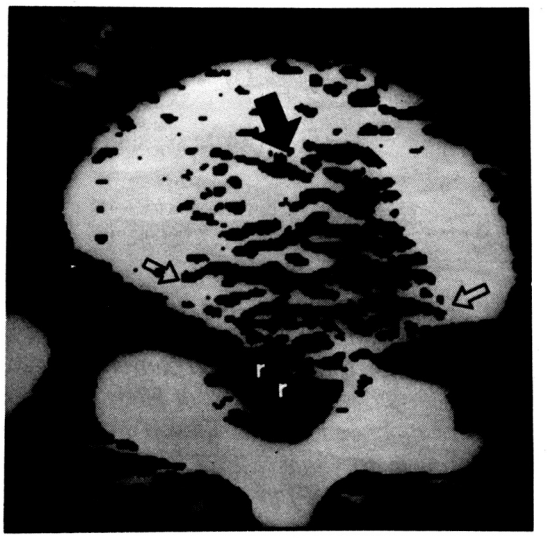

Fig. 2. MSCT scan of an HNP (patient No. 5) showing dislocation of the center of NP in the left paracentral direction (black arrow). There is diffuse permeation of the posterior segment by the elements of HNP (white arrows) and disruption of AF representing rupture (r).

was selected for MSCT study. Once the particular level of slicing was determined, the window width was narrowed down to 1 and window level was adjusted to bring out NP and AF as clearly as possible as two different structures. The ordinary window width was 512 and window level was 30. The latter was raised up to about 80.

The MSCT images so obtained were evaluated in terms of (1) dislocation of the center of NP in relation to the ovoid ring of AF, (2) permeation of AF by elements of HNP, (3) rupture of AF, and (4) protrusion of NP. The permeation was defined as the presence of diffuse but discrete low-density "black dots" of NP within "white ringlike zone" of AF and the rupture was defined as clear disruption of the outermost layer of AF by NP material (Fig. 2). The protrusion was defined as thrusting of NP material beyond the normal posterior saliency of AF, by which HNP is diagnosed usually on the standard CT. For the sake of a semiquantitative analytical system, the dislocation, permeation, rupture, and protrusion were evaluated in terms of the direction, extent, presence or absence, and grade by arbitrary criteria. Thus, the dislocation and protrusion was classified into posterior central (PC), right or left posterior paracentral (RPPC or LPPC), and right or left posterior lateral (RPL or LPL). Here the posterior part of AF was defined as that portion of AF which is delimited bilaterally by the

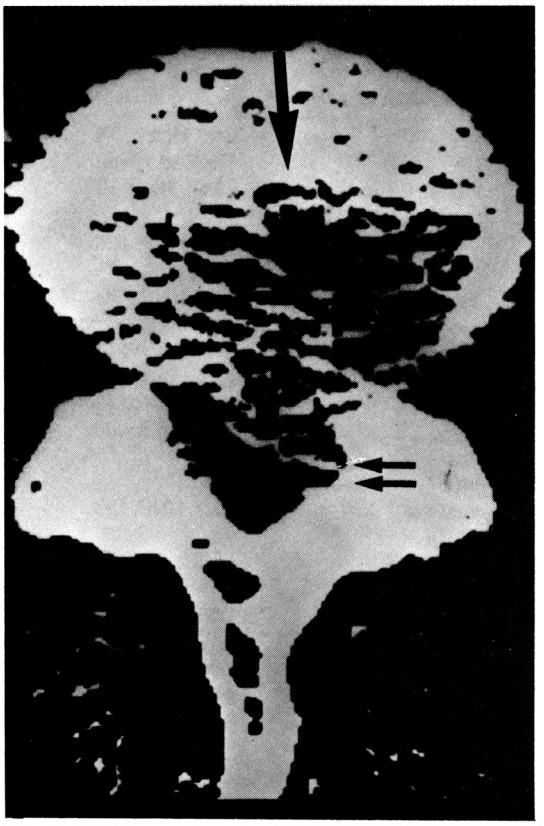

Fig. 3. MSCT scan of another HNP (Patient No. 6) showing dislocation of the center of NP (arrow) as well as marked protrusion of NP with the tip reaching the midline of bony spinal canal (double arrows).

