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Case Study

Increasing the cervical and lumbar lordosis is possible despite overt osteoarthritis and spinal stenosis using extension traction to relieve low back and leg pain in a 66-year-old surgical candidate: a CBP® case report

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Abstract. [Purpose] To present the case of the dramatic relief of low back pain, leg pain and disability in an older female with osteoarthritis, lumbar spinal stenosis and hypolordosis of the cervical and lumbar spine. [Participant and Methods] A 66-year-old female presented with chronic low back pain, right leg pain, numbness and weakness. Despite being recommended for surgery, the patient sought alternative treatment. The patient was treated with Chiropractic BioPhysics® rehabilitation of the spine with the objective to increase the lumbar and cervical lordoses. Cervical and lumbar extension exercises and traction were performed as well as spinal manipulation. Treatment was performed approximately three times per week for 6.5 months. [Results] Re-assessment after treatment demonstrated significant reduction of low back pain, leg pain and other health improvements. X-rays showed structural improvements in the cervical and lumbar spine despite advanced osteoarthritis. [Conclusion] Lumbar and cervical hypolordosis subluxation may be increased in those with spinal deformity caused symptoms, despite the presence of osteoarthritis and degenerative stenosis of the spine. Spinal x-rays as used in the assessment and monitoring of patients being treated with contemporary spinal rehabilitation methods are not harmful and should be used for routine screening purposes.

Key words: Spinal stenosis, Spinal arthritis, Low back pain

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INTRODUCTION

Chronic low back pain (LBP) is associated with performance-base disability in older patients[1)]. Despite the historic lack of consensus for the best treatment approach for this disorder[2)], recent evidence finally points to a definitive biomechanical etiology of lumbar hypolordosis causing LBP[3)].

This is welcome news as recent advances in the therapeutic application of lumbar extension traction to increase the lordosis associated with low back pain has proven successful and also superior over traditional methods not employing methods that increase the lordosis[4–6)].

Lumbar extension traction was first documented in the literature in 2002[7)]. It is theorized to cause ligamentous creep-relaxation to the spinal ligaments and discs[8, 9)]. As other treatments such as spinal manipulation are only a fraction of a second

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in nature, these and similar methods will not routinely result in restoration of the lumbar lordosis[10].

Several clinical trials, case reports and case series have documented successful patient outcomes incorporating Chiropractic BioPhysics® (CBP®) rehabilitation methods including extension traction methods to treat lumbar spine hypolordosis induced LBP[4–7, 11–14]. Of the evidence reported on CBP methods, there has only been one case report that recently described the successful non-surgical increase in cervical lordosis in a patient suffering from cervico-cranial symptoms having cervical kyphosis and osteoarthritis[15]. To the authors knowledge there is no known report featuring the improvement of lumbar lordosis in a patient having simultaneous lumbar spine osteoarthritis.

This case demonstrates the dramatic reduction of LBP, leg pain and associated disability by CBP treatment methods in an older female surgical candidate having both cervical and lumbar spine hypolordosis and concurrent spinal osteoarthritis.

PARTICIPANT AND METHODS

On 10/16/17, a 66-year-old female presented to the office with a chief complaint of lower back pain, as well as pain, numbness and weakness in the right leg. The patient also reported to suffer from upper back pain, high blood pressure and acid reflux. There was a previous history of neck pain and headaches. The daily activities of sit-to-stand, sleeping and walking were significantly difficult and painful because of her complaints.

The patient scored a 62% ('crippling back pain') on the Oswestry low back pain disability questionnaire[16] (ODI) and scored a 32% (100%=normal) on the lower extremity functional scale (LEFS). It must be noted that at the time of presentation, the patient was recommended for lumbar spinal surgery, but refused and sought out alternative treatment. In fact a recent MRI report of the lumbar spine dated 9/1/17 concluded: "diffuse multilevel degenerative disc disease as evident by disc height loss and disc dessication throughout." There was also evidence of central canal stenosis from L2–S1, and neural foraminal stenosis from L3–S1.

Upon examination, shoulder compression, Jackson's compression, and maximal cervical compression elicited pain bilaterally from C5–T2. The neck flexors were weak upon muscle testing. The triceps, biceps, brachial, patellar, and Achilles reflexes were +1 bilaterally. There was pain upon all lumbar ranges of motion: flexion, extension, bilateral lateral flexion, as well as bilateral rotation, passively and actively from L4−S1 bilaterally. Miner's sign, Kemps, straight leg raiser, and Milgram's tests were positive with pain on the right L5/S1 region. The trunk flexors and extensors were weak upon muscle testing.

