COMPARISON OF EXPOSURE TO RADIATION DURING PERCUTANEOUS TRANSPEDICULAR PROCEDURES, USING THREE FLUOROSCOPIC TECHNIQUES

COMPARAÇÃO DA EXPOSIÇÃO À RADIAÇÃO DURANTE PROCEDIMENTOS PERCUTÂNEOS TRANSPEDICULARES USANDO TRÊS TÉCNICAS FLUOROSCÓPICAS

COMPARACIÓN DE LA EXPOSICIÓN A LA RADIACIÓN DURANTE PROCEDIMIENTOS PERCUTÁNEOS TRANSPEDICULARES UTILIZANDO TRES TÉCNICAS FLUOROSCÓPICAS

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ABSTRACT

Objective: To compare radiation exposure to the surgeon, patient and radiation technician during percutaneous access of the vertebral pedicle, using three different fluoroscopic imaging set up. Methods: Percutaneous access in pedicle T9-L5 of nine adult male cadavers using three different fluoroscopic set ups: standard C-arm, C-arm with L-arm, and the biplanar technique. The radiation dose exposure of the surgeon, radiation technician, and cadaver were measured using dosimeter in each procedure and in real time. Results: The radiation dose absorbed by the surgeon was higher when using the standard C-arm fluoroscopic technique than when using the C-arm with L-arm or the biplanar technique. Conclusions: The use of the C-arm with L-arm, or the biplanar fluoroscopic technique, for percutaneous access to the vertebral pedicle, reduces the radiation exposure of the surgeon compared to the standard C-arm fluoroscopic technique.

Keywords: Lumbar vertebrae; Thoracic vertebrae; Fluoroscopy; Radiation dosage; Minimally invasive surgical procedures.

RESUMO

Objetivo: Comparar a exposição à radiação do cirurgião, paciente e técnico de radiologia durante acesso percutâneo do pedículo vertebral, usando três diferentes técnicas fluoroscópicas. Métodos: Acesso percutâneo do pedículo vertebral de T9-L5 de nove cadáveres de adultos do sexo masculino usando três diferentes técnicas de fluoroscopia: arco cirúrgico padrão, arco cirúrgico com braço em "L" e técnica biplanar. A radiação recebida por cirurgião, cadáver e técnico de radiologia foi mensurada com dosímetro em cada procedimento e em tempo real. Resultados: A dose de radiação absorvida pelo cirurgião foi maior com o uso do arco cirúrgico padrão, em comparação com o uso de arco cirúrgico com braço em "L" ou com técnica biplanar. Conclusões: O uso do arco cirúrgico com braço em "L" ou da técnica biplanar para acesso percutâneo do pedículo vertebral reduz a exposição do cirurgião à radiação em comparação com a técnica fluoroscópica com arco cirúrgico padrão.

Descritores: Vértebras lombares; Vértebras torácicas; Fluoroscopia; Dosagem de radiação; Procedimentos cirúrgicos minimamente invasivos.

RESUMEN

Objetivo: Comparar la exposición a la radiación del cirujano, paciente y técnico de radiología durante el acceso percutáneo del pedículo vertebral, utilizando tres técnicas fluoroscópicas diferentes. Métodos: Acceso percutáneo del pedículo vertebral de T9-L5 de nueve cadáveres de adultos del sexo masculino utilizando tres técnicas fluoroscópicas diferentes: arco en C estándar, arco en C con brazo en L y técnica biplanar. La radiación recibida por cirujano, cadáver y técnico de radiología se midió usando dosímetro en cada procedimiento y en tiempo real. Resultados: La dosis de radiación absorbida por el cirujano fue mayor cuando se usó la técnica del arco en C estándar, en comparación con el arco en C con brazo en L o con técnica biplanar. Conclusiones: El uso del arco en C con brazo en L o de la técnica biplanar para el acceso percutáneo del pedículo vertebral reduce la exposición a la radiación del cirujano en comparación con la técnica fluoroscópica con arco en C estándar.

