Surgeon's radiation exposure in the internal fixation of distal radius fractures

FERNANDO VANOLI, LUCIANO GENTILE, SANTIAGO L. IGLESIAS, ESTEBAN LOBOS CENTENO, MARÍA PILAR DIAZ, CHRISTIAN A. ALLENDE NORES

Allende's Institute of Limbs Reconstructive Surgery Sanatorio Allende, Córdoba

Received on December 4th; 2016; accepted after evaluation on May 20th 2017 • FERNANDO VANOLI, MD • fer_vanoli@hotmail.com

ABSTRACT

Introduction: The aim of this study is to show referential values of the radiation doses absorbed by surgeons while performing open reduction and internal fixation with volar locking plate in unstable fractures of the distal radius.
Materials and Methods: Between May and December 2015 we evaluated prospectively exposure to radiation in two surgeons using dosimeters in thorax, neck and wrist in surgery of unstable fractures of the distal radius. We calculated a relative index for each surgery so as to identify the differences between the exposed regions and establish referential values for exposure monitoring.
Results: We evaluated operative results in 50 patients' surgeries. The surgical procedure averaged 40 minutes (2.06 SD); we find statistically significant differences between both surgeons ($p=0.043$). The average exposure time to the C-arm was 75 seconds and it differed significantly between the two surgeons ($p=0.007$) and between regions ($p<0.05$). There was less radiation on the thorax (protected by the lead vest, 0.04 mSv) than there was in the other two (unprotected) regions. 0.017 mSv—wrist and 0.18 mSv— thyroid gland.
Conclusions: In open reduction and internal fixation of fractures in the distal radius, surgeons are exposed to direct radiation during fluoroscopy, which varies as the exposed regions do and is not homogeneous between professionals. The amount of radiation received by surgeons, when only fractures of the distal radius are considered, cannot be associated with greater risk of cancer or the development of malignancy.

Key words: Radiation; C-arm; distal radius fractures.
Level of evidence: II

EXPOSICIÓN A LA RADIACIÓN DE LOS CIRUJANOS EN LA FIJACIÓN INTERNA DE FRACTURAS DE RADIO DISTAL

RESUMEN

Introducción: El objetivo de este estudio es proveer valores de referencia de dosis de radiación absorbida por el cirujano en la reducción abierta y fijación interna con placa volar de fracturas inestables de radio distal.
Materiales y Métodos: Entre mayo y diciembre de 2015, se evaluó prospectivamente la exposición a la radiación de dos cirujanos, usando dosímetros en tórax, cuello y muñeca en las cirugías de fracturas inestables de radio distal. Se construyó un índice relativo para cada cirugía a fin de identificar las diferencias entre los sitios y establecer valores de referencia para el monitoreo de la exposición.

Conflict of interests: The authors have reported none.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed) • http://dx.doi.org/10.15417/674

Resultados: Se evaluaron los resultados en las cirugías de 50 pacientes. El procedimiento quirúrgico promedió 40 minutos (DE 2.06); se hallaron diferencias estadísticamente significativas entre los dos cirujanos (p = 0,043). El tiempo promedio de exposición del arco en C fue de 75 segundos y difirió significativamente entre los cirujanos (p = 0,007) y entre los sitios (p <0,05). Hubo menos radiación en el tórax (protegido con chaleco de plomo, 0,04 mSv) que en los otros dos sitios (no protegidos): muñeca 0,017 mSv y tiroides 0,18 mSv.
Conclusiones: En la reducción abierta y fijación interna de fracturas de radio distal, los cirujanos están expuestos a la radiación directa durante la fluoroscopia, la cual varía conforme el sitio de exposición y no es homogénea entre los profesionales. La cantidad de radiación recibida por los cirujanos, cuando se consideran aisladamente las fracturas de radio distal, no puede asociarse a un mayor riesgo de cáncer o desarrollo de malignidad.

