http://dx.doi.org/10.1590/S1808-185120222101250506


# RELATIONSHIP BETWEEN VERTEBRAL VESSELS AND CORTICAL PATH SCREWS IN CORTICAL TRANSFIXATION

## *RELAÇÃO DOS VASOS VERTEBRAIS COM PARAFUSO DE TRAJETO CORTICAL COM TRANSFIXAÇÃO DA CORTICAL*

## *RELACIÓN DE LOS VASOS VERTEBRALES CON TORNILLO DE TRAYECTORIA CORTICAL CON TRANSFIJACIÓN CORTICAL*

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## RESUMEN

Introduction: This study aims to evaluate the safety of using the cortical path screw with transfixation of the second cortical bone in relation to the vascular structures. Methods: This retrospective observational study (level of evidence: III, study of non-consecutive patients) analyzed data from the medical records of patients who underwent computed angiotomography scans of the abdomen at Hospital Mater Dei, measuring, in millimeters, the distance between the point of the lumbar vertebra considered the anatomical reference for the transfixation of the second cortical bone and the vascular structures adjacent to the spine (abdominal aorta, inferior vena cava, iliac vessels, segmental lumbar arteries). Results: Forty-eight patients were evaluated, with a mean age of 60 years (±8 years, 41-75), of whom 52% were male and 48% female. The measurements obtained between the pre-vertebral vessels and the possible screw exit points did not demonstrate contact in any of the vertebrae studied. Conclusions: The measurements obtained suggest the safety of using the cortical path screw transfixing the second cortical bone. Knowing the position of the vessels is essential to reduce intra- and postoperative complications related to spinal instrumentation. ***Level of evidence III; Study of non-consecutive patients.***

**Keywords:** Cortical bone; Spinal fusion; Manipulation, lumbar; Spinal fractures.

## *RESUMO*

*Introdução: Este trabalho objetiva avaliar a segurança do uso do parafuso de trajeto cortical com transfixação da segunda cortical óssea com relação às estruturas vasculares. Métodos: Estudo observacional retrospectivo (nível de evidência: III, estudo de pacientes não consecutivos) analisou dados de prontuários de pacientes submetidos ao exame de angiotomografia computadorizada do abdome no Hospital Mater Dei, realizando a medida, em milímetros, entre o ponto da vértebra lombar considerado a referência anatômica para a transfixação da segunda cortical óssea e as estruturas vasculares adjacentes à coluna (aorta abdominal, veia cava inferior, vasos ilíacos, artérias lombares segmentares). Resultados: Foram avaliados 48 pacientes, com média de idade de 60 anos (±8 anos, 41-75), sendo 52% do sexo masculino e 48% do feminino. As medidas obtidas entre os vasos pré-vertebrais e os pontos possíveis de saída do parafuso não demonstraram contato, em todas as vértebras estudadas. Conclusões: As medidas obtidas sugerem a segurança do uso do parafuso de trajeto cortical transfixando a segunda cortical óssea. Conhecer a posição dos vasos é essencial para reduzir as complicações intra e pós-operatórias relacionadas à instrumentação da coluna vertebral.* ***Nível de evidência III; Estudo de pacientes não consecutivos.***

***Descritores:*** *Osso cortical; Fusão vertebral; Manipulação da coluna lombar; Fraturas da coluna vertebral.*

## *ABSTRACT*

*Introducción: Este estudio tiene como objetivo evaluar la seguridad del uso del tornillo de trayectoria cortical con transfijación de la segunda cortical ósea con respecto a las estructuras vasculares. Métodos: Estudio observacional retrospectivo (nivel de evidencia: III, estudio de pacientes no consecutivos) que analizó datos de registros médicos de pacientes sometidos a examen de angiografía por tomografía computarizada de abdomen en el Hospital Mater Dei, realizando la medición, en milímetros, entre el punto de la vértebra lumbar considerado la referencia anatómica para la transfijación de la segunda cortical ósea y las estructuras vasculares adyacentes a la columna (aorta abdominal, vena cava inferior, vasos ilíacos, arterias lumbares segmentarias). Resultados: Se evaluaron 48 pacientes, con una edad promedio de 60 años (±8 años, 41-75); 52% eran hombres y 48% mujeres. Las medidas obtenidas entre los vasos prevertebrales y los posibles puntos de salida del tornillo no demostraron contacto en todas las vértebras estudiadas. Conclusiones: Las medidas obtenidas sugieren la seguridad de utilizar el tornillo de trayectoria cortical transfijando la segunda cortical ósea. Conocer la posición de los vasos es fundamental para reducir las complicaciones intra y postoperatorias relacionadas con la instrumentación espinal.* ***Nivel de evidencia III; Estudio de pacientes no consecutivos.***

