Original scientific paper

Clinical and Radiological Morphometry of Posterior Parts of Thoracic and Lumbal Vertebras

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A B S T R A C T

The aim of this work is to measure clinically important dimensions of thoracic and lumbal vertebras. Charts of one-hundred and seventeen patients with implanted internal fixateur on the thoracic and lumbal spine between 01.01. 2008. and 31.3.2010. at the Department for Orthopedics and Traumatology, of the Sarajevo Clinical center were retrieved, and only 14 patients, with 46 vetrtebras and 89 pedicles have had complete documentation (clearly visible measured structures on X-ray and CT scans). Digitalized antero-posterior and latero-lateral X-ray, and transversal and sagital CT scans were basic inputs for measurement of height and width of the pedicle – PH, PW, axial and vertical cortico-cortical transpedicular distances – AL, VL, and interpedicular distance – IP. The correction of enlargement on X-ray pictures was performed according to known dimensions of implants and length scale on CT scans. Enlargement of those parameters, from T1 to L5 level was from 50 to 150%. This increasing was not always linear, sometimes there was even decreasing. For instance, the IP on second and third thoracic vertebra was shorter compared to the first thoracic vertebra. Pedicles from the third to the eighth thoracic vertebra were narrower compared to the second thoracic vertebra. The importance of this work is in to analyze the mentioned dimensions by methods available to the clinician. Every other in vivo measurement is impossible because of the excessive surgical approach, while preoperative CT scanning with a great number of slices per one millimeter for this purpose is not ethical.

Key words: *spine, vertebra, pedicul, dimensions, implant*

Introduction

The spine is a flexible weight-bearing rod consisted of 24 mobile and 9 immobile segments – vertebras. There are three degrees of freedom for rotational and less for translational motions between each mobile vertebra (7 cervical, 12 thoracic and 5 lumbal). Generally, thoracic and lumbal vertebra have common anatomical characteristics. An anterior, massive cylindrical part, the vertebral body has an oval shape on the trans-section. The biggest part of the posterior aspect of the vertebra is a flat osseous structure, left and right lamina. Both laminas are connected in the midline, gradually transforming into spinosus processus which is in the sagital plane. Left and right, superior and inferior articular processes have their basses at the lateral ends of corresponding laminas. Described anterior and posterior parts of thoracic and lumbal vertebras are connected with left and right tubular osseous structure (pedicles). The pedicles form the lateral walls of the spinal channel. A great clinical importance in spinal surgery has the knowledge of anatomical-radiological characteristics of vertebral pedicles (pedicular width and height – PW, PH, axial and vertical transpedicular cortico-cortical distances – AL, VL, and interpedicular distance – IP; Figure 1 and 2).

Received for publication August 27, 2012

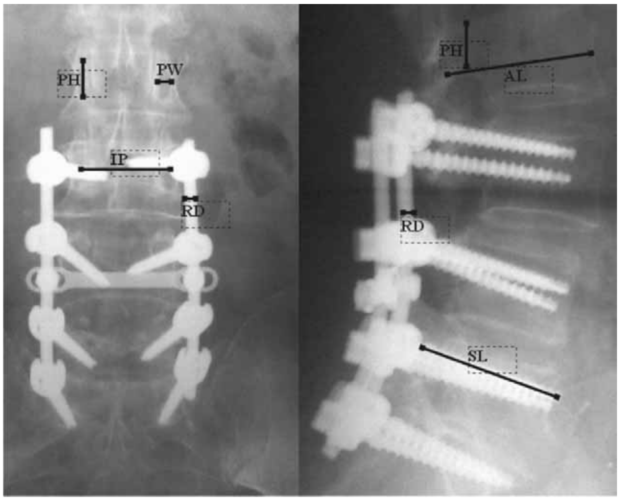

Fig. 1. Antero-posterior and latero-lateral X-ray scans after internal fixation of the lumbal spine with its morphometric parameters: PW, PH, IP, AL, VL, and rod diameter – RD, and screw length SL.