Descriptores: Vértebras lumbares; Vértebras torácicas; Fluoroscopía; Dosificación de radiación; Procedimientos quirúrgicos mínimamente invasivos.

INTRODUCTION

The percutaneous transpedicular approach has been extensively used in minimally invasive spine procedures for pedicle screw insertion, vertebroplasty and kyphoplasty.[1-3] This approach minimizes tissue trauma and blood loss, and improves patient recovery. However, the technique requires fluoroscopic guidance, which can result in significant levels of radiation exposure to the surgeon, patient and radiation technician. Furthermore, in the percutaneous setting, the anatomical landmarks are lacking, and this requires time-consuming fluoroscopy guidance.[4-8] The patient's exposure is limited to one

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procedure, but the surgeon and operating room staff are repeatedly exposed to radiation, during multiple procedures.[8-11]

The most common equipment used in intraoperative image acquisition is the c-arm, due to its capacity to present real time images. Exposure to radiation in the operating room can be reduced by using personal protective equipment (PPE), reducing the fluoroscopy time, adequate positioning of c-arm, and other techniques.[12] The concept of this study was developed in light of the increased use of the percutaneos approach to the vertebral pedicle, and the concern to reduce the harmful effects of fluoroscopy. The aim of the study was to quantify the radiation dose measurements to surgeons, the radiation technician, and the patients during the percutaneous approach to the pedicle, using three fluoroscopy techniques for image acquisition.

METHODS

The study was performed at the Anatomy Laboratory of the Medical School of Ribeirão Preto – USP. Nine adult male cadavers were used, and the focuses of the study were the bilateral vertebrae pedicles from T9 to L5 (n=162 pedicles). The cadaver vertebrae were divided into 3 groups: Group A (T9, T10 and T11), Group B (T12, L1 and L2) and Group C (L3, L4 and L5). In order to define the sequence of the vertebra to be studied, simple random selection was performed, with blinded letters, always ensuring that the level of the vertebra and the image acquisition techniques were not repeated in the series of procedures. This method was approved by the ethics committee of the Hospital das Clínicas of Ribeirão Preto, University of São Paulo.

The instruments used for the percutaneous approach to the vertebrae pedicles were: Jamshidi® needle and Kirchner wire (K-wire). The fluoroscopy equipment used for the image acquisition was: GE/OEC 9900 Elite, Salt Lake City, UT, USA and GE/OEC 9800 Plus Super C, Salt Lake City, UT, USA. The active dosimeter RaySafe i2 (Unfors RaySafe AB, Billdal, Sweden) was used to measure exposure to radiation, in real time.

Percutaneous approach to the vertebral pedicle

A single surgeon performed all the procedures, and was blinded to which cadaver was being used. The bilateral approach always started on the right side. The vertebra and pedicle were identified in the anteroposterior (AP) image. A 5 mm incision was then executed at the identified pedicle height, and the Jamshidi® needle was positioned according to the anatomical standard references. The Jamshidi® needle was introduced using an image intensifier for guidance, through AP image acquisition, until it tip could be seen at the center of the vertebral pedicle. The lateral vertebral image was then acquired, and the position of the Jamshidi® needle was verified, to ensure that its tip was located between 3 and 4 mm anterior to the posterior vertebral cortical. The working cannula was then introduced, up to 3 or 4 mm anterior to the posterior vertebral cortical. The K-wire was introduced through the Jamshidi® needle, after removing the trocar, and was used as a guide to introduce the cannulated puncher. The percutaneous approach to the pedicle was considered completed when the K-wire was introduced through the Jamshidi® needle and positioned in the vertebral body.

Fluoroscopic set up

The C-arm was operated by the same radiation technician in each procedure. It was positioned on the side of the cadaver opposite to the surgeon, to reproduce the most common scenario. The radiation technician and surgeon had a defined area to work in, around the table.

The fluoroscopic mode was continuous in all the techniques. This is not very significant, considering all the acquisitions were taken in a single shot. The range of source voltage was 40-120 kV, and the current was 0.2-10 mA.