narrowest point of the intervertebral foramen as shown by MSCT (Fig. 1). The central and paracentral portion of the posterior part denoted the middle and both lateral one third, respectively. The (far) lateral portion was the area lying laterally to the posterior part (Fig. 1). The extent of permeation of the posterior part of AF was graded arbitrarily into mild, moderate, and marked when the involved area was less than one third, between one and two thirds, and more than two thirds of the posterior part, respectively. The dislocation of the center of NP and the rupture of AF was expressed simply by presence or absence because quantification of these two findings was not possible. The protrusion, however, could be graded according to the reach of the posteriorly protruded tip of NP within the anterior half of the bony spinal canal. Thus, when the tip reached less than the anterior one third, the protrusion was graded as mild. When the tip reached the middle and posterior one third, the protrusion was graded as moderate and marked, respectively (Fig. 3).

RESULTS

The pertinent clinical symptoms and MSCT and operative findings are summarized in Table 1. All 20 patients had more or less severe back pain with radiation to the buttock, thigh, lower leg, ankle, and/or foot. The pain preceded patient's hospital visit by months and years. The pain was right sided in 50%, left sided in 45%, and bilateral in 5%. The side of radiating pain and HNP matched well in all patients with lateralized pain. In the seven patients with central HNP, pain was either right or left sided in 43% and bilateral in 14%. The dislocation of the center of NP in the direction of herniation was noted in 75% (Fig. 4). There was no correlation between the pre-

Fig. 4. MSCT scan of still another HNP (Patient No. 17) showing right paracentral rupture of NP with associated permeation giving rise to an appearance of "volcano in eruption" (white arrow). The last sign can be seen also in Figures 2 and 3. The center of NP is not significantly dislocated in this patient.

Table 1. Summary of clinical data and MSCT and surgical findings in 20 patients with herniated nucleus pulposus (HNP)

Case	Age/Sex	Clinical Symptoms	Measure-Set CT Findings	Surgical Findings
		Low-Back Pain Radiating Pain to	Dislocation/Permeation* Rupture Site/Protrusion**	
1	24/M	Yes	Yes/+++	L4/5 HNP, RPL
		Right lower leg/foot	RPL/+	Thick lig flavum
2	36/M	Yes	Yes/+++	L5/S1 HNP, RPL
		Right calf	RPPC/++	
3	38/F	Yes	No/++	L4/5 HNP, RPL
		Right lower leg	RPL/++	
4	53/M	Yes	Yes/+++	L4/5 HNP, Central
		Right lwoer leg	PC/+++	Vein engorgement
5	32/F	Yes	Yes/+++	L5/S1 HNP, LPL
		Left lower leg/foot	LPPC/++	Thick lig flavum
6	51/M	Yes	Yes/+++	L4/5 HNP, LPL
		Left buttock/thing/foot	LPPC/+++	Thick lig flavum
7	42/M	Yes	Yes/+++	L5/S1 HNP, RPL
		Right lower leg/ankle	RPPC/++	
8	41/F	Yes	Yes/++	L4/5 HNP, LPL
		Numbness in left calf	LPPC/++	
9	22/M	Yes	Yes/++	L5/S1 HNP, Central
		Both lower legs	PC/++	
10	47/M	Yes	Yes/+++	L5/S1 HNP, RPL
		Right thigh/lower leg	RPL/+	
11	45/F	Yes	No/+++	L4/5 HNP, LPL
		Left thigh/lower leg	LPPC/+	Nodular type
12	44/M	Yes	No/++	L4/5 HNP, Central
		Right buttock/lower leg	PC/++	
13	48/F	Yes	Yes/++	L5/S1 HNP, LPL
		Left lower leg	LPPC/+++	Thick lig flavum
14	37/M	Yes	Yes/++	L4/5 HNP, Central
		Left lower leg	PC/++	
15	37/F	Yes	Yes/++	L4/5 HNP, Central
		Right lower leg	PC/++	
16	37/F	Yes	Yes/+++	L4/5 HNP, LPL
		Left lower leg	PC/++	
17	33/M	Yes	Yes/+++	L4/5 HNP, RPL
		Right buttock/lower leg	RPPC/++	Recurrent HNP
18	50/M	Yes	No/++	L5/S1 HNP, LPL
		Left-lower leg	LPPC/++	Thick lig flavum
19	36/F	Yes	No/+++	L4/5 HNP, RPL
		Numbness in right calf	RPL/+	
20	43/F	Yes	Yes/++	L5/S1 HNP, Central
		Left lower leg	PC/++	