***Descriptores:*** *Hueso cortical; Fusión vertebral; Manipulación lumbar; Fracturas de la columna vertebral.*

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Received on 03/30/2021 accepted on 10/19/2021

Reviewed by: Dr. Renato Tavares Daher/Dr. Marcos Antonio Tebet

## INTRODUCTION

Years after the introduction of vertebral instrumentation (1962), posterior instrumentation techniques were developed and Eduardo Luque (1973) proposed segmental vertebral instrumentation with arthrodesis, a technique with the advantages of speed, efficiency, and no need for an external brace.[1-3] Despite this, in follow-up studies it has been associated with postoperative complications, such as pseudarthrosis, local instability, synthesis material failure, and injuries of the nerve structures.[4-7]

At around the same time, Raymond Roy Camille (1964/1977) proposed spinal deformity correction using pedicle screw fixation.[8-9] This is the gold standard technique when it comes to instrumentation for the treatment of thoracolumbar spine injuries.[10] Although the biomechanical performance is superior to the older methods, failures are still possible, especially in osteoporotic bones.[11-13]

In search of a spine fixation system with fewer complications, Santoni described a new technique using lumbar spine screws, called cortical trajectory screws or simply cortical screws, which offered mechanical advantages, especially when applied to osteoporotic bone (Figure 1).[14-20]

Subsequently, Resende described a modification of the cortical screw technique described by Santoni, proposing a bicortical application.[15-16] Although experimental, the bicortical fixation techniques emerged as an alternative to reduce fixation failures. Pedicle screws used bicortically in the thoracolumbar spine run up against a risk of vascular injury.[15]

The main objective of this study is to evaluate the relationship in millimeters, in the bicortical technique described by Resende, between the exit point of the cortical screw and the lumbar blood vessels (abdominal aorta, inferior vena cava, iliac blood vessels, lumbar segmental arteries). The secondary objective is to evaluate the same relationship considering the sex of the patient.

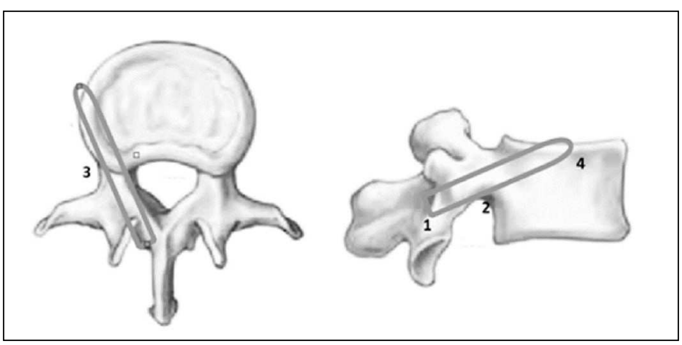


**Figure 1.** Trajectory of the cortical screw proposed by Santoni. (1) point of entry (3 mm medially to the lateral edge of the pars), (2) in the inferomedial wall of the pedicle, (3) in the antero-lateral wall of the pedicle, and (4) in the lateral edge of the superior endplate of the instrumented vertebra.

## METHODS

This is a retrospective observational study that collected and analyzed data from the medical records of patients who had undergone spiral computed angiotomography (CTA) of the abdomen (Toshiba 160-channel Aquilion PRIME model TSX 303A – Manufacturer: Toshiba Medical System Corporation 1385, Shimoishigami Otawara-shi, Tochigi Japan), at the Hospital Mater Dei (HMD) during the period from January 2019 to June 2020. The study was approved by the Institutional Review Board (Identification: 40678720.4.0000.5128), and the Informed Consent Form was waived.

Male and female patients over 18 years of age submitted to CTA of the abdomen were included. Cases with a history of trauma, lumbar spine surgery, anatomical changes, or skeletal immaturity identified during the examination were excluded.