The three fluoroscopy techniques used for the image acquisition were:

1. One C-arm fluoroscopic technique using GE/OEC9900 (GE/OEC 9900 Elite, Salt Lake City, UT, USA) without L-arm (SmartView).
2. One C-arm fluoroscopic technique using GE/OEC9900 (GE/OEC 9900 Elite, Salt Lake City, UT, USA) with L-arm (SmartView).
3. Two C-arm fluoroscopic technique (biplanar) using GE/OEC9900 (GE/OEC 9900 Elite, Salt Lake City, UT, USA) and GE/OEC9800 (GE/OEC 9800 Plus Super C, Salt Lake City, UT, USA).

The L-arm (SmartView) was unlocked in techniques 2 and 3 to enable the C-arm to reach additional angulations more quickly and easily. SmartView also allowed the image intensifier to be placed beside the surgeon, keeping to the traditional operating room workflow (C-arm located on the side opposite to the surgeon).

Radiation Measurement

The radiation measurement was performed by checking the dose shown in the fluoroscopic equipment (GE/OEC 9900 ELITE, Salt Lake City, UT, USA and GE/OEC 9800 PLUS Super C, Salt Lake City, UT, USA). The dosimeters were placed over the lead apron on the surgeon's chest, in the same position on the radiation technician, and at the side of the cadaver. The measurement was performed in real time, by four electronic dosimeters. The results of each procedure were computed by accessing the time stamped dose data. The RaySafe i2 device consists of four dosimeters that measure radiation every second. The dose data is transferred wirelessly to a real time display on a tablet. The measurement was taken in micro Sievert (μSv). Only three dosimeters were used for the study. One was placed in the patient, another on the physician, and the third on the radiation technician. The measurement of the dosimeter placed on the patient was disregarded, since it was necessary to keep moving the position of the dosimeter, in order to access the vertebra, and this would have interfered in the result.

The radiation dose was measured from the first x-ray emission (localization of the vertebral pedicle) on the right side of the vertebra, until the introduction of K-wire inside the Jamshidi@ needle on the left side of the vertebra. The air kerma computed by the equipment – the absorbed dose at a reference point - was reported in mGy. This data is a good estimation of patient peak skin dose, and was used as the indicator of patient dose exposure. The tested hypothesis was that the use of L-arm and/or the biplanar technique might reduce the radiation exposure during percutaneous access to the vertebral pedicle

Statistical analysis

The results of the radiation dose absorbed by the dosimeters placed on the surgeon and on the cadaver did not present normal distribution when evaluated by three different methods: histogram shape, Shapiro-Wilk test, and comparison between value of the mean and the median. Therefore, the Kruskal-Wallis test and Pairwise comparisons of means with equal variance were used to compare the radiation dose absorbed using the three different techniques. The high spread of the data in cadavers 1 to 5 indicates the learning curve of the procedure, so we performed a second analysis of the data excluding the first five cases. Small Stata 13.1 software was used for the statistical analysis reported in the study.

RESULTS

Bilateral vertebrae pedicles T9 to L5 (n=162 pedicles) of nine adult male cadavers were used in the study. No radiographic signs of malformation or fracture were found during the study.

Figure 1 shows the results of the radiation dose shown by the dosimeter placed over the lead apron on the surgeon's chest, for the three different fluoroscopic techniques. The Kruskal-Wallis test showed a difference between the three groups (P = 0.0001).

Pairwise comparison showed a difference between techniques 2 and 3 compared to technique 1, (Table 1) implying that the use of the L-arm (SmartView) and the two C-arm fluoroscopic (biplanar) techniques have less radiation exposure to the surgeon.