Radiographic assessment of the lumbar spine (Fig. 1) revealed lumbar hypolordosis as measured from L1–L5 (−22.3° vs. −40°[17, 18]) or as measured from L1–S1 (−49.2° vs. −72°[17, 18]) by the Harrison posterior tangent (HPT) method. This method has very good standard error of measurement (<3°)[19–21]. The sacral base angle (horizontal to sacral base) was 34.1° (vs. 40° normal[17, 18]), and sagittal balance (T12 balance over vertical line from posterior-inferior S1) was slightly backward −6.6 mm (vs. 0 mm ideal). The lateral cervical image (Fig. 2) showed forward head translation (34.9 mm vs. 0-15 mm normal[22, 23]), loss of lordosis (16.3° vs. −31 to 42 normal[22–24]), and a reduced atlas plane line (atlas to horizontal: −12.3° vs. −24 to 29° normal[22, 23]).

Treatment incorporated CBP spinal rehabilitation methods[25–27]. These methods use lumbar and cervical extension traction for correcting hypolordosis as opposed to traditional 'distraction' traction that may yield temporary symptomatic relief, but will not restore lordosis. These methods have been proven effective in several clinical trials[4–7, 28–30].

The patient performed traction in a seated position receiving both a lumbar spine and cervical spine extension traction in the Universal Traction System (UTS, Las Vegas, NV, USA) (Fig. 3). Traction was performed for 15 minutes each treatment session. The patient also received spinal manipulative therapy as well as spine extension exercises. Exercises were performed standing facing away from a wall with a block between the wall and pelvis, the patient was instructed to extend the cervical spine as well as the lumbar spine and hold for a few seconds (Fig. 4). Fifty repetitions were repeated each session. Treatment protocol was planned to be three times per week for six months. The patient consented to the publication of these results including pictures and radiographs.

RESULTS

Follow-up assessment on 1/15/18, after 39 treatment sessions revealed all orthopedic tests and cervical and lumbar ranges of motion to be within normal limits (WNL). Upper extremity reflexes were +2 with the patellar and Achilles reflexes being +1 bilaterally.

A re-examination on 4/30/18, after 39 further treatments (78 treatment sessions overall) demonstrated a left patellar reflex of +2 and the right patellar reflex a +1. The Achilles reflexes were +2 bilaterally. Spinal ROM was increased in all directions, and all other orthopedic tests were unremarkable. Significant improvements on follow-up disability questionnaires showed an 18% on the ODI (vs. 62%), and an 85% on the LEFS (vs. 32%).

Repeat radiography on 5/3/18 revealed a clinically significant increase in lumbar lordosis by 7.6° (−29.9° vs. −22.3°) as measured by L1–L5 ARA or an increase by 11.4° (−60.6° vs. 49.2°) as measured by L1–S1 ARA (Fig. 1). The cervical lordosis improved by 10.5° (−26.8° vs. −16.3°), the forward head translation reduced (29.8 mm vs. 34.9 mm), and the atlas plane line increased (−23.2° vs. −12.3°) (Fig. 2).

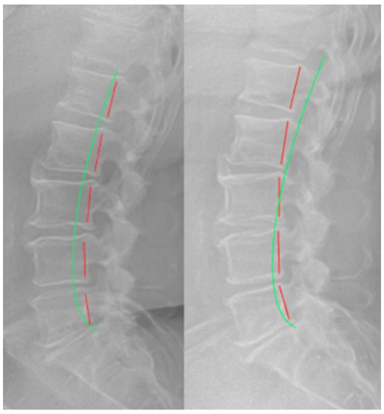

Fig. 1. Lateral lumbar radiographs. Left: Initial (Oct. 16, 2017) showing hypolordosis and overt osteoarthritis particularly from L2–S1. Right: Follow-up (May 3, 2018) showing increase in lordosis after treatment.

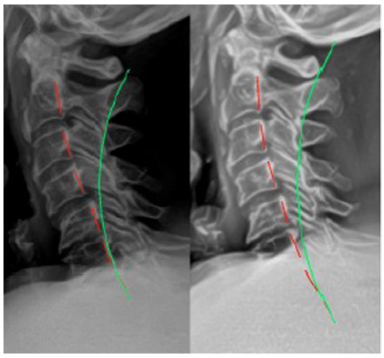

Fig. 2. Lateral cervical radiographs. Left: Initial (Oct. 16, 2018) showing forward head translation, hypolordosis, and a reduced atlas plane line as well as overt osteoarthritis from C2–C7. Right: Follow-up (May 3, 2018) showing improvement in alignment.