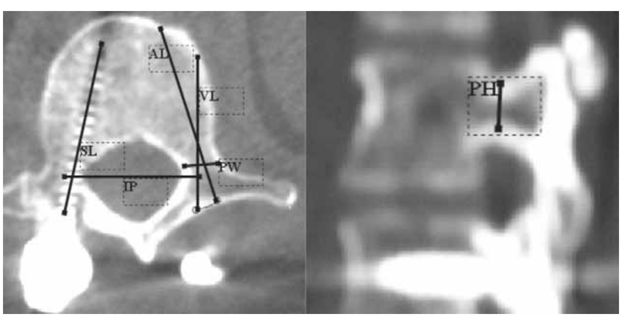

Fig. 2. Transversal and sagital CT scans with its morphometric parameters and clearly visible transpedicular screws.

In the Table 1 there is literary data for pedicular widths and heights, axial and vertical transpedicular cortico-cortical distances, and interpedicular distances for thoracic and lumbal vertebras for healthy adult male persons[1–4], although individual variation can be significant and misleading. Shape, dimensions and internal structure of each vertebra are the most important morphometric characteristics for one vertebra. Clinical methods for its estimations are X-ray and CT scanning.

The aim of this work is to measure clinically important dimensions of thoracic and lumbal vertebras on X-ray and CT scan and compare them with referral values.

Patients and Methods

Charts of one-hundred and seventeen patients with implanted internal fixateur on the thoracic and lumbal spine between 01.01.2008. – 31.3.2010. at the Department for Orthopedics and Traumatology, of the Clinical centre of Sarajevo were retrieved and only 14 patients, with 46 vertebras and 89 pedicles have had complete documentation (clearly visible measured structures on X-ray and CT scans) (Table 2). Most common indications for the posterior stabilization were vertebral fracture, tumor, scoliosis, degenerative disease and spondylodiscitis. Including criteria were: performed CT scan after surgery (mostly because of postoperative pain due to the progression of the disease, repeated trauma, estimating of bone consolidation, new neurological symptoms), and charts which contain X-ray and CT scans with clearly visible all measured parameters and transpedicular screws on its whole length on X-ray and CT scans, and data about type and dimensions of implanted screws.

The last including criteria were the crucial because we have made correction of distortion of dimensions ac-

TABLE 1
PEDICULAR WIDTH AND HEIGHT; AXIAL AND VERTICAL TRANSPEDICULAR CORTICO-CORTICAL DISTANCE, AND INTERPEDICULAR DISTANCE IN MILLIMETERS.

Vertebra	Pedicular width (PW)	Pedicular height (PH)	Axial length (AL)	Vertical length (VL)	Interpedicular length (IP)
T 1–4	6.5 (5.6–7.9)	12	39	31	24–25
T 5–9	5.5 (4.7–6.1)	12	45	41	26–29
T 10–12	7 (6.3–7.8)	14	43	42	30–33
L 1	8	15	52	45	34
L 2	9	16	53	46	36
L 3	11	15	52	45	38
L 4	13	15	49	41	38
L 5	18	14	52	33	38

TABLE 2
NUMBER OF ANALYZED VERTEBRAS FROM T1 TO L5 VERTEBRAS (N=46/89).

Number of analyzed	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	L1	L2	L3	L4	L5
Vertebras	2	2	1	1	1	1	1	1	1	2	3	3	6	8	5	5	3
Pediculs	4	4	2	2	2	2	2	2	2	2	5	5	12	15	10	10	6

cording to known dimensions of implants. CT scans have had a length scale for additional recheck.

This study is ethically acceptable because all postoperative CT scanning with their additional irradiations of patients are performed due to the medical indication, and not due to this study.

Digitalized antero-posterior and latero-lateral X-ray, and transversal and sagital CT scans were basic inputs for measurement of height and width of the pedicle – PH, PW, axial and vertical transpedicular cortico-cortical distances – AL, VL, and interpedicular distance – IP. The CorelDRAW 9 software was used for visual measurement of IP, PW, PH, AL, VL parameters, analogous to Figures 1 and 2. Each parameters has got suffix (r, X, CT), according to its origin (r – for data from referent literature, X – for data measured on X-ray scans, CT – for data measured on CT scans). Correction of values measured on X-ray scans was in average about 20% (ratio between actual length of implants and its length measured on X-ray scans)[5,6]. The values AL X and IP CT were not measurable. Due to a low number of analyzed pedicles (Table 2), comparative statistics were not applicable.