The confidence intervals for cadavers 1 to 5 concerning dose of radiation to the surgeon were much wider than for cadavers 6 to 9. (Figure 2) The high spread of the data indicates the learning curve of the procedure, which was confirmed by Levene's test (p=0.004). The values for exposure to radiation for the surgeon from cadavers 1 to 5 were then submitted to a second evaluation. According to Levene's test, cadavers 6 to 9 presented a smaller spread for exposure to radiation of the surgeon (p=0.147) and only these values were considered in this step. Figure 3 shows the results of the Kruskal-Wallis test for the 3 groups of techniques (P = 0.0032) for the cadavers 6 to 9, evidencing difference between the groups.

Pairwise comparison between the techniques also showed a difference between techniques 2 and 3 compared to technique 1 (Table 2) after removing the results for the first 5 cadavers and eliminating the learning curve. This demonstrates that the use of the L-arm (SmartView) and the two C-arm fluoroscopic (biplanar) techniques are associated with less exposure to radiation to the surgeon.

Figures 4 and 5 show the result of the radiation dose demonstrated by the dosimeter placed on the lateral of the cadavers between the 3 different fluoroscopic techniques. The Kruskal-Wallis test showed no difference between the three techniques when evaluating all 9 cadavers (p=0.25) and when evaluating only cadavers 6 to 9 (p=0.0514).

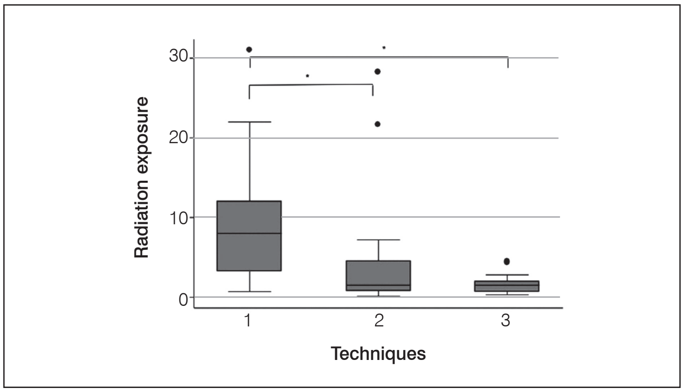

Figure 1. Kruskal-Wallis equality-of-populations rank test showing difference between the 3 techniques. 1 One C-arm fluoroscopic technique, 2 One C-arm fluoroscopic with L-arm technique, 3 Two C-arm fluoroscopic technique.

Table 1. Pairwise comparisons of means of the 2 groups of fluoroscopic techniques.

Technique	Contrast	Std. Err	[95% Conf. Interval]	
2 vs 1	-4.244296	1.765931	-7.76299	-.7256023
3 vs 1	-7.488296	1.765931	-11.00699	-3.969602
3 vs 2	-3.244	1.799571	-6.829723	.3417228

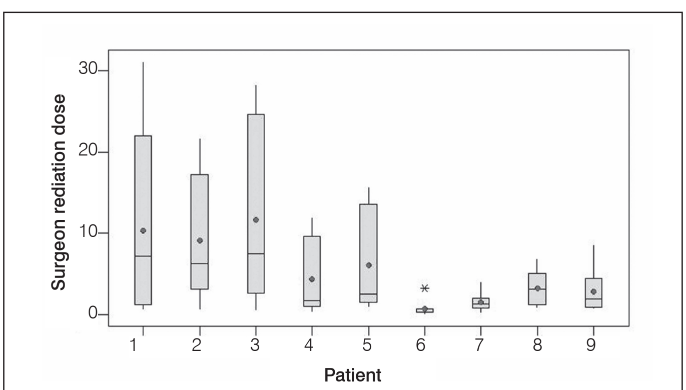

Figure 2. Variation of the sum of the surgeon's exposure to radiation in the three different procedures in each cadaver.

DISCUSSION

The results of this study show that the use of articulate L-arm and the use of the biplanar C-arm technique reduces exposure to radiation to the surgeon during percutaneous access to the vertebral pedicle. To our knowledge there are no reported studies related to the use of standard C-arm compared to the C-arm with the articulate L-arm, as performed in this study.