Palabras clave: Radiación; arco en C; fracturas de radio distal.
Nivel de Evidencia: II

Introduction

Intra-operative C-arm fluoroscopy is essential to get anatomic bone reduction, adequate stabilization and approaches less invasive in fractures. The development of new technologies has allowed surgeons an important decrease in the size of these devices, with easier use in operating rooms. The C-arm allows the surgeon to reduce fractures and insert implants with no ample devitalization of soft tissues, what results in a less invasive surgical tendency.[1]

In spite of all the clear benefits associated with the use of these devices, radiation exposure is still a problem. Mastrangelo et al. found fivefold cancer incidence in professionals exposed to radiation as compared to those who had been not.[2] The adverse effects of radiation are well documented in the specialized literature and include greater risk of skin cancer, cataracts, thyroid cancer and leukemia.[3-5]

Although especially in Operating Rooms surgeons have gowns, gloves, protective spectacles and even lead thyroid collars, only 80.4% of orthopedic surgeons uses

Figure 1. Dosimeters position in the surgeons.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

protection 75% of the times, and only 42.4% acknowledges the use of the lead thyroid collar.[6]

The aims of these study are to show the referential values of the doses of radiation absorbed by surgeons while operating on unstable fractures in the distal radius treated by open reduction and internal fixation with volar locking plates, and determine the exposure degree of the surgeons' hands, thorax and neck during such procedures so as to determine the risk of developing cancer.

Materials and Methods

Between May and December 2015 we analyzed prospectively radiation absorption in two surgeons who operated on 50 patients >18 years of age, of both sexes, admitted in our institution due to distal radius fracture and that were treated by open reduction and internal fixation with volar locking plates. We excluded the patients with fractures treated by other osteosynthesis methods or by other surgeons. We used three dosimeters—one in the surgeons' thorax (covered by a lead vest); one on their anterior region of the neck (external to the thyroid protector); and the last one in their right (dominant) wrist (Figure 1).

For the procedure we always used the same hand operating table and the C-arm reset, always respecting the same distance from the tube to the wrist (50 cm). We used a SIEMENS Siremobil Compat L C-arm, whose characteristics are the following: maximal power entrance of 1.4 kW, maximal tube current of 12.2 mA, free space of 78 cm, immersion depth of 73 cm, orbital movement of 130º and analogical navigation interface. For radiation absorption we used three AGFA dosimeters, which are film dosimeters used in radiographic films to capture the absorbed radiation.

We used the Henry anterior approach for the open reduction of the fracture.[7] Once we got to the radial bone, we carried out fracture reduction and osteosynthesis with volar locking plate. We decided to evaluate the absorption of radiation in these types of fractures because indirect reduction by traction is needed, thus exposing hands to radiation (Figure 2). Fractures were sub-divided according to the AO classification.

As the dose received was analyzed accumulatively after n1=29 and n2= 21 surgeries for two surgeons (from now on CA and FP respectively) we calculated a radiation relative index (RI) per surgery so as to get individual exposure levels and compare average exposure between the analyzed regions represented by the three dosimeters. The RI (individual for each surgeon during each surgery in each region) is defined as the ratio between the received accumulative dose and the total of distal radius surgeries carried out by each professional