Fig. 3. Spine traction set-up. Seated patient is having simultaneous cervical and lumbar spine stretched into (hyper) extension as they are relaxed.

Fig. 4. Spinal exercise. Patient extended cervical and lumbar spine and held for several seconds and repeated.

DISCUSSION

This case demonstrates the increase in cervical and lumbar lordosis in a patient having corresponding hypolordosis and overt spinal osteoarthritis as well as MRI-verified lumbar spine central canal and foraminal stenosis. The treatment resulted in a clinically significant increase in both cervical and lumbar lordosis with simultaneous decrease in LBP, leg pain and associated disability.

Although there is substantial evidence supporting the routine improvement of lumbar lordosis by use of lumbar extension traction methods as a part of a spinal rehabilitation program, we believe this is the first case documenting the structural improvement in a patient having substantial osteoarthritis of the lumbar spine.

Osteoarthritis of the spine is known to be associated with increased biomechanical loading of the anterior vertebral bodies with loss of the normal lordotic position; in fact, Harrison et al. demonstrated the anterior vertebral body margins experience 6–10 × the loading when in a kyphosis vs. a normal lordosis for the cervical spine[31, 32)]. It is known that structure determines function in the spine; therefore, abnormal structural alignment causes abnormal motion[33, 34)]. Surgical studies have verified that spinal segments adjacent to spinal fusions degenerate rapidly when the fusion is out of the normal physiologic spinal alignment as the adjacent joints are required to biomechanically compensate and make up for the loss of motion, leading to 'adjacent disc disease'[35–37)].

Thus regarding osteoarthritic changes in the spine, it is believed that altered spinal alignment (i.e. hypolordosis) alters segmental coupling patterns that will, over time, lead to degenerative changes via Wolff's law[38, 39)]. Evidence in support of poor posture leading to spinal degeneration comes from long-term clinical studies such as that by Hohl[40)] and Norris and Watt[41)], who demonstrated that patients with cervical kyphosis after injury have a significantly higher incidence of degenerative changes.

It should be mentioned that the official MRI report stated 'normal lordosis' in the lumbar spine. First, because MRI images are usually done in the recumbent position, accuracy regarding sagittal spine alignment assessment is not accurate[34, 42)]. Further, a visual interpretation of the spinal curvature is also not accurate[43, 44)]. Thus, accurate assessment of human lordosis should come from x-ray or MRI in a standing position, and must be measured and not visually interpreted, as Tuck and Peterson state: "it is advisable that measuring the lumbar lordosis … should be performed routinely…."

In this case, despite lumbar spine central canal and foraminal stenosis, structural correction of the spine was achieved. It is logical that as the spine deteriorates over time, the progression of osteoarthritic changes will make structural spinal correction less amenable, at least by non-surgical means. Therefore, it is highly recommended that patients get their spines and postural alignment corrected prior to significant degenerative changes. It may be wise to radiographically assess all patients at the first onset of back complaints for screening purposes. This would allow a definitive structural diagnosis (e.g. hypolordosis vs. hyperlordosis) and allow for proper evidence-based treatment (i.e. CBP care) to correct the spine alignment years prior to the onset of degenerative changes that then would likely be prevented in the first place (or at least slowed/delayed).

It should be noted that the typical assumed superior treatment for lumbar spinal stenosis is surgery[45)]. Nonsurgical approaches, however have demonstrated the ability to offer improvement for spinal stenosis patients[45)]. A recent Cochrane review stated that it is uncertain which approach is superior in the treatment of these patients and that the advantage of nonsurgical treatments are that no alternative treatments offer harmful side effects, whereas surgical complications range form 10–24%[46)]. The advantages of the methods used in this case are that they are non-surgical, and that it is a structural rehabilitation (as opposed to functional rehabilitation) that may better address the causative nature of the symptoms related to this disorder; that is the restriction of the spinal canal causing neurologic compromise.

The use of x-rays for the assessment of spinal disorders is essential for contemporary structural spine treatments. Although x-rays are thought to be dangerous because of the radiation exposures[47–49)], it is now known that x-rays are at a level that is 100 times less than the radiation dose threshold that is actually carcinogenic[50, 51)]. Therefore, routine use of x-rays for the assessment, screening and follow-up of patients receiving modern non-surgical spine correcting treatments is safe and should be the standard for optimum patient outcomes[52)].