Simulation of the cortical screw trajectory followed Santoni's original description[14] and was performed using Carestream Picture Archiving and Communication System software (PACS - version 11.4.1.1011 - Manufacturer: Carestream, Rua Pequetita, 215, Bairro Vila Olímpia, São Paulo, SP, Brazil) for image analysis.

The simulation process began with the identification of the pedicle and pars interarticularis (coronal plane) to obtain the point of entry of the screw, located at five o'clock (left pedicle) and seven o'clock (right pedicle). This was followed by the elaboration of the path, via a line inclined at 25° caudo-cranially (sagittal plane) and 10° medio-laterally (axial plane) (Figure 2).

Once the simulation of the ideal cortical screw path had been performed bilaterally for each vertebra, the exit point in the second cortical layer was obtained using the software. This point was projected in three planes: axial, sagittal, and coronal (Figure 3).

The distance between the screw exit point in the transitional region of the superior vertebral plate and the lateral wall and the vessels was measured in millimeters (mm). In the coronal plane, the distances to the lumbar segmental arteries at levels L1 to L5 on the right and left were evaluated. In the axial plane, the distance to the aorta and vena cava at levels L1 to L5, and the right and left common iliac arteries and the right and left common iliac veins, at levels L4 and L5 were measured according to the anatomical variations of each patient.

The research data were processed using statistical program R, version 3.6.3 (Manufacturer: R Development Core Team, Free Software Foundation - 51 Franklin Street, Fifth Floor, Boston, MA 02110 USA). Analysis of the confidence interval (CI) of 95% was used to evaluate the means of the clinical variables. The Kolmogorov-Smirnov test verified the assumption of normality of the sample distribution with a p-value greater than 5%. In the bivariate analysis, the parametric Student´s t test was used to evaluate the differences between the sex of the patients and the clinical variables.

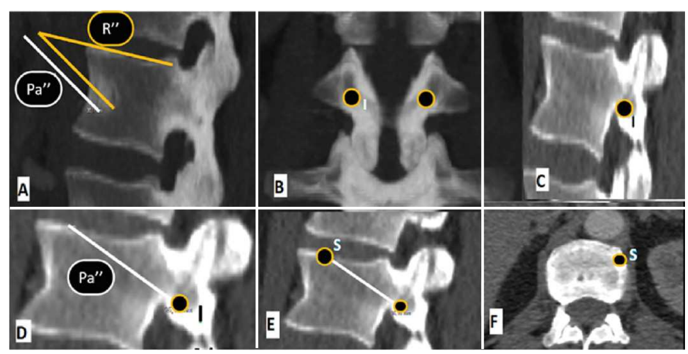


**Figure 2.** (A) A line drawn at 25° caudo-cranially, (B) the pedicle located in the coronal plane and the point of entry, (C) point of entry in the sagittal plane, (D) (E) trajectory of the screw in the sagittal plane, (E)(F) point of exit in the axial plane.

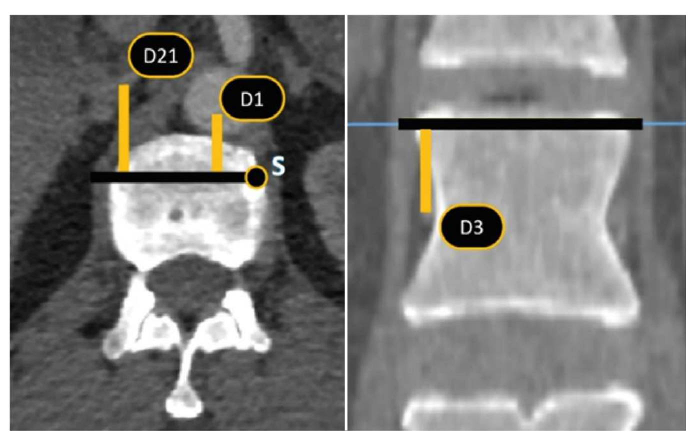


**Figure 3.** The exit point was identified in the axial plane and the measurements for the iliac artery (D21), the vena cava (D1), and the right and left common iliac arteries were taken. The measurements for the segmental arteries were taken in the coronal plane.

## RESULTS

Forty-eight patients were included in the study, 25 (52%) of whom were male and 23 (48%) of whom were female. The mean age was 60 years (±8 years, minimum age 41 years, maximum age 75 years).

