Annals of Physical Medicine and Rehabilitation

Case Report

Energy Spectrum CT Differential Diagnosis of Idiopathic Calcification and Ossification of Adult Intervertebral Disc: A Report of Three Cases

Xiaolin Wu[1#], Wenbin Cong[2#], Hongfei Xiang[1], Guoqing Zhang[1], Zhu Guo[1] and Bohua Chen[1*]*

[1]Department of Orthopedics, The Affiliated Hospital of Qingdao University, China

[2]Department of Radiology, The Affiliated Hospital of Qingdao University, China

[#]Authors contributed equally

Abstract

Background: Calcification of adult intervertebral disc is a rare clinical disease, and its imaging diagnosis directly affects the formulation of the operation plan. In this study, three cases are used to illustrate that the application of energy spectrum CT as the preoperative diagnosis can better reflect the pathological situation and structure of the focus, further helping with preoperative judgment.

Case presentation: We report two cases of idiopathic calcification of adult thoracic intervertebral disc. In addition to Routine CT and MRI before the operation, energy spectrum CT was taken to produce analytical diagnosis of the lesions. According to the results, the surgical resection mode was determined. The postoperative confirmation was highly consistent with the image diagnosis. Likewise, a case of posterior margin of vertebral body and ossification of intervertebral disc was selected for the same diagnosis procedure, and the two were compared for differentiation.

Conclusion: In the illustration that the texture of the vertebral canal presser being uncertain, the energy spectrum can identify the calcium type of the presser, as well as the atomic number histogram being able to fix the absolute content value and the distribution rule of calcium. Meanwhile, the calcium-water astigmatism map can resolve the calcium deposition mode, with better estimation of the focus presser hardness.

Keywords: Intervertebral disc; Idiopathic calcification; Ossification; Energy spectrum CT; Energy spectrum diagnosis

Abbreviations

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; HAP: Hydroxyapatite Crystal; OPLL: Ossification of the Posterior Longitudinal Ligament; DFOV: Display Field of View; Kev: Kiloelectron Volt

Background

The calcification of intervertebral disc is a sort of degenerative disease with abnormal deposition of calcium salt in cartilage, which was primarily discovered by Von Luschka [1]. Its pathology is mainly characterized by the amorphous deposition of calcium salt without the role of chondrocytes. The composition analysis of in vitro samples is mostly hydroxyapatite crystal (Ca10 (PO4) 6 (OH) 2, HAP) [2]. Due to the lack of effective direct clinical imaging diagnosis and the low incidence rate of the disease, the clinical features are frequently confused with Ossification of the Posterior Longitudinal Ligament (OPLL), together with rim ossification of the intervertebral disc. Regular preoperative CT is not sensitive to the identification of calcium salt deposits. Despite of calcification and ossification being completely different pathological processes, it is demanding to predict the texture and possible components of the lesion. It often falls into the situation of problematic differential diagnosis, which affects the planning of operation and delays the operation time. Dual energy CT is a non-invasive examination method that can distinguish the material components and structures. For its suitability and handiness in examination and analysis, it could provide sufficient diagnostic basis for doctors. In this group of cases, preoperative energy spectrum CT imaging analysis was used, and single energy CT energy spectrum curve, calcium distribution histogram, material density scatter diagram were obtained successively, and parallel to liver, brain, coronary artery and aortic calcium. The hardness characteristics of calcium deposition lesions were attained by contrast differentiation of calcification, edge of vertebral body/ ossification of intervertebral disc. It was confirmed that the preoperative diagnosis method was an effective method to detect such intraspinal space occupying lesions.

Citation: Wu X, Cong W, Xiang H, Zhang G, Guo Z, Chen B. Energy Spectrum CT Differential Diagnosis of Idiopathic Calcification and Ossification of Adult Intervertebral Disc: A Report of Three Cases. Ann Phys Med Rehabil. 2021; 1(1): 1004.