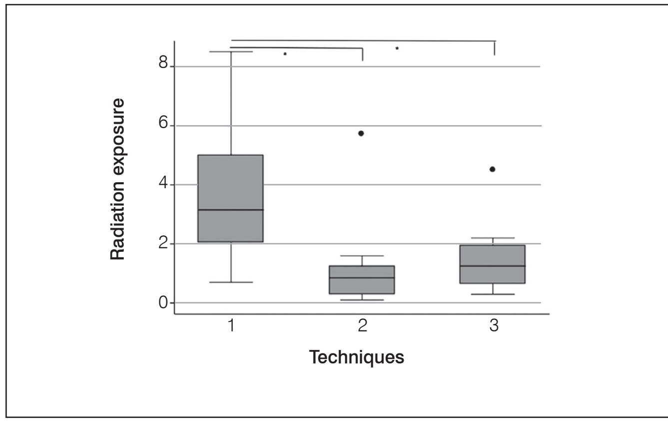

Figure 3. Kruskal-Wallis equality-of-populations rank test showing difference between the 3 techniques in the cadavers from 6 to 9. 1 One C-arm fluoroscopic technique, 2 One C-arm fluoroscopic with L-arm technique, 3 Two C-arm fluoroscopic technique.

Table 2. Pairwise comparisons of means of the 2 groups of fluoroscopic techniques after removing the first 5 cadavers form the results.

Technique	Contrast	Std. Err	[95% Conf. Interval]	
2 vs 1	-2.491667	.7234964	-3.963631	-1.019702
3 vs 1	-2.166667	.7234964	-3.638631	-.6947023
3 vs 2	.325	.7234964	-1.146964	1.796964

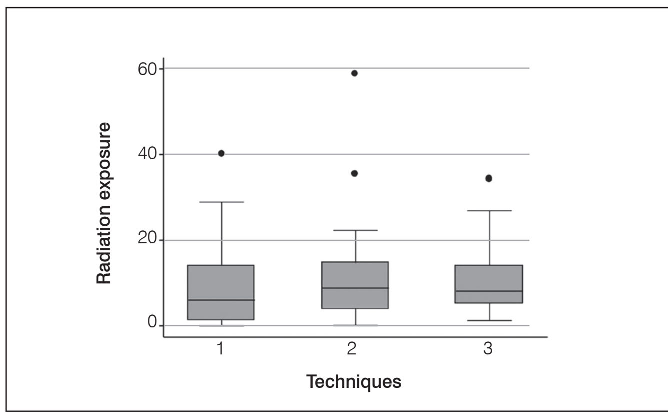

Figure 4. Kruskal-Wallis equality-of-populations rank test showing no difference between the 3 techniques. 1 One C-arm fluoroscopic technique, 2 One C-arm fluoroscopic with L-arm technique, 3 Two C-arm fluoroscopic technique.

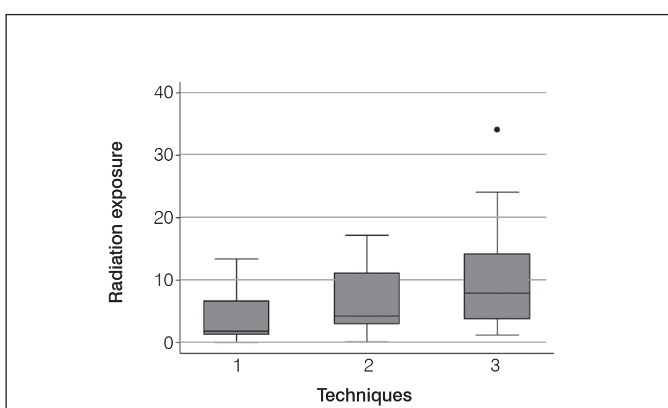

Figure 5. Kruskal-Wallis equality-of-populations rank test showing no difference between the 3 techniques in the cadavers from 6 to 9. 1 One C-arm fluoroscopic technique, 2 One C-arm fluoroscopic with L-arm technique, 3 Two C-arm fluoroscopic technique.