The mean, maximum, and minimum distances and standard deviations from the transfixation point of the bicortical screw to the aorta (Table 1), vena cava (Table 2), right (Table 3) and left (Table 4) lateral segmental arteries, the right (Table 5) and left (Table 6) common iliac arteries, and the right and left common iliac veins (Table 7) are summarized below. For the vena cava, there was a difference between the means. For the right common iliac vein, the p-value ($p<0.05$) was statistically significant when compared between the sexes. The data are summarized together in Figure 4.

As for the correlation between the clinical variables and sex, an association was identified in the variables Vena Cava (L1-L4), Aorta (L2-L4) and the common iliac artery. The men had a greater distance between the screw and the vascular structure than the women. The respective distances in millimeters for men and women were 35.6 and 27.86 (Vena Cava L1 - $p=0.019$), 31.92 and 19.52 (Vena Cava L2 – $p<0.001$), 22.38 and 14.17 (Vena Cava L3 – $p<0.001$), 17.64 and 10.98 (Vena Cava L4 – $p<0.001$), 19.54 and 15.62 (Aorta L2 – $p<0.001$), 22.66 and 17.17 (Aorta L3 – $p<0.001$), 21.98 and 16.90 (Aorta L4 $p<0.001$), 20.73 and 14.15 (left common iliac artery - $p=0.001$), and 25.39 and 17.54 (right common iliac artery $p<0.001$). The other variables presented no differences between the sexes (Table 8).

## DISCUSSION

This study was the first in the Brazilian literature to simulate and measure the distance from the screw tip to the vessel, using the technique described by Resende. In the measurements obtained, there was no contact between the prevertebral vessels and the possible screw exit points in any of the vertebrae studied.

**Table 1.** Measurements in relation to the aorta in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | P-value |
| Aorta L1 | 48 | 16.48 | 4.69 | 15.16 | 17.81 | 0.310 |
| Aorta L2 | 48 | 17.67 | 3.97 | 16.54 | 18.79 | 0.692 |
| Aorta L3 | 48 | 20.03 | 5.22 | 18.55 | 21.50 | 0.085 |
| Aorta L4 | 42 | 19.56 | 4.77 | 18.12 | 21.01 | 0.129 |
| Aorta L5 | 6 | 18.56 | 5.78 | 13.93 | 23.19 | 0.657 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 2.** Measurements in relation to the vena cava in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| Vena Cava L1 | 48 | 31.89 | 11.69 | 28.59 | 35.20 | 0.838 |
| Vena Cava L2 | 46 | 25.72 | 10.54 | 22.67 | 28.76 | 0.278 |
| Vena Cava L3 | 48 | 18.44 | 7.68 | 16.27 | 20.62 | 0.051 |
| Vena Cava L4 | 47 | 14.38 | 5.36 | 12.85 | 15.91 | 0.092 |
| Vena Cava L5 | 22 | 12.75 | 4.76 | 10.76 | 14.74 | 0.796 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 3.** Measurements in relation to the right lateral segmental artery in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| rLsa L1 | 48 | 10.56 | 1.81 | 10.05 | 11.07 | 0.632 |
| rLsa L2 | 47 | 11.49 | 2.64 | 10.74 | 12.25 | 0.836 |
| rLsa L3 | 48 | 10.93 | 1.98 | 10.37 | 11.49 | 0.358 |
| rLsa L4 | 46 | 10.62 | 2.44 | 9.92 | 11.33 | 0.763 |
| rLsa L5 | 12 | 12.44 | 3.74 | 10.32 | 14.55 | 0.003 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. rLsa: Right Lateral Segmental Artery, SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 4.** Measurements in relation to the left lateral segmental artery in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| lLsa L1 | 48 | 10.53 | 2.27 | 9.89 | 11.17 | 0.066 |
| lLsa L2 | 48 | 10.78 | 2.25 | 10.14 | 11.42 | 0.651 |
| lLsa L3 | 48 | 10.22 | 2.24 | 9.58 | 10.85 | 0.521 |
| lLsa L4 | 45 | 10.88 | 2.28 | 10.22 | 11.55 | 0.157 |
| lLsa L5 | 14 | 10.75 | 3.61 | 8.86 | 12.64 | 0.133 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. lLsa: Left Lateral Segmental Artery, SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 5.** Measurements in relation to the right common iliac artery in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| rcla L4 | 5 | 22.51 | 7.28 | 16.13 | 28.89 | 0.588 |
| rcla L5 | 42 | 21.65 | 7.59 | 19.36 | 23.95 | 0.224 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. rcla: Right Common Iliac Artery, SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 6.** Measurements in relation to the left common iliac artery in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| lcla L4 | 5 | 19.95 | 6.93 | 13.87 | 26.03 | 0.461 |
| lcla L5 | 43 | 17.52 | 6.88 | 15.46 | 19.58 | 0.116 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. lcla: Left Common Iliac Artery, SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