Publisher Name: Medtext Publications LLC

Manuscript compiled: Jun 24th, 2021

***Corresponding author:** Bohua Chen, Department of Orthopedics, The Affiliated Hospital of Qingdao University (East District), 59# Haier Road, Qingdao, Shandong, China, 266003, E-mail: bhchen@hotmail.com

Zhu Guo, Department of Orthopaedics, The Affiliated Hospital of Qingdao University, Qingdao, China, 266000, E-mail: guozhugz@126.com

Case Presentation

Case 1

Male, 37 years old, who had been having Lumbosacral pain with numbness and weakness of both lower limbs was admitted to the hospital in January. One month ago, the hospital accepted "T12/

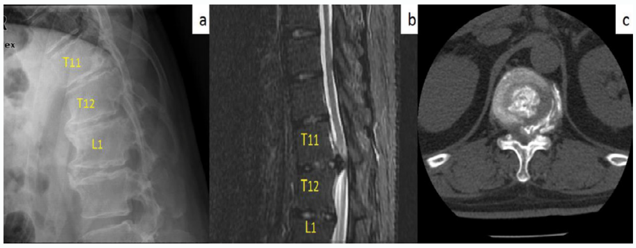

Figure 1: a. Case 1 X-ray lateral position of thoracolumbar spine before operation; b. T2 fat suppression image of sagittal MRI before operation; c. axial position image of T11/12 space of routine CT tissue window before operation.

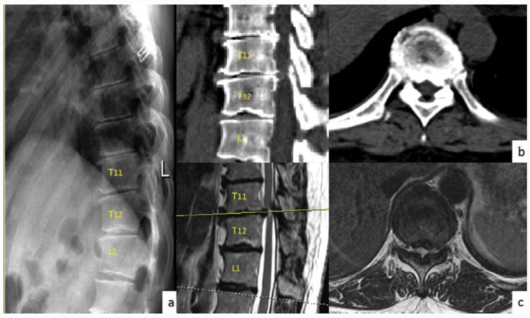

Figure 2: a. Case 3 X-ray lateral position of thoracolumbar spine before operation; B. T2 and axial position of sagittal MRI before operation; C. 3D reconstruction of sagittal position and axial position of T11/12 interstitial tissue window with CT before operation.

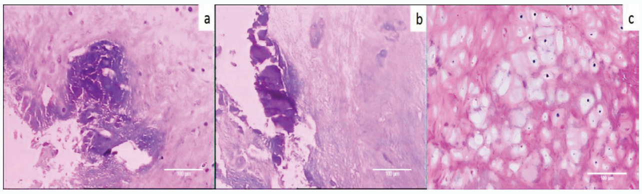

Figure 3: a. Pathology of calcification in Case 1(x200), more chondrocytes and amorphous calcium deposits; b. pathology of calcification in Case 2(x200), small amount of chondrocytes and amorphous calcium deposits c. pathology of partial ossification in Case 3(x200), chondrocytes and shaped calcium deposits.

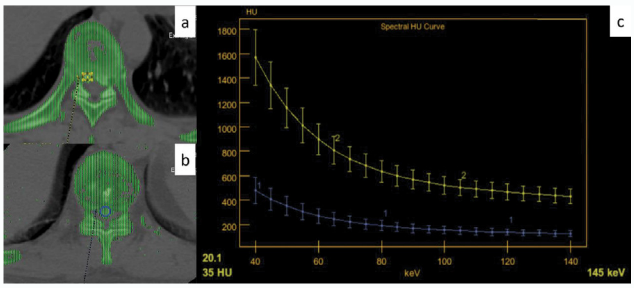

Figure 4: a. Case 3 energy spectrum analysis of ossification focus DFOV selected rendering map; b. Case 2 energy spectrum analysis of calcification focus DFOV selected rendering map; c. energy spectrum curve of calcification focus and ossification focus.

L1 nucleus pulposus removal radiofrequency ablation minimally invasive surgery". After the operation, the chest and waist pain gradually appeared, accompanied by numbness and weakness of both lower limbs. Physical examination: on T11-12 plane, there were postoperative scars, T10-L2 spinous process and paravertebral tenderness, skin pain on both sides of the lateral leg and the back of the foot decreased. The muscle strength of extensor dorsalis of the left ankle was grade II, the muscle strength of the extensor dorsalis of the right toe was grade II, the tendon reflex of both sides was weakened, the clonus of the right ankle was (+), the Babbinski sign of both sides was (-). CT and MRI (Figure 1) of thoracic vertebrae were performed in the hospital, which indicated that "the T12/L1 space was decreased after operation, and the T11/12 intervertebral disc in front of thoracic canal was hard occupying lesion?" In the energy spectrum CT scan, we considered "idiopathic calcification of adult intervertebral disc" and "resection of calcification focus after decompression of thoracic vertebral canal". When the focus was removed, it was relatively tough and easy to be removed, and the content of adhesion with the fibrous ring was in the shape of "toothpaste". The postoperative pathology suggested that fibrocartilage calcification (Figure 3a) was formed.