The vertebral pedicle screw has frequently been used as support for system fixation or in the approach when performing vertebroplasty or kyphoplasty.[1-3,13,14] The surgical procedures used to fix the vertebral pedicle screw require radiographic navigation in two planes (antero-posterior and lateral views).[1,13,15,16] During open procedures, a clear orientation is provided by the anatomical landmarks of the vertebrae, which results in less radiation exposure to the surgeon, patients and operating room team, compared to minimally invasive surgery (MIS) techniques.[1,5] In percutaneous procedures, anatomical landmarks are lacking, and longer radiation exposure times are required compared to open procedures. The greater exposure of patients and operating room staff to radiation, and the associated risks,[1,7,8,15] have prompted the development of new technologies for intraoperative image acquisition and intraoperative image navigation, such as computed tomography, magnetic ressonance imaging and other techniques.[3,16-21] However, real time fluoroscopic monitoring is still the most widely used technique for percutaneous access to the vertebral pedicle, due to its lower cost, portability and flexible clinical application.

There is a tendency in diferent fields that use fluoroscopy guided procedures to reduce the exposure to radiation.[1,3,20-22] Considering the different techniques to perform MIS procedures, biplanar fluoroscopy has been frequently used for surgical spine procedures.[3,15,20,21,23] Comparison of radiation exposure in single C-arm (no articulate arm) versus two C-arm simultaneous fluoroscopy (biplanar fluoroscopy using two fixed positioned C-arms) during guidance of medial-lateral and cranial-caudal access to the vertebral pedicle has been reported to reduce significantly the radiation to the surgeon, scrub technician and operating room staff during minimally invasive access to the vertebral pedicle.[3,8,15,20] Li et al.[12] reported reduced radiation exposure using the biplanar two-fluoroscopic technique, compared to the single fluoroscopic technique to perform vertebroplasty, but the dose reduction was only significant for the patient, and not for the surgical team.

The results using technique 2 were better than expected, as the dose levels were comparable to those of technique 3. The simple use of the L-arm feature significantly reduced the radiation dose absorbed by the surgeon. The L-arm can position the image intensifier next to surgeon, so that the operating room workflow maintains the same footprint as a standard C-arm, but with less and faster movements. Since the L-arm can preserve the isocenter of the anatomy, different angulations can be reached without losing the center of the image. Consequently, the number of x-ray shots are reduced due to easy localization of the area of study. As a result, the radiation dose is reduced, as the technician can easily find the location of the anatomy required by the surgeon.

In this study, there was no statistical difference between technique 2 and 3. Nevertheless, these techniques presented different results in relation to time and exposure. The values observed with the two--fluoroscopic techniques (biplanar) presented a narrower variation. This is due to the static use of the equipment, and can be significant for longer procedures, such as scoliosis and kyphosis corrections. This will be verified through further investigation by the researchers.

Of the operating room personnel, the surgeon receives the highest mean radiation doses, since he or she is being positioned next to the patient. Therefore, every effort should be made to minimize this exposure.[1,6,23] The patient's exposure is limited to one operation. However, the surgeon and operating room staff are repeatedly exposed to radiation during multiple procedures. All efforts must therefore be made to reduce radiation levels during minimally invasive surgery (MIS).

CONCLUSION

Besides the already known practices such as C-arm position, use of lead aprons, thyroid shields, protective eyewear, keeping at a safe distance from the source of radiation, and low-dose pulsed fluoroscopy, the results of our study showed that the use of one C-arm with articulated L-arm (SmartView) or two C-arm (biplanar) simultaneous fluoroscopic technique can also contribute to reduce the surgeon's exposure to radiation during percutaneous access to the vertebral pedicle.

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CONTRIBUTION OF THE AUTHORS: AN carried out the percutaneous procedures. CFPSH wrote the manuscript and performed the statistical analysis. HLAD conceived of the study, participated in its design and coordination and helped to draft the manuscript. All the authors read and approved the final manuscript.

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