**Table 7.** Measurements related to the right and left common iliac veins in millimeters.

| Variable | N | Mean | SD | Confidence Interval | | P-value |
|---|---|---|---|---|---|---|
| | | | | IL 95% | SL 95% | |
| rclv L5 | 23 | 11.64 | 6.65 | 8.92 | 14.35 | 0.036 |
| lclv L5 | 23 | 15.82 | 6.40 | 13.21 | 18.44 | 0.618 |

Results identified according to a 95% confidence level, Kolmogorov-Smirnov normality test. rclv: Right Common Iliac Vein, lclv: Left Common Iliac Vein, SD: Standard deviation, IL: Inferior limit, SL: Superior limit.

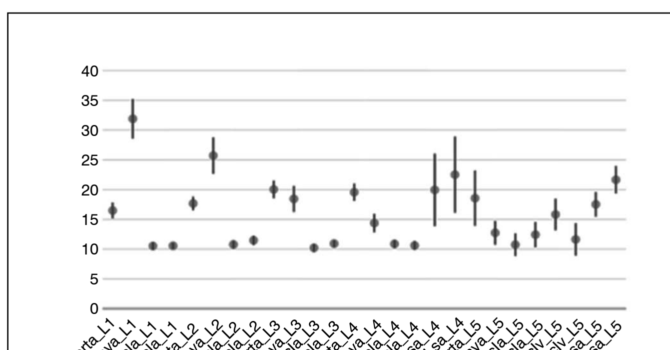


**Figure 4.** Measurements and confidence intervals for all the vessels.

The cortical trajectory screw can reach up to four points of contact with the cortical bone, namely, the entry point into the pars interarticularis, the inferomedial wall of the pedicle, the anterolateral wall of the pedicle, and the lateral cortex of the vertebral body, touching it, but not piercing it.[21]

The modification proposed by Resende used the insertion technique described by Santoni, combining the perforation of the second cortical bone, insertion of the screw, and transfixation. Biomechanical studies in swine vertebrae have shown a 46% increase in pullout force with the bicortical screw.[14,16]

**Table 8.** Measurements in relation to the pre-vertebral vessels and comparison by sex in millimeters.

| Variable | Female | Male | Statistic | p-value |
|---|---|---|---|---|
| Aorta L1 | 15.24 | 17.63 | -1.81 | 0.076 |
| Vena Cava L1 | 27.86 | 35.6 | -2.43 | 0.019 |
| lLsa L1 | 10.58 | 10.49 | 0.13 | 0.898 |
| rLsa L1 | 10.96 | 10.20 | 1.48 | 0.146 |
| Aorta L2 | 15.62 | 19.54 | -3.93 | p<0.001 |
| Vena Cava L2 | 19.52 | 31.92 | -4.91 | p<0.001 |
| lLsa L2 | 10.71 | 10.85 | -0.21 | 0.836 |
| rLsa L2 | 11.93 | 11.11 | 1.07 | 0.291 |
| Aorta L3 | 17.17 | 22.66 | -4.3 | p<0.001 |
| Vena Cava L3 | 14.17 | 22.38 | -4.42 | p<0.001 |
| lLsa L3 | 9.91 | 10.50 | -0.91 | 0.369 |
| rLsa L3 | 10.99 | 10.88 | 0.19 | 0.853 |
| Aorta L4 | 16.90 | 21.98 | -4.04 | p<0.001 |
| Vena Cava L4 | 10.98 | 17.64 | -5.44 | p<0.001 |
| lLsa L4 | 10.60 | 11.13 | -0.79 | 0.436 |
| rLsa L4 | 10.12 | 11.09 | -1.38 | 0.175 |
| lcla L5 | 14.15 | 20.73 | -3.56 | 0.001 |
| rcla L5 | 17.54 | 25.39 | -3.96 | p<0.001 |

Results were identified according to a confidence level of 95% for the t test for two independent variables. rcla: Right Common Iliac Artery, lcla: Left Common Iliac Artery, rLsa: Right Lateral Segmental Artery, lLsa: Left Lateral Segmental Artery, rclv: Right Common Iliac Vein, lclv: Left Common Iliac Vein.