A limitation to this case is that it represents only a single patient outcome. Another limitation is the lack of long-term follow-up. Further, despite the improvements in this patient's health, the alignment of the spine remains suboptimal. Therefore, the patient should theoretically receive further treatment for the goal of further postural improvement to 'near normal.' Importantly, given the arthritic changes, there will be physical limitations as to the ultimate spinal correction attainable; other considerations involve the practicality of whether the patient would choose to continue treatment and be able to financially continue. In this case, the patient chose to remain on a 'maintenance' treatment schedule of two times a month. Further research is needed on the effectiveness and limitations of structural spinal improvements by CBP methods for different spinal conditions including osteoarthritis and spinal stenosis.

Conflict of interest

PAO is paid by CBP NonProfit for writing the manuscript; DEH teaches chiropractic rehabilitation methods and sells products to physicians for patient care used in this manuscript.

REFERENCES

1) Wettstein M, Eich W, Bieber C, et al.: Pain intensity, disability, and quality of life in patients with chronic low back pain: does age matter? Pain Med, 2018, [Epub ahead of print]. [Medline] [CrossRef]

2) Bogduk N: Management of chronic low back pain. Med J Aust, 2004, 180: 79–83. [Medline]

3) Chun SW, Lim CY, Kim K, et al.: The relationships between low back pain and lumbar lordosis: a systematic review and meta-analysis. Spine J, 2017, 17: 1180–1191. [Medline] [CrossRef]