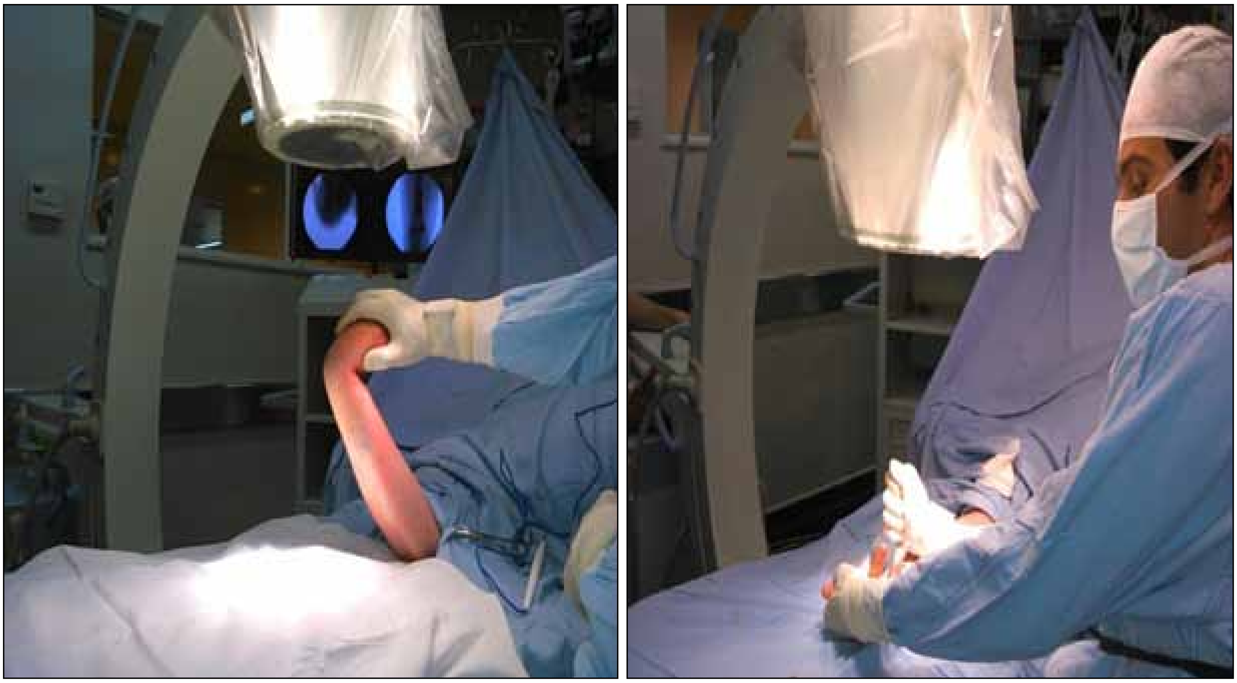

Figure 2. Reduction maneuvers and hands exposure.

calculated by means of the fluoroscopy amount of time used in each surgery. RI can be calculated as follows:

$$IR_i^k = \frac{d_s^k}{n_k} t_i^k ,$$

where k represents the professional, *k=1,2*; d is the total dose or that detected by the dosimeter in each region (vest, wrist and thyroid gland) which has been accumulated in the I surgeries, i=1,…., I (I= 29 or 21/ k=1 or k=2, respectively), and t represents the fluoroscopy amount of time used in each surgery by the k-th professional. These individual figures are added so as to evaluate the total radiation dose in every region of analysis.

We carried out an explorative analysis to describe the study, and used hypothesis tests for differences in RIs averages in both professionals together and, within each surgeon, to evaluate possible differences in the RIs averages in each region of analysis (vest vs. wrist, wrist vs. thyroid gland, etc.)

All the routines and analysis were carried out using the Stata 14.0 program (Statacorp LP. College Station, TX, USA. 2014).

Results

We analyzed the results of surgeries in 50 patients from May to December 2015. Sixty four percent of them were women who averaged 53 years of age (15.19 standard deviation [SD], ranging from 23 to 78). The total amount of time for each surgery was 40 minutes (2.06 SD), with significant differences between each surgeon (43 vs. 36 min, p=0.0436, respectively, for surgeons 1 and 2); reduction and osteosynthesis in fractures of the distal radius required 75-second radiation exposure (between 12 and 450 seconds); the current used by the C-arm was of 0.65 mA (0.20 SD), varying as the duration of the surgery did; there was no association with sex (p=0.2652), age (p=0.111) or presence/absence of fracture in the ulnar styloid process (p= 0.7921).

According to the AO classification, 54% of the fractures were type A; 14%, type B and, 32%, type C. The average length of the incision was of 4.3 cm (0.82 SD), with a minimum of 3 and a maximum of 6.5 cm.

The accumulated radiation doses (dosimeter) calculated throughout the surgeries for both surgeons are shown in the Table. Given the fact that for these absorbed doses it was not possible to register isolated amounts (unique accumulated amount) and, therefore, to get some notion of their accuracy, comparisons were made between the calculated RIs, by means of their dosimeters for each region of analysis. The average figures and their SDs, as well as p-values for such comparisons, are shown in the Table. We verified that, generally speaking, there are significant differences between surgeons (p=0.007) and between regions of analysis; for both, radiation in the thorax is less than it is in the other two regions. In one of the surgeons (FP), the RI for the thyroid gland was the highest one of the three doses calculated (0.0071), with no significant differences (p=0.545) with surgeon 1 (k=1). The distribution pattern of the calculated and relative dose, described by the total RI, was different in each surgeon; the three regions (vest, wrist, thyroid gland) got 8%, 50% and 42% in k= 1 (CA) and 15%, 31% and 54% in k=2 (FP).