The screw is directed towards the supero-lateral region of the vertebral body and shorter screws are used. Thus, with transfixation of the second cortical bone, the exit extremity region is in the cranial third and the posterior two thirds of the wall of the vertebral body wall. Theoretically, this region does not involve violation of the disc space or a direct risk of injury to the prevertebral vessels, corroborating the data found in the present study, which did not identify any case in which the screw make contact with the prevertebral vessels.[15,21-23]

Also corroborating the present findings, a study reviewed 664 cases of vertebral instrumentation and identified 15 (0.22%) cases of invasion of the vascular structure, reinforcing that injury to the large vessels of the thoracolumbar spine is rare and is preceded by a screw that touched or deformed the vessel.[17]

As for surgical technique, one study analyzed 65 CTA images of the lumbar spine to determine the best positioning of the bicortical screw in relation to the large lumbar vessels and considered that a distance of 5 or more mm between the screw and the vessel is safe.[15]

Regarding the variability between patients, one author compared the path of the abdominal aorta in healthy individuals and in patients with degenerative lumbar scoliosis and concluded that the vessel follows its course without deviation or change in the distance from the spine. However, in patients with kyphosis, the distance may be increased by moving the spine away from the vessel. The author reported that the reduced elastic capacity of the tissues in elderly patients have a beneficial effect as the vessels remain in their anatomical position.[24]

CTA was chosen for image analysis with the goal of increasing sensitivity in the identification of small-caliber vessels, such as the lumbar segmental arteries. They arteries originate on the posterior surface of the aorta and follow a dorsolateral course in the middle third of the vertebral body.[25] The diameter of the segmental artery increases proportionally from L1 to L4, with its smallest diameter in L5, a fact that corroborates the technical difficulty encountered in identifying the arteries at this level, even using images captured after the administration of contrast and digitalized to facilitate it.[26]

A study of the morphology of the vena cava reported that its distance from the anterior cortex of the vertebral bodied tends to increase as it ascends through the abdomen and that the distance tends to be smaller in females, considering the degenerative changes suffered in the lumbar spine secondary to menopause.[27]

In our samples, aiming for the correct positioning of the cortical screw by following the Santoni technique, we observed that even after extending the screw during simulation, there was no contact with the vessels studied.[16] It is important to emphasize that, despite the study cited, there is no consensus in the current literature regarding the safe distance from the screw to the vessel and several studies report that the screw in contact with the vessel can cause the formation of pseudoaneurysms.[28,29]

A noteworthy strong point of our study is that the measurements were taken in a systematic manner, using an objective method, easily reproducible by other research centers. Among the limitations, it should be noted that the measurements were taken by a single trained researcher and with data collection at a single center, limiting the sample analyzed. Another limitation was the exclusion of patients with any deformity or previous spine surgery, given that the bicortical screw technique is more recommended in the elderly who experience a greater number of changes and a predisposition for treatment failure.

## CONCLUSIONS

In the measurements obtained through analysis of CTA exams, no contact between the prevertebral vessels and any of the possible cortical screw exit points in the transfixation of the second cortical bone was observed, corroborating the authors' expectations, and demonstrating that the modification to the technique is safe in relation to the vessel surrounding the lumbar spine.

This is the first study to corroborate the safety of using this technique. Additional studies are needed to further specify safe surgical practices and the safest location for transfixation of the second cortical bone using the cortical trajectory screw technique.


## ACKNOWLEDGEMENTS

Thanks to my preceptors, especially to Dr. Rogério Lúcio Chaves Resende and the Rede Mater Dei, the location where the present study was conducted.

All authors declare no potential conflict of interest related to this article.

**CONTRIBUTIONS OF THE AUTHORS:** Each author made significant individual contributions to this manuscript. RMG, RLCR, JSL, LCMF, and GRA: data tabulation, data analysis, literature review, writing and review of the work.


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