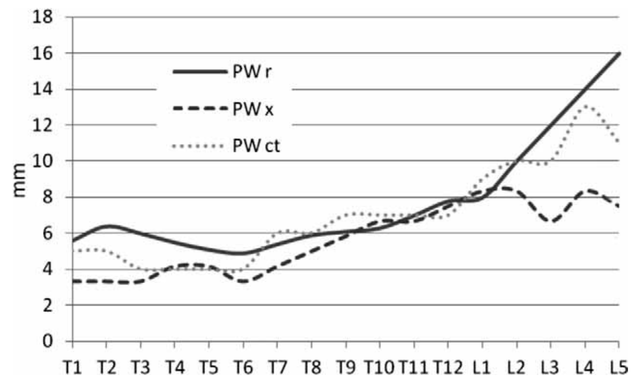

Fig. 3. Non-linear incensement of pedicular width from T1 to L5 level.

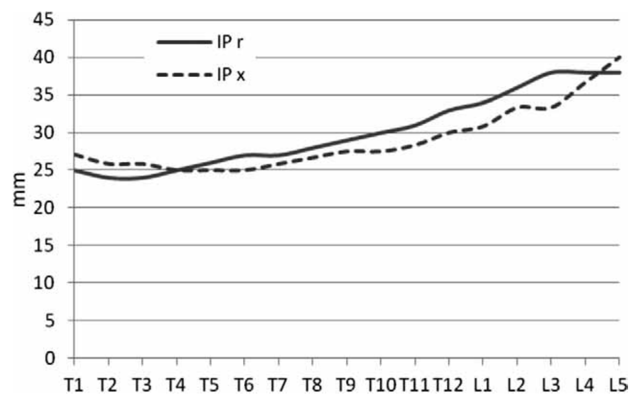

Fig. 4. Non-linear incensement of interpedicular distance from T1 to L1 level.

Results

In the Table 3 the values of thirteen data were presented for each 12 thoracic and 5 lumbal vertebras (after corrections of picture distortion).

Graphically were presented only parameters whose incensement from T1 to L5 level was not regular (IP – Figure 3 and PW – Figure 4).

Discussion

This article has shown that dimensions of thoracic and lumbal vertebras differs significantly. The common characteristic of all measured parameters is its almost linear increment from upper to lower levels (T1 to L5 vertebra). In average that increment was from 50 to 150%. But, there are some exceptions. The interpedi-

TABLE 3
AVERAGE VALUES OF ALL MEASURED PARAMETERS IN MILLIMETERS;

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	L1	L2	L3	L4	L5
IP r	25	24	24	25	26	27	27	28	29	30	31	33	34	36	38	38	38
IP X	27	26	26	25	25	25	26	27	27	27	28	30	31	33	33	37	40
PW r	6	6	6	6	5	5	5	6	6	6	7	8	8	10	12	14	16
PW X	3	3	3	4	4	3	4	5	6	7	7	7	8	8	7	8	7
PW CT	5	5	4	4	4	4	6	6	7	7	7	7	9	10	10	13	11
PH r	8	8	8	9	9	10	10	11	12	12	12	14	15	16	15	15	14
PH X	4	4	5	5	6	3	5	11	12	12	12	14	12	12	12	13	12
PH CT	5	5	6	6	6	4	7	13	14	14	13	12	13	14	13	16	14
VL r	31	31	33	36	40	40	40	41	41	42	42	42	45	46	45	41	33
VL X	29	30	32	34	38	39	40	42	42	50	49	52	52	54	42	49	51
VL CT	32	33	35	37	40	40	45	50	51	51	50	53	56	54	52	53	55
AL r	39	39	40	42	43	43	43	43	43	45	45	45	52	53	52	49	52
AL CT	35	36	38	42	45	45	50	45	45	55	59	54	56	58	53	54	54

r – for referral data, X and CT – for the values on X-ray and CT scans.

cular distance on second and third thoracic vertebra (IP/T2, T3) is shorter than on the first thoracic vertebra (IP/T1). The pedicular height and the cortico-cortical distance measured vertically through pedicle, »paradoxaly« is decreasing from the second to the fifth lumbal vertebra (PH and VL/L2-L5), as well as the pedicular width from the third to the eighth thoracic vertebra (PW/T3-T8) in comparison to the second thoracic vertebra (PW/T2).

Irrespective to the measuring method (X-ray or CT scan), there are not observed significant differences comparing to the referral data, due to correction of X-ray scanning distortion. Oscillation of each parameter on X-ray and CT scans are a consequence of individual variability and relatively low number of analyzed vertebras. In spite that, trend lines of parameters measured on X-ray and CT scans follow trends of corresponding referent line from T1 to L5 and strict including criteria.