Table. Values of absorbed doses and calculated indexes

Absorbed radiation doses—Indexes	Average values (standard deviation) CA(k=1)		Average values (standard deviation) FP(k=2)	
	I = 29	p	I = 21	p
Total RI	0.0125 (0.0130)*		0.0053 (0.0023)*	0.007
Vest RI (1)	0.00096 (0.0010)	-	0.00081 (0.0004)	-
Wrist RI (2)	0.0063 (0.0065)	0.002 (1 vs. 2)	0.0016 (0.0007)	<0.0010
Thyroid gland RI (3)	0.0053 (0.0055)	0.002 (1 vs. 3) 0.544 (2 vs. 3)	0.0029 (0.0012)	0.0004 0.0071
Accumulated doses: -Vest -Wrist -Thyroid gland	0.25 0.02 0.13 0.11		0.13 0.02 0.04 0.07	

RI = relative index.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

Discussion

Generally speaking, surgeons are exposed to radiation both directly and dispersedly. The International Commission of Radiological Protection[8] has set out the rules for protection against radiation, including the limitation of doses. The maximum limit of admissible dose is 20 mSv for the body and 500 mSv for the hands. However, the limit of yearly doses for unclassified staff (e.g. orthopedic surgeons) is just 30% of those limits (i.e. 150 mSv for the hands).[9] The limit of radiation for the thyroid gland is 300 mSv.[10] Although our study does not covers one year but just 8 months, we can infer that the absorbed radiation at our institution might not exceed the yearly limit (0.18 mSv).

This can contribute with some notions of the possible role that surgeons' continuous exposure plays in relationship with the presence of some conditions associated with this factor. On the other hand, if the orthopedic practices used here are to be kept, the amounts of absorbed doses that we found, which are far from the permitted limits, would not justify the use of other types of fluoroscopic instruments. In fact, we should acknowledge that surgeons are not exposed to radiation only in distal radius fractures; therefore, this RI should be added to every procedure that surgeons are exposed to fluoroscopy in.

The distribution of the secondary dose around the patient is not uniform and does not follow precisely the reverted law as the case is when it comes to punctual sources (disperse radiation), and the staff should use a great number of dosimeters to register the dose absorbed by different parts of the body such as eyes, forehead, neck, thyroid gland, fingers and hands.[11] The use of individual dosimeters can lead researchers to underestimate the effective dose. In this study, we tried to elucidate this aspect, establishing three different regions for exposure assessment.

A unique dosimeter under a protective gown for the whole body is not enough to assess the dose of radiation in other parts of the body; one dosimeter on the gown and another one beneath it is a good practice for staff which is highly exposed to radiation.

Both the inadequate or careless use of protection devices and bad practices (for example, surgeons' hands-direct exposition to the X-ray beam) could cause high radiation doses in unexpected regions and poor correlation between dosimeter data.[12] We suggest that dosimeters should be kept beneath the lead gown (for the whole body estimation), out of the platform at shoulder level, on the thyroid gland protector and in the hand.[12,13] Modern dosimeters such as thermoluminescent dosimeters can go on the forehead, on the thyroid gland protector, in ring shape. These ones should be used by the staff during procedures to assess the exact radiation dose in such anatomic regions.[14-16] We use film dosimeters because they are affordable, easy to use and resistant to daily use, sensitive to light and humidity, and they allow researchers to keep a permanent register of the accumulated dose, in general in periods of one month.

Tuhoy et al. made research in four orthopedic surgeons on the radiation received by their hands and whole body throughout one year using fluoroscopy and dosimeters in thorax, finger and beneath the lead gown. In 198 surgical procedures, they showed that the exposure time for the hands was 133 seconds with 0.063-mSv radiation per case. The average dose for the dosimeter beneath the lead gown was 0.01 mSv throughout the year. The authors conclude that the radiation that hand surgeons are exposed to might reach the yearly limit (500 mSv in the USA) after 7900 procedures carried out in one year.[4] In our series, exposure time was significantly shorter (75 vs. 133 s.), probably due to the fact that fluoroscopy is given by technicians specialized in radiology and not by the surgeon.