Case 2

Male, 65 years old, who had been having chest and waist pain for 8 months, and came for treatment after aggravating and numbness in the lower extremities for 2 month. There was radiation pain to both buttocks at night, accompanied by chest and waist "band sense", physical examination: T10/L1 paravertebral tenderness, decreased skin pain below the groin, normal feeling in the saddle area, left hip extension muscle strength grade IV, normal bilateral tendon reflex, bilateral Babinski sign (-). Routine X-ray, CT and MRI were performed in the hospital, indicating "hard space occupying lesion at T10/L1 disc level in front of thoracic vertebral canal?" According to the analysis of energy spectrum CT scan (Figure 4b), we considered "idiopathic calcification of adult intervertebral disc" and performed "resection of calcification focus after decompression of thoracic vertebral canal". The focus was soft and closely related to the fibrous ring, and the content was in the shape of "toothpaste". The pathology after the operation indicated "formation of broken cartilage and calcification focus" (Figure 3b).

Case 3

Female, 48 years old, two lower limbs with acid swelling for 8 months, aggravating with weakness, admitted in April. Physical examination: skin hypoesthesia in bilateral inguinal area and perineum, bilateral flexion hip muscle strength grade IV, bilateral knee tendon reflex (+ +), bilateral Babinski sign (-). Routine X-ray, CT and MRI examination (Figure 2) were performed in the hospital, which indicated that "osteophyte formation at T11/12 disc level and hard space occupying lesions at corresponding level?" While the energy spectrum CT scan (Figure 4a) considered "T11/12 posterior ossification formation". In spite of the performance of posterior decompression of thoracic spinal canal, some lesions were still taken out in the front of the side for pathological examination. It was hard to remove the lesions, the texture was rigid, and it was not easy to take out the lesions in blocks. The postoperative pathological examination suggested "fibrous ring ossification formation" (Figure 3c).