4) Moustafa IM, Diab AA: Extension traction treatment for patients with discogenic lumbosacral radiculopathy: a randomized controlled trial. Clin Rehabil, 2013, 27: 51–62. [Medline] [CrossRef]
5) Diab AA, Moustafa IM: Lumbar lordosis rehabilitation for pain and lumbar segmental motion in chronic mechanical low back pain: a randomized trial. J Manipulative Physiol Ther, 2012, 35: 246–253. [Medline] [CrossRef]
6) Diab AA, Moustafa IM: The efficacy of lumbar extension traction for sagittal alignment in mechanical low back pain: a randomized trial. J Back Musculoskeletal Rehabil, 2013, 26: 213–220. [Medline] [CrossRef]
7) Harrison DE, Cailliet R, Harrison DD, et al.: Changes in sagittal lumbar configuration with a new method of extension traction: nonrandomized clinical controlled trial. Arch Phys Med Rehabil, 2002, 83: 1585–1591. [Medline] [CrossRef]
8) Oliver MJ, Twomey LT: Extension creep in the lumbar spine. Clin Biomech (Bristol, Avon), 1995, 10: 363–368. [Medline] [CrossRef]
9) Panjabi MM, White AA: Biomechanics in the musculoskeletal system. Churchill Livingstone, 2001.
10) Plaugher G, Cremata EE, Phillips RB: A retrospective consecutive case analysis of pretreatment and comparative static radiological parameters following chiropractic adjustments. J Manipulative Physiol Ther, 1990, 13: 498–506. [Medline]
11) Brown J, Jaeger J, Polatis T, et al.: Increasing the lumbar lordosis by seated 3-point bending traction: a case series utilizing Chiropractic BioPhysics technique. Chiropr J Aust, 2017, 45: 144–154.
12) Troyanovich SJ, Buettner M: A structural chiropractic approach to the management of diffuse idiopathic skeletal hyperostosis. J Manipulative Physiol Ther, 2003, 26: 202–206. [Medline] [CrossRef]
13) Paulk GP, Harrison DE: Management of a chronic lumbar disk herniation with chiropractic biophysics methods after failed chiropractic manipulative intervention. J Manipulative Physiol Ther, 2004, 27: 579. [Medline] [CrossRef]
14) Fedorchuk C, Mohammed H: Improvement in GERD following reduction of vertebral subluxations and improved sagittal alignment utilizing Chiropractic Biophysics protocol. Ann Vert Sublux Res, 2014, June 26: 99–109.
15) Fortner MO, Oakley PA, Harrison DE: Non-surgical improvement of cervical lordosis is possible in advanced spinal osteoarthritis: a CBP® case report. J Phys Ther Sci, 2018, 30: 108–112. [Medline] [CrossRef]
16) Fairbank JC, Couper J, Davies JB, et al.: The Oswestry low back pain disability questionnaire. Physiotherapy, 1980, 66: 271–273. [Medline]
17) Janik TJ, Harrison DD, Cailliet R, et al.: Can the sagittal lumbar curvature be closely approximated by an ellipse? J Orthop Res, 1998, 16: 766–770. [Medline] [CrossRef]
18) Harrison DD, Cailliet R, Janik TJ, et al.: Elliptical modeling of the sagittal lumbar lordosis and segmental rotation angles as a method to discriminate between normal and low back pain subjects. J Spinal Disord, 1998, 11: 430–439. [Medline] [CrossRef]
19) Harrison DE, Harrison DD, Cailliet R, et al.: Cobb method or Harrison posterior tangent method: which to choose for lateral cervical radiographic analysis. Spine, 2000, 25: 2072–2078. [Medline] [CrossRef]
20) Harrison DE, Harrison DD, Cailliet R, et al.: Radiographic analysis of lumbar lordosis: centroid, Cobb, TRALL, and Harrison posterior tangent methods. Spine, 2001, 26: E235–E242. [Medline] [CrossRef]
21) Harrison DE, Holland B, Harrison DD, et al.: Further reliability analysis of the Harrison radiographic line-drawing methods: crossed ICCs for lateral posterior tangents and modified Risser-Ferguson method on AP views. J Manipulative Physiol Ther, 2002, 25: 93–98. [Medline] [CrossRef]
22) Harrison DD, Janik TJ, Troyanovich SJ, et al.: Comparisons of lordotic cervical spine curvatures to a theoretical ideal model of the static sagittal cervical spine. Spine, 1996, 21: 667–675. [Medline] [CrossRef]
23) Harrison DD, Harrison DE, Janik TJ, et al.: Modeling of the sagittal cervical spine as a method to discriminate hypolordosis: results of elliptical and circular modeling in 72 asymptomatic subjects, 52 acute neck pain subjects, and 70 chronic neck pain subjects. Spine, 2004, 29: 2485–2492. [Medline] [CrossRef]
24) McAviney J, Schulz D, Bock R, et al.: Determining the relationship between cervical lordosis and neck complaints. J Manipulative Physiol Ther, 2005, 28: 187–193. [Medline] [CrossRef]
25) Harrison DD, Janik TJ, Harrison GR, et al.: Chiropractic biophysics technique: a linear algebra approach to posture in chiropractic. J Manipulative Physiol Ther, 1996, 19: 525–535. [Medline]
26) Oakley PA, Harrison DD, Harrison DE, et al.: Evidence-based protocol for structural rehabilitation of the spine and posture: review of clinical biomechanics of posture (CBP) publications. J Can Chiropr Assoc, 2005, 49: 270–296. [Medline]
27) Harrison DE, Betz JW, Harrison DD, et al.: CBP structural rehabilitation of the lumbar spine: Harrison Chiropractic Biophysics Seminars, Inc. 2007.
28) Moustafa IM, Diab AA, Taha S, et al.: Addition of a sagittal cervical posture corrective orthotic device to a multimodal rehabilitation program improves short- and long-term outcomes in patients with discogenic cervical radiculopathy. Arch Phys Med Rehabil, 2016, 97: 2034–2044. [Medline] [CrossRef]
29) Moustafa IM, Diab AA, Harrison DE: The effect of normalizing the sagittal cervical configuration on dizziness, neck pain, and cervicocephalic kinesthetic sensibility: a 1-year randomized controlled study. Eur J Phys Rehabil Med, 2017, 53: 57–71. [Medline]
30) Moustafa IM, Diab AA, Hegazy FA, et al.: Does rehabilitation of cervical lordosis influence sagittal cervical spine flexion extension kinematics in cervical spondylotic radiculopathy subjects? J Back Musculoskeletal Rehabil, 2017, 30: 937–941. [Medline] [CrossRef]
31) Harrison DE, Harrison DD, Janik TJ, et al.: Comparison of axial and flexural stresses in lordosis and three buckled configurations of the cervical spine. Clin Biomech (Bristol, Avon), 2001, 16: 276–284. [Medline] [CrossRef]
32) Harrison DE, Jones EW, Janik TJ, et al.: Evaluation of axial and flexural stresses in the vertebral body cortex and trabecular bone in lordosis and two sagittal cervical translation configurations with an elliptical shell model. J Manipulative Physiol Ther, 2002, 25: 391–401. [Medline] [CrossRef]
33) Takeshima T, Omokawa S, Takaoka T, et al.: Sagittal alignment of cervical flexion and extension: lateral radiographic analysis. Spine, 2002, 27: E348–E355. [Medline] [CrossRef]
34) Meakin JR, Gregory JS, Aspden RM, et al.: The intrinsic shape of the human lumbar spine in the supine, standing and sitting postures: characterization using an active shape model. J Anat, 2009, 215: 206–211. [Medline] [CrossRef]
35) Katsuura A, Hukuda S, Saruhashi Y, et al.: Kyphotic malalignment after anterior cervical fusion is one of the factors promoting the degenerative process in adjacent intervertebral levels. Eur Spine J, 2001, 10: 320–324. [Medline] [CrossRef]
36) Faldini C, Pagkrati S, Leonetti D, et al.: Sagittal segmental alignment as predictor of adjacent-level degeneration after a cloward procedure. Clin Orthop Relat Res, 2011, 469: 674–681. [Medline] [CrossRef]

