Journal of Orthopaedics 15 (2018) 205–209

Contents lists available at ScienceDirect

Journal of Orthopaedics

journal homepage: www.elsevier.com/locate/jor

Original Article

Anatomical differences in the bony structure of L5 and L4: A possible classification according to the lateral tilt of the pedicles

Giorgio Cacciola[a,*], Giuseppe Anastasi[a], Salvatore Bertino[a], Giuseppina Rizzo[a], Giuseppina Cutroneo[a], Fabio Trimarchi[a], Alessandro Pisani[b], Pietro Cavaliere[b], Andrea Barbanera[c], Daniele Bruschetta[a,d]

[a] University of Messina, Department of Biomedical, Dental Sciences and Morphological and Functional Images, Messina, Italy
[b] Istituto Ortopedico del Mezzogiorno d'Italia "Franco Scalabrino", Dipartimento di Chirurgia Vertebrale, Messina, Italy
[c] A.O.N. SS Antonio Biagio e Cesare Arrigo, Dipartimento di Neurochirurgia, Alessandria, Italy
[d] IRCCS Neurolesi "Bonino Pulejo", Messina, Italy

ARTICLE INFO

Keywords:
Pedicle
Classification
PLT
Screw fixation
Lumbar spine
3D CT
3D MRI

ABSTRACT

The aim of this study is to underline the necessity of a better knowledge of pedicles anatomy in order to improve surgical treatment of spine disorders such us low back pain, spinal fractures and scholiosis. A classification of pedicles lateral tilt which could help surgeons before the application of screws during transpedicular fixation is reported. Anatomical differences in the orientiation of the pedicles of L5 and L4 have been found. For each patient that met the inclusion criteria underwent: Radiography of the lumbo-sacral region, CT examination, MRI acquisition. Patients were divided into three categories thanks to 3D direct volume rendering of CT scan. Subjects belonged to W-Type, V-Type and U-type depending on their morphometric features. The subdivision was further implemented with measurements of the distance between pedicles and adjacent nervous structures. Concerning L5, W-Type (WT) exhibited a lateral tilt of L5 larger than 36°, V-Type exhibited a lateral tilt of L5 from 30° to 36°, U-type exhibited a lateral tilt of L5 smaller than 30°. Concerning L4, WT exhibited a lateral tilt of 28.4°, VT exhibited a lateral tilt of of 25.1, UT exhibited a lateral tilt of 22.2°; we assume that the degree of lateralization of L4 depends on the one of L5. The way the screw is applied during surgical treatment is clinically relevant, thus our classification may be very useful in order to decrease surgical risk and improve conditions of patients after surgical treatment.

1. Introduction

Pedicle Screw Fixation (PSF) is a standard technique used by spinal surgeons in the treatment of spine disorders to obtain posterior spinal column fusion. The purpose of PSF is to improve conditions of patients suffering from a wide range of. Arthrodesis of the vertebral bodies is often performed to obtain a better outcome. This technique was first employed by Roy-Camille in 1963 for spinal fractures treatment.[1] After PSF introduction, several studies regarding the surgical anatomy and biomechanics of the pedicles have been carried out. Pioneering anatomical studies[2] demonstrated that the pedicles of the lower thoracic and lumbar regions allow for a stable anchorage of the vertebral bodies thanks to their morphology.[3] The main reason that made surgeons choose the pedicles for PSF derives from anatomical factors, since the surgeon seeks the strongest site accessible posteriorly to obtain a satisfactory three-dimensional fixation. This led to an extension of surgical indications for the treatment of several spine disorders through PSF.[4,5] However, although such procedure has been introduced more than fifty years ago, and currently represents one of the most employed surgical procedures, it is not free from complications. In 1993 K. Follet and B. Dirks defined the Failed Back Surgery Syndrome (FBSS) as a "Surgical end-stage after one or several operative interventions on the lumbar neuroaxis, indicated to relieve lower back pain, the radicular pain of the combination of both without positive effect".[6]

Pain represents the fundamental anamnestic element in formulating a suspected diagnosis of FBSS. The lack of resolution of painful symptoms in the immediate postoperative period may be indicative of a surgery performed in a technically incorrect or incomplete way. Pain presenting months or years after surgery could be indicative of a new pathology, caused by biomechanical deficiency due to an erroneously performed procedure, whereas the immediately post-operative appearance of a "new pain, indicative of nerve root irritation", must lead

* Corresponding author at: A.O.U.G. Martino, Via Consolare Valeria n°1 98147, Messina, Italy.
E-mail address: dr.cacciola@gmail.com (G. Cacciola).

https://doi.org/10.1016/j.jor.2018.01.024
Received 8 December 2016; Received in revised form 27 September 2017; Accepted 14 January 2018

to consider an improper positioning of one or more pedicle screws. If that is the case, a CT Scan of the operative segment should be immediately performed to evaluate the trajectory of the screws and, if improper positioning is confirmed, the patient should return to the operating room for repositioning of the screw/s as soon as possible. During the last years, a significant reduction of incidence of "new leg pain" has been observed (i.e., the percentage of secondary foraminal stenosis has been reduced from 58% in 1981 to 25% in 2013) due to improvement in surgical technique and in the quality of implants,[7] on the other hand the incidence of neuropathic pain caused by improper pedicle screw positioning has undergone a slight reduction (14% in 1981, compared to 10% in 2013).[7]

Taking into account these simple premises, the purpose of the present study is investigating the variability of the lumbar vertebral bodies and pedicles along with their relationship with nervous structures within lumbar spine. Our aim is to identify the morphotype with a closer relationship to post-operatory complication after PSF, thus giving clinical resonance to this research.