However, this is just theoretical time, due to the likely variations in the position of the hand (Figure 3) and the distance between the hand and the collimator, not to mention the quality of the bone. In another study, Singer et al. showed that hand exposure during procedures guided by fluoroscopy with the use of a dosimeter-ring implied a fluoroscopy time of 51 seconds and 0.2-mSv exposure per case.[17]

On the other hand, Thompson et al. calculated a total of 0.01 mSv per surgeon.[18] The comparison between these studies shows how insignificant separate absorption is. In our case, the dose for one surgeon was 0.26 mSv and for the other one was 0.13 mSv, although they are not directly comparable because they were registered in different way, i.e. in this work they were calculated accumulative and individually by means of the RI. This study showed results that, at the level of the calculated RI of absorbed dose, suggest significant differences in exposure in the thyroid gland and the wrist as compared to the surgeon's thorax.

In our study, we verified that the dosimeter in the thorax was the one receiving the lowest radiation, because it was beneath the lead vest. The remaining dosimeters received similar amounts of radiation, although the one in the thyroid gland was in front of the thyroid lead protector, and the other one was right on the skin, thus assessing the direct impact of radiation on the hand.

Indexes are variables that intend to assess or objectify quantitatively individual (or collective) events, especially events that are difficult to measure, so as to back preventive actions or act modifying such responses. They are necessary to objectify a given situation and, at the same time, evaluate its temporal behavior comparing

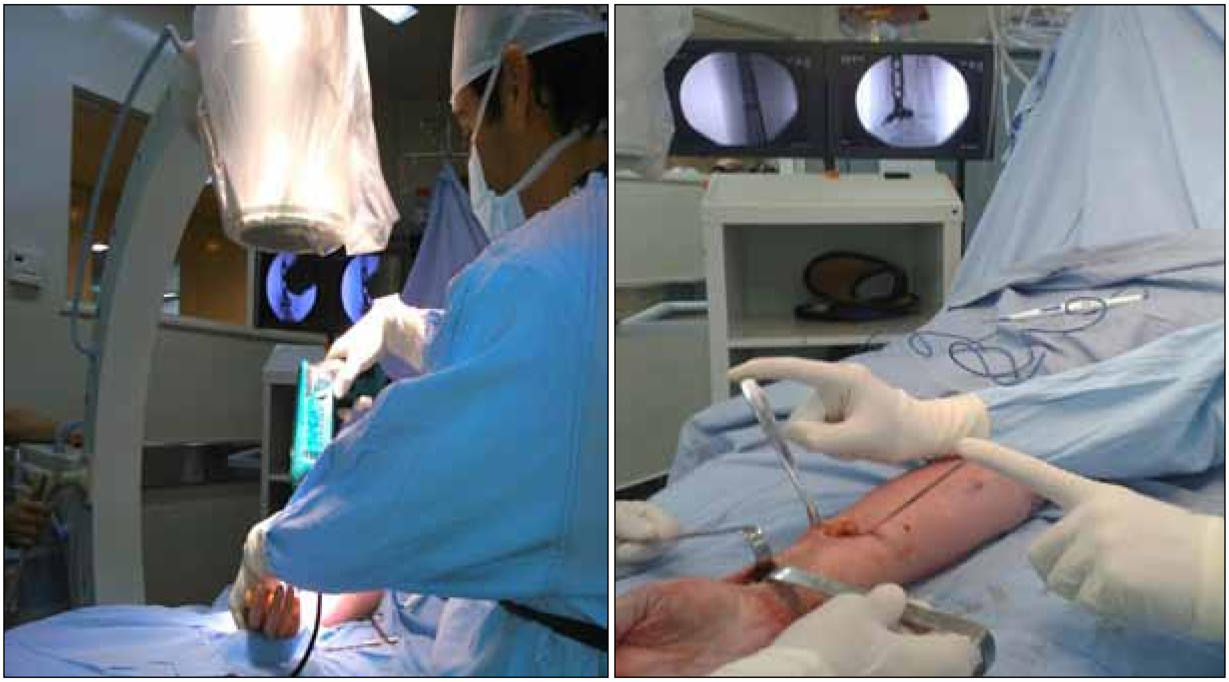

Figure 3. Variations in hands position.

them with other situations that use the same measurement method.

Without them we would find it difficult to make comparisons.

The index that we calculated in this work provides us with an indicator which, if used in the future by other professionals at other institutions, in this sense might help make comparisons, thus becoming an objective element to monitor the doses absorbed by such surgeons in their professional practice. It is calculated individually for each surgery (what is not feasible with the dosimeter per se) and it is relative to all the situations of exposure, making out of this calculation a characteristic independent of the total number of surgeries that the surgeon carries out.