General linear increment of measured parameters from upper to lower levels is related to vertical human posture and gradual increment of weight bearing from T1 to L5. Mentioned exceptions and other absences of increments are mostly evident in the midthoracic spine. That can be explained by the fact that a part of axial weight bearing is transmitted on the rib-sternum construction (mechanical by-pass).

Pedicular and interpedicular dimensions are essential for implantation of transpedicular screws in spinal surgery[7–9]. Posterior spondylodesis is the strongest way of spine fixation, due to the fact that transpedicular cortico-cortical distance is the longest cortico-cortical transvertebral distance. The transpedicular screw is about two times longer then translaminar or transcorporal screw at the same level. Besides that, additional advantages of transpedicular screw are that a pedicle is mostly consisted of strong cortical bone in comparison to the cancelous vertebral body bone structure, and that such a screw passes through all three vertebral columns (posterior, middle, anterior). For accurate performing of that method, knowledge of anatomical and radiological characteristics of spine is essential. Technical, physiological and pathological factors which can cause distortion of our perception have to be recognized on time[10–13].

Interpretation of standard X-ray scans can be complicated on many ways[14,15]. Previous studies on lumbal spine based on CT scans have revealed superiority of CT scans over the X-ray scans in demonstration of artificial pedicular and vertebral body damage[16]. The CT scans have good correlation with a macroscopic situation during transpedicular screw placement on the cadavers[17]. The importance of this work is in to analyze the mentioned dimensions by methods available to the clinician. Every other in vivo measurement is impossible because of excessive surgical approach, while preoperative CT scanning with a great number of slices per one millimeter for this purpose is not ethical.

Limitation of this study is a relatively low number of analyzed pedicles and a low reproducibility. The biggest problem during the study was the absence of high resolution on CT scans. That was the reason for excluding of great number of charts (103 from 117). The individual, physiological and pathological variations of each parameter point on the necessity of analyzing more pedicles. Otherwise, a surgeon must be aware that each patient has their absolute dimensions, and that great variations are possible. The data in this study has to be on mind as starting values for recalculation due to each noted variation visible on scans. In spite of that, this study has revealed that if we respect the mentioned limitations of X-ray and CT scanning methods, they can be sufficient in the clinical practice.

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KLINIČKA I RADIOLOŠKA MORFOMETRIJA STRAŽNJIH DIJELOVA GRUDINIH I SLABINSKIH KRALJEŽAKA

SAŽETAK

Cilj ovog rada je izmjeriti klinički značajne dimenzije torakalnih i grudinih kralježaka. Od 117 pacijenata sa implantiranim unutarnjim fiksatrom torakalne ili lumbalne kralježnice u periodu 01.01.2008. – 31.3.2010. na Klinici za ortopediju i traumatologiju u Sarajevu, uključujuće kriterije (jasno vidljive mjerene strukture na RTG i CT snimcima, podaci o dimenzijama implantata) je ispunilo 14 pacijenata sa 46 kralježaka, odnosno 89 pedikla. Digitalizirani antero-posteriorni i laterolateralni RTG snimci, te transferzalni i sagitalni CT scan-ovi bili su osnova sa koje su mjerene visina i širina pedikla – PH, PW, osovinska i vertikalna transpedikularna kortiko-kortikalna distanca – AL, VL i interpedikularna udaljenost – IP. Na osnovu poznatih dimenzija vijaka i dužinske skale na CT scanovima vršila se je korekcija uvećanja na RTG snimcima. Povećanje svih parametara, idući od viših ka nižim nivoima iznosilo je 50 do 150%. Ovaj porast nije uvijek bio linearan, na određenim segmentima evidentirano je i smanjenje istih; IP na drugom i trećem torakalnom je kraća u prosjeku nego na prvom torakalnom kralješku. Pedikli trećeg do osmog torakalnog kralješka su u prosjeku uži od pedikla na drugom torakalnom kralješku. Značaj ovog rada jeste u činjenici da su ovi parametri analizirani dostupnim metodama. Svaki drugi način in vivo mjerenja nije moguć zbog ekscesivnosti kirurškog pristupa, dok pre-operativna CT analiza sa velikim brojem slice-ova po jednom milimetru za ovu svrhu etički nije opravdana.