Note. *Permeation was the presence of "black spots" of low-density elements of nucleus pulposus within "white band-like zone of high-density" annulus fibrosus. + = mild, ++ = moderate, +++ = marked. **Protrusion was thrusting of elements of HNP beyond the normal saliency of the posterior contour of the disk, +=mild, ++=moderate, +++=marked. PC=posterior central, RPPC=right posterior paracentral, LPPC=left posterior paracentral, RPL=right posterior lateral, LPL=left posterior lateral.

sence or absence of dislocation and the extent of permeation or between the presence or absence of dislocation and grade of the protrusion. The site of rupture was PC in 35%, RPPC in 15%, LPPC in 30%, RPL in 20%, and LPL in nil. The permeation was moderate in extent in 45% and marked in 55%. A clear disruption of the AF was noted in every patient. Sixty percent of HNP involved L4/5 disk and 40% L5/S1 disk. The protrusion was mild in 20%, moderate in 70%, and marked in 10%. The site of rupture along the posterior border of AF was well visualized as equally as on standard CT in 85%, more clearly

seen on standard CT in 10%, and seen better on MSCT in 5%. Again there was no correlation between the extent of permeation and grade of protrusion.

DISCUSSION

CT was applied to the diagnosis of HNP as early as 1979 by Meyer, Haughton, and Williams. Since then, a number of publications on CT studies on HNP has appeared (Bahk and Lee, 1988; Chafetz, 1982; Firooznia et al., 1984). However, mainly because the standard CT could not image NP from AF of the disk as two separate structures, CT diagnosis of HNP has been inevitably based on indirect findings such as bulging or protrusion of disk contour (not the disk itself) (Bahk and Lee, 1984; Bahk and Lee, 1988; Chafetz, 1982; Firooznia et al., 1984; Fries et al., 1982). Recently, by using MSCT, we were able to image NP and AF as two distinctive structures in the subjects in their 4th or younger decades as shown in Figure 1 (Lee and Bahk, 1986; Meyer et al., 1979; Williams et al., 1980). In our department, MSCT is performed by adjusting the window width of CT scanner from ordinary 512 down to 1 and by raising the window level from ordinary 30 up to about 80. By MSCT, NP could be depicted as a large centrally placed ovoid structure, the internal architecture of which is characterized by mottlings with black and white dots, whereas AF as a white ring-like structure, which surrounds NP (Fig. 1). Our recent studies revealed that with age, low-density black dots were gradually replaced by high-density white dots due to senile changes including the loss of water especially in NP (Bahk and Lee, 1988; Lee and Bahk, 1986).

MSCT of the 20 patients with proven HNP in the present series showed dislocation of the center of NP in 75% (Figs. 2, 3, and 4). The permeation and rupture of AF were connected one another and occured in the same direction. The permeation was generally much more prominent than the rupture giving rise to an appearance of "volcano in eruption" (Figs. 2, 3, and 4). The site of rupture along the posterior saliency of AF was visualized as clearly as on standard CT in 85% and better than on standard CT in 5%. MSCT permitted us to grade severity of protrusion within the bony spinal canal, and in 80% the protrusion was moderate to marked in grade. There was no correlation between the extent of permeation and the grade of protrusion.

The side of radiating pain and the site of HNP matched well in all patients who had a lateralized pain. In 7 patients with central HNP, pain was lateralized either to the right or left side in 3 (43%) and bilateral in 1 (14%).

In summary, MSCT was proven to be useful in providing us with specific findings of HNP which may be used semiquantitatively to evaluate clinical symptoms and signs and to plan a spinal surgery in the patients who are in their age of younger than the 4th decade during which period NP can be usually imaged as distinctive structure from AF.

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