Conclusions

This study showed that there are significant differences in the amount of exposure to radiation between surgeons and between the regions of the body assessed (thorax, thyroid gland and wrist). The amount of radiation received by surgeons, when only fractures of the distal radius are considered, cannot be associated with greater risk of cancer or the development of malignancy, but it will be the result of the addition of the radiation every surgeon has been exposed to during all the procedures requiring fluoroscopy what will determine whether or not every particular case runs the risk of developing cancer. Therefore, it is essential that surgeons acknowledge the importance of using all protective measures available to decrease exposure to radiation.

Bibliography

1. Gutierrez Olivera N, Ruchelli L, Iglesias S, Capomassi M, Allende C. Minimally invasive plate osteosynthesis in distal radius fractures with metaphyseal extension: A series of 13 cases. *Chir Main* 2015;34(5):227-233.

2. Mastrangelo G, Fedeli U, Fadda E, Giovanazzi A, Scoizzato L, Saia B. Increased cancer risk among surgeons in an orthopaedic hospital. *Occup Med (Lond)* 2005;55(6):498-5003. Frazier TH, Richardson JB, Fabré VC, Callen JP. Fluoroscopy-induced chronic radiation skin injury: a disease perhaps often overlooked. *Arch Dermatol* 2007;143(5):637-640.

3. Frazier TH, Richardson JB, Fabré VC, Callen JP. Fluoroscopy-induced chronic radiation skin injury: a disease perhaps often overlooked. *Arch Dermatol* 2007;143(5):637-640.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

4. Tuohy CJ, Weikert DR, Watson JT, Lee DH. Hand and body radiation exposure with the use of mini C-arm fluoroscopy. *J Hand Surg Am* 2011;36(4):632-638.
5. Cogan DG, Martin SF, Kimura SJ. Atom bomb cataracts. *Science* 1949;110(2868):654.
6. Chou LB, Chandran S, Harris AH, Tung J, Butler LM. Increased breast cancer prevalence among female orthopedic surgeons. *J Womens Health (Larchmt)* 2012;21(6):683-689.
7. Henry AK. *Extensile exposure*, 2nd ed. Baltimore: Williams and Wilkins; 1970:100.
8. International Commission on Radiological Protection. ICRP Publication 60: 1990. Recommendations of the International Commission on Radiological Protection. *Ann ICRP* 1991;2:1-3.
9. Hafez MA, Smith RM, Matthews SJ, Kalap G, Sherman KP. Radiation exposure to the hands of orthopaedic surgeons: are we underestimating the risk? *Arch Orthop Trauma Surg* 2005;125(5):330-335.
10. Bekanntmachung der Neufassung der Röntgenverordnungvom 2003. *Bundesgesetzblatt* 2003;1:604-635.
11. Vañó E, González L, Guibelalde E, Fernández JM, Ten JI. Radiation exposure to medical staff in interventional and cardiac radiology. *Br J Radiol* 1998;71(849):954-960.
12. Faulkner K, Harrison RM. Estimation of effective dose equivalent to staff in diagnostic radiology. *Phys Med Biol* 1988;33(1): 83-91.
13. Niklason LT, Marx MV, Chan HP. Interventional radiologists: occupational radiation doses and risks. *Radiology* 1993;187(3): 729-733.
14. Rampersaud YR, Foley KT, Shen AC, Williams S, Solomito M. Radiation exposure to the spine surgeon during fluoroscopically assisted pedicle screw insertion. *Spine (Phila Pa 1976)* 2000;25(20):2637-2645.
15. Mechlenburg I, Daugaard H, Soballe K. Radiation exposure to the orthopaedic surgeon during periacetabular osteotomy. *Int Orthop* 2009;33:1747-1751.
16. Harstall R, Heini PF, Mini RL, Orler R. Radiation exposure to the surgeon during fluoroscopically assisted percutaneous vertebroplasty: a prospective study. *Spine (Phila Pa 1976)* 2005;30:1893-1898.
17. Singer G. Radiation exposure to the hands from mini C-arm fluoroscopy. *J Hand Surg Am* 2005; 30:795-917.
18. Thomson CJ, La Londe DH. Measurement of radiation exposure over a one-year period from Fluoroscan mini C-arm imaging unit. *Plast Reconstr Surg* 2007;119:1147-1148.