Discussion and Conclusions

Calcification and ossification are the outcomes of histopathological changes. The abnormal deposition of calcium in tissues caused by diverse reasons leads to sclerosis. In terms of calcification, the pathological process is the amorphous deposition of calcium salt on the non-bone like matrix, while the ossification is the stereotyped deposition on the bone like matrix. The process of the two pathological changes and the degree of hardening of lesions are unalike. The calcification of adult idiopathic intervertebral disc is mostly seen in the "marginal type" calcification of intervertebral disc. Meanwhile, the tissue changes generally from the fibrous ring, which may result from external factors such as trauma and inflammation acting on the local fibrous ring, resulting in the amorphous deposition of calcium salt in the local fibrous ring tissue, and then the calcification result after a series of complex absorption process [3]. The pathological picture shows that the calcification focuses on the edge of the fibrous ring, the structure of calcification is loose and independent of normal fibrous chondrocyte nests, which are arranged in "concentric ring" with scattered chondrocyte nests in the lesions (Figure 3a and b). The ossification of intervertebral disc edge and the posterior vertebral body edge are common in degenerative bone and cartilage lesions. The tissue sources are different, except calcium salt is deposited in the corresponding tissues. Bone cells participate in the formation of ossification, which makes calcium salt form bone structure deposition. The trigger and formation process are still unspecified at present [4]. Pathological pictures demonstrate that the ossification extends far away based on the calcified cartilage / bone cell area. The ossification focus is uniform and presents a "beam structure", the inner surface does not contain bone cells, there is no crack or connective tissue filling in the ossification focus, the ossification focus is dense and has obvious boundary with the surrounding tissue (Figure 3c). In the process of spine surgery, there are usually vertebrate tissues protruding into the spinal canal from the level of intervertebral disc. Most of these lesions characterized by calcium deposition are ossification and calcification, which have no effect on the light ones and affect the nervous function on the heavy ones. Surgical resection and decompression becomes the main hand segment to solve this kind of disease. Nevertheless, when choosing the surgical approach, spine surgeons normally give the X-ray system of the focus CT and MRI are used to determine the nature of the lesions, so as to develop a less risky way of neurode compression. This experience is habitually determined by the texture of the lesions and the location of the contents of the spinal canal. That is, the lesion is soft and easy to be removed, and it is easy to choose posterior surgery. If the lesion is hard, the posterior surgery is difficult, and the lateral surgery is easy to choose. Therefore, it is particularly imperative to decide the nature of the compression products. This principle was also followed in the three cases of adult idiopathic intervertebral disc calcification and ossification before operation, but it is challenging for ordinary CT to judge the presser materials. The calcification and ossification of the intervertebral disc showed high-density structure on conventional CT, but the texture of the lesion was as soft as "toothpaste" after removal. Although the MRI signal of calcification was different from that of ossification [5], with poor evidence, it often resulted in misjudgment. Energy spectrum CT is a kind of CT technology, which uses double kinds of substances to absorb different and specific X-rays with distinctive energy [6]. Compared with conventional single energy CT imaging, the greatest advantage of energy spectrum CT is that it can use dissimilar means and methods of attenuation characteristics to distinguish similar substances, which are difficult to realize simply with CT value [7]. Additionally, three patients with posterior edge ossification of intervertebral disc/vertebral body, five patients with cerebral calcification, four patients with hepatic calcification, six patients with coronary calcification and four patients with active vein calcification were selected. Medical energy spectrum CT was used, i.e. 128 slice dual energy CT (GE, Milwaukee, Wisconsin, USA), set scanning parameters: tube current, 200 mA; layer thickness and reconstruction interval: 5 mm, 5 mm; display field of view (DFOV): 20 cm; interval: 0.531:1; pixel interval: 0.430 mm; spiral instantaneous switch between 140 kVp and 80 kVp. Image reconstruction and analysis are performed using advanced workstation (AW 4.7; GE Healthcare, USA), all organ unit scans are routine diagnosis and treatment processes of scanning main pathological unit, which have been approved and filed by family members and patients them with informed consent and hospital ethics approval. There was no side effect and additional injury to the examination and diagnosis. It processed by data blind method, and automatically generated single energy value (keV) - CT value (HU) energy spectrum attenuation curve, calcium content atomic number histogram and calcium water-based scatter diagram. Compared with the energy spectrum curve of calcification and ossification, it can be seen that the curve of calcification is below the curve of ossification, indicating that the energy spectrum of calcification and ossification is different. Temporarily, the material properties are different. By contrast, the energy spectrum curve trend of calcification in liver, brain, coronary artery and aorta is similar, (Figure 5) indicating that the material types in the focus are similar, but the nature of the focus is different, and the average CT value of calcification is low under the condition of 70 Kev (Figure 4). The density of ossification focus, that is to say, the density of ossification focus, which represents the composition of similar substances, is higher than that of calcification focus. The density distribution histogram of calcium content under the condition of 70 Kev, i.e. the effective atomic number histogram, shows that most of the voxels in calcified foci contain between 60 mg/ cm^3 and 100 mg/cm^3 of calcium. While most of the voxels in ossified foci contain between 180 mg/cm^3 and 280 mg/cm^3 of calcium, which means that the average distribution of calcium content in calcified foci is also significantly lower than that in ossified foci. What is more, the atomic number distribution of ossified foci with bone structure is relatively balanced. The distribution of atomic number of calcified foci is close to the partial distribution, indicating that the structure of ossified foci is more regular and orderly than calcified foci (Figure 6). The calcium content of calcified foci is 50 mg/cm^3 - 100 mg/cm^3, which is lower than the average density of calcified foci 170 mg/cm^3 - 260 mg/cm^3. That is to say, the average density of calcium salt in the whole ossification focus is higher (Figure 7). The scatter plot of the density of calcification focus in different tissues is generated. The fitting curve of each group of scatter plot is drawn as figure (Figure 8) according to the principle of energy spectrum CT to determine substances; two "basic substances" can express any kind of substance attenuation [8]. The formula is µsubstance = Dcalcium * µcalcium + Dwater * µwater. (under µ substance: 70 Kev, the average energy attenuation value of the measured substance, D calcium: the weight value of the average density of the measured calcium, mg/cm^3, Dwater: the weight value of the average density of the measured water, mg/cm^3, µ water: 70 Kev, the average energy attenuation value of the measured level, µ calcium and µ water are known, which are obtained by looking up the table). From the fitting curve, the fitting curve of the substance is linear. The slope k can be expressed as K = D calcium / Dwater, then µ Substance = D calcium * (µ calcium + 1 / K * µ water). Thus, the larger the K is, the higher the weight of the measured calcium is, and the smaller the K is, the lower the weight of the calcium is. Compared with the ossification focus, the calcification focus Kcalcification > ossification focus Kossification, so the energy spectrum curve of the calcification focus is slower than that of the ossification focus (Figures 4,7). That is, the curve is slower, which also explains why the CT values of the two similar calcium containing lesions in conventional multi energy CT are similar. Consequently, it is reasonable to take K as the deposition efficiency of calcium salt, and verify that the rest of calcification lesions are consistent with the results (Figure 8), it is worth noting that the measured density here is not the absolute content value, which needs to be distinguished from