37) Park MS, Kelly MP, Lee DH, et al.: Sagittal alignment as a predictor of clinical adjacent segment pathology requiring surgery after anterior cervical arthrodesis. Spine J, 2014, 14: 1228–1234. [Medline] [CrossRef]
38) Frost HM: Wolff's Law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod, 1994, 64: 175–188. [Medline]
39) Frost HM: A 2003 update of bone physiology and Wolff's Law for clinicians. Angle Orthod, 2004, 74: 3–15. [Medline]
40) Hohl M: Soft-tissue injuries of the neck in automobile accidents. Factors influencing prognosis. J Bone Joint Surg Am, 1974, 56: 1675–1682. [Medline] [CrossRef]
41) Norris SH, Watt I: The prognosis of neck injuries resulting from rear-end vehicle collisions. J Bone Joint Surg Br, 1983, 65: 608–611. [Medline] [CrossRef]
42) Oakley PA, Harrison DE: Reply to "Lumbar lordosis: study of patients with and without low back pain". Clin Anat, 2004, 17: 367. [Medline] [CrossRef]
43) Frymoyer JW, Phillips RB, Newberg AH, et al.: A comparative analysis of the interpretations of lumbar spinal radiographs by chiropractors and medical doctors. Spine, 1986, 11: 1020–1023. [Medline] [CrossRef]
44) Tuck AM, Peterson CK: Accuracy and reliability of chiropractors and Anglo-European college of chiropractic students at visually estimating the lumbar lordosis from radiographs. Chiropr Tech, 1998, 10: 19–26.
45) Weinstein JN, Tosteson TD, Lurie JD, et al.: Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the Spine Patient Outcomes Research Trial. Spine, 2010, 35: 1329–1338. [Medline] [CrossRef]
46) Zaina F, Tomkins-Lane C, Carragee E, et al.: Surgical versus non-surgical treatment for lumbar spinal stenosis. Cochrane Database Syst Rev, 2016, (1): CD010264 10.1002/14651858.CD010264.pub2. [Medline]
47) Siegel JA, Pennington CW: The mismeasure of radiation. Debunking the flawed science that low-dose radiation may cause cancer; in fact, it may even be beneficial. Skeptic Mag, 2015, 20: 46–51.
48) Sacks B, Meyerson G, Siegel JA: Epidemiology without biology: false paradigms, unfounded assumptions, and specious statistics in radiation science (with commentaries by Inge Schmitz-Feuerhake and Christopher Busby and a reply by the authors). Biol Theory, 2016, 11: 69–101. [Medline] [CrossRef]
49) Siegel JA, McCollough CH, Orton CG: Advocating for use of the ALARA principle in the context of medical imaging fails to recognize that the risk is hypothetical and so serves to reinforce patients' fears of radiation. Med Phys, 2017, 44: 3–6. [Medline] [CrossRef]
50) Cuttler JM, Welsh JS: Leukemia and ionizing radiation revisited. J Leuk (Los Angel), 2015, 3: 1–2.
51) Oakley PA, Cuttler JM, Harrison DE: X-ray imaging is essential for contemporary chiropractic and manual therapy spinal rehabilitation: radiography increases benefits and reduces risks. Dose Response, 2018, 16: 1559325818781437. [Medline] [CrossRef]
52) Oakley PA, Harrison DE: Radiophobia: 7 reasons why radiography used in spine and posture rehabilitation should not be feared or avoided. Dose Response, 2018, 16: 1559325818781445. [Medline] [CrossRef]