2. Materials and method

For the present study 325 healthy subjects were enrolled (166 male 51,1%, and 159 female 48,9) with a mean age of 62 y.o (range from 34 to 72 y.o.), see Table 1. All subjects who carried out examinations for other reasons, mostly for diagnostic investigation of the urinary tract, were informed of the study purpose and signed an informed consent in accordance with the declaration of Helsinki for the ethical principles of medical research for living people.

Considering the clinical anatomical purpose of this study, the following exclusion criteria were chosen: i) musculoskeletal congenital deformities, ii) previous fractures of the spine and/or of the pelvis and iii) previous surgeries at the lumbar spine or hip.

A CT examination (Kc 120, mAs 400, slice thickness of 0,6 mm) of the lumbar spine was acquired to study the morphology of the pedicles. A MRI scan (Coherent Gradient Echo in an Ultra Fast Echo Sequence in order to obtain T1-weighted isotropic volumes for high resolution scans) was acquired to study the relationship between the pedicles and nerve roots for each patient. First, the lateralisation angle of the pedicles (PLT) from L_1 to L_5 was assessed in the TC axial plane calculating the angle between the line passing through the centre of the pedicle to the anterior margin of the vertebral body and the line passing through the posterior and anterior margins of the vertebral body corresponding to the emergence of the pedicle. Then, the sample was divided into three categories, according to the PLT of L5 pedicles: (1) W-Type (WT), with a PLT $>$ 36°, (2) V-Type (VT), with a PLT between 30° and 36° and (3) U-Type (UT), with a PLT $<$ 30°. The nomenclature of each category refers to the letters W, V and U: W refer to the widest degree of lateralization, V an intermediate degree and U the narrowest one).

The pedicles bone morphometry from L_1 to L_5 was evaluated by the CT scan. The following measures were considered: pedicle width (PW, the transverse axis of the pedicle), pedicle height (PH, the vertical axis of the pedicle), interpedicular distance (IPD, distance between the pedicles at their emergency from the rostral part of the vertebral body). MRI scans were taken into account to analyzethe reciprocal position assumed by the pedicles and the nervous structures. The following measures were considered: pedicle-inferior root distance (PIRD, defined as the distance between pedicle and the nerve roots of the lower level), pedicle-superior root distance (PSRD, defined as the distance between the pedicle and the nerve roots at the upper level), root exit angle (REA), and the nerve root diameter (NRD).

Morphometric measures (including bone morphometry and distance between pedicles and nervous structures) were analysed by a linear regression model conducted using commercial software (Prism 7.0 Mac OS by GraphPad) to assess regression coefficient between two variables (PLT of L5 and the other measures). The regression coefficents were considered strongly significant with a p-value $<$ 0.05 while a weaker significance is assume for p $<$ 0.10.

Table 1
Demographic data.

Parameters	N°/%
Number of patients	325
Age	62 y.o. ± 12 (from 34 to 72)
Male	166/51,7%
Female	159/49,3%
BMI (Kg/m^2)	29,4 ± 6,2

3. Results

3.1. Pedicle lateral tilt

3.1.1. PLT

The average degree of PLT of the pedicle in each of the three categories at L4 is 34,2° and depends on the PLT of L5 (SD ± 4,3° R square = 0.04688 and P-value = 0.0175). The average degree of lateralization in L3 was 22.2° (SD ± 1.8° R square = 0.037 P-Value = 0.1031), in pedicles of L2 and L1 the degree was 21.2° (SD ± 1.5 R Square = 0.09094 and p-value = 0.13401) and 20.7° (SD ± 1.5° R Square 0.04716 p-value = 0.11318) respectively as (see Image 1).

3.2. Bony morphometric measures compared to PLT of L5 (see Image 2)

3.2.1. PW

The average transverse diameter of L5 pedicles was 17,38 mm and depends on the PLT of L5 (SD ± 1,5 mm R Square = 0.4092 p-value = 0.0186). A weaker statistically significant correlations was found between PW at L4 (mean value of 12,81 mm) and PLT of L5, (SD ± 1,12 R Square = 0.00832 P-value = 0.0856) .

3.2.2. PH

The average longitudinal diameter of L5 pedicles was 11,38 mm and depends on the PLT of L5 (SD ± 0.95 mm R square = 0.3856 p-value = 0.035). No statistically significant correlation was found between pH at L4 (mean value of 12,38 mm, SD ± 1,12 mm R square = 0,0387 p-value = 0,1434) and PLT of L5.

3.2.3. IPD

The average IPD at L5 was 28,8 mm and depends on the PLT of L5 (SD ± 4,9 mm R square = 0.4892 p-value = 0.0102). The average IPD at L4 is 26,9 mm and depends on the PLT of L5 (SD ± 3,8 mm R Square = 0.467 p-value = 0.0461).

There were not significant changes along pedicles of L1, L2 and L3 for bone morphometric measures relating to L5 PLT (p-value $>$ 0.10 for each measures).

3.3. Distance between pedicles and adjacent nervous structures compared with PLT of L5 (see Image 3)

3.3.1. PSRD

The average PSRD at L5 is 4,72 mm and showed no statistically significant relation with PLT of L5 (SD ± 0.34 mm R square = 0.0321 p-value = 0.2139); the average PSRD at L4 is 4,81 mm and showed no statistically significant relation with PLT of L5 (SD ± 0.28 mm R square = 0.0298 mm p-value 0.2342).

3.3.2. REA

The average REA at L5 is 41,5° and showed a statistically significant relations with PLT of L5 (SD ± 4,2° R square = 0.328 p-value = 0.0287); the average REA at L5 is 39,4° and showed a