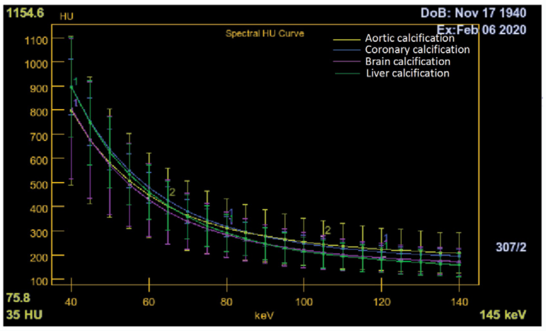

Figure 5: Energy spectrum curve of calcification focus of liver, brain, coronary artery and aorta.

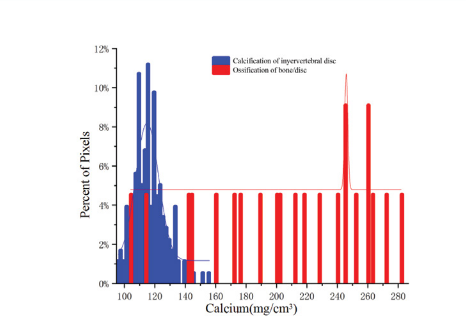

Figure 6: Comparison of atomic number distribution histogram between ossification focus and calcification focus (CA).

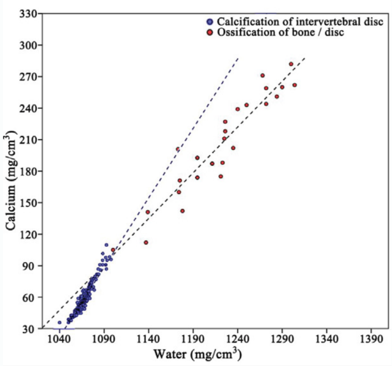

Figure 7: Comparison of scatter plot and regression curve of total calcium salt average density of ossification and calcification.

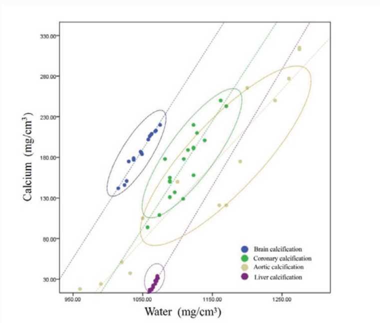

Figure 8: Comparison of scatter plot and regression curve of total calcium density in calcified areas of liver, brain, coronary artery and aorta.

the absolute value of calcium content [9]. In summary, the key point of surgical differentiation of calcium salt related focuses lies in its hardness estimation. Under the same circumstances, several vital factors related to the hardness of lesions include: calcium salt type, absolute calcium salt content, calcium salt deposition mode (arrangement and structure), which is hard to distinguish as conventional CT, energy spectrum CT energy spectrum to identify calcium salt type, column atomic number determination to estimate the absolute calcium salt content and row. The calcium water astigmatism can get the information of calcium salt deposition mode, and the lesions can be determined by the combination of the three. Hence, the operation plan is more accurate.

Declarations

Ethics approval and consent to participate

The study was approved by the human ethic committee of the affiliated hospital of qingdao university. All patients provided written informed consent and the project was in accordance with the Helsinki Declaration of 1975.

Consent for publication

Written informed consent was obtained from the patient/parents/legal guardians for publication of this Case Report and any accompanying images and videos. A copy of the written consent is available for review by the Editor of this journal.

Funding

The funder has no interest relationship and directly participates in any situation in the research. The fund provides the following material support, This study was funded by the National Natural Science Foundation of China (81802190,81772412), these fund supported hardware acquisition funds in research design and clinical data collection; Shandong Provincial Science Foundation, China (ZR2019BH084) provided administrative license for large device applications.

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