The Great Hidden Risk.

Faaiz Ali Shah*

*Associate Professor Orthopaedics
Lady Reading Hospital Peshawar

Corresponding author:
Faaiz Ali Shah
E-mail:faaizalishah@yahoo.com

Fluoroscopy or C-arm imaging is frequently used in Orthopaedic surgery and Orthopaedic surgeons are exposed to excessive ionizing radiation and they can be considered as high risk health care workers for occupational radiation exposure.[1] This radiation exposure is an additional occupational hazard besides other risks of surgery because Orthopaedic surgeons are not classified radiation workers.[2] Unfortunately majority of Orthopaedic surgeons lack the awareness and are less sensitive to radiation hazards because the effects of excessive radiation are manifested overs months or years and are not immediately manifested or observed.[3] The C-arm fluoroscopy emits x-ray radiation which produces free radicals due to ionizing effects which lead to direct DNA damage, cell death and biological damage.[4]

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The hazards of ionizing radiation are classified as Deterministic (Non-stochastic) and Stochastic.[5] The deterministic effects are dose dependent effects which occurs above tissue specific threshold. Since the threshold level for tissues damage are very high therefore the adverse effects are manifested within hours to months and may include acute radiation syndrome, hair loss, thyroiditis, infertility, dermatitis and even death.[6] The Stochastic effects are due to cumulative radiations and are exhibited without an apparent threshold but with a dose dependent probability. These effects are manifested years or decades after radiation exposure due to accumulation of radiation in the body and Orthopaedic surgeons are more prone to this type of radiation hazard. Examples of Stochastic radiation hazards are genetic mutations and various cancers.[7]

An Orthopaedic surgeon is exposed to radiation hazards mainly from two sources namely the primary radiation exposure which occurs when the surgeon's hand or other body part comes in between the C-arm x-ray tube and the image intensifier and the scatter radiation exposure is sustained when the primary radiation beam interacts with other objects like patient body in its path.[8] It has been found that Orthopaedic surgeons are exposed to increased radiation from scatter radiation as compare to primary radiation.[4,9] Alonso[10] noted that beyond 2 meter distance from the radiation source the scatter radiation is insignificant. A standard C-arm is responsible for 1200 to 4000 mrem/min of primary radiation while the scatter radiations at 2 feet are 5 mrem/min and at 1 feet 1 mrem/min from the beam of C-arm.[11]

The International Commission on Radiological Protection (ICRP)[12] recommended that the annual safe radiation exposure for the general public should not exceed 1mSv and for occupations involving radiation exposure 20 mSv per year (averaged over five year) is the safe limit for the body, 20 mSv for the eye,150 mSv for the thyroid, 500 mSv for the hands and 500 mSv for the skin. Orthopaedic surgeons are exposed to radiations five times more than other health care workers. It has been estimated that the frequency of different malignancies were 29% in Orthopaedic surgeons when compared with control (4%).[13] Rampersaud[14] reported that radiation exposure in spine surgery was ten times more than other musculoskeletal surgeries with radiation of 58.2 mrem/min (Sv =100 mrem) to the hands during pedicle screw fixation. Singer[8] revealed that the Orthopaedic surgeon's trunk is exposed to 100 mrem radiation and hands to 150 mrem during locking of an intramedullary nail with mean C-arm time of 5 minutes. Muller[15] reported that an Orthopaedic surgeon's thyroid gland is exposed to 3.32 mrem/min radiation when C-arm is used in lateral position in intramedullary nail fixation but wearing thyroid shield can minimize this hazard by factor of 70. Mastrangelo and colleague[13] are of the opinion that Orthopaedic surgeon are five times more prone to have cancer during their life time than other healthcare workers. Literature reported higher prevalence of breast cancers and other cancers

among the female Orthopaedic surgeons when compared with the general population.[1,16-18]

Various methods haven been described in the literature for minimizing radiation hazards to the Orthopaedic surgeons while using standard C-arm fluoroscopy. Using thyroid lead protection shield of 0.5 mm reduces the surgeon's exposure by factor 12 while 0.35 mm shield reduces the radiation dose by factor 7. Protective lead glasses(0.35mm to 0.75mm) decreases the radiation exposure to eyes by factor 10.[19,20] Orthopaedic surgeons and assistants should wear lead apron(0.5 mm),thyroid shields and lead googles because lead shield minimizes radiation exposure by factor 4 in lateral view and by a factor of 16 in the AP view. Wearing lead apron within 2 meters of C-arm is mandatory.[10,21] It has been shown that the intensity of ionizing radiation is inversely proportional to the square of distance from the source of radiation and the safe distance from the primary beam of radiation is 18 inches. Therefore the surgeon and his assistant should maintain minimum distance of 18 inches from the primary beam of radiation.[22] The surgeon must wear at least one dosimeter to monitor the whole body radiation exposure. Pre operative planning, optimum technical skills and familiarity with the procedure and instruments significantly reduces operative time and radiation exposure.[23] A trained C-arm operator avoids unnecessary radiation exposure. Continuous C-arm imaging exposes an Orthopaedic surgeon to significantly higher radiation than pulsed imaging. The radiation dose is reduced to 70% with pulse mode.[24] The C-arm should be used in intermittent mode with 3 seconds burst of imaging with long off interval.[22,25] There should be an alarming system to warn the excessive C-arm use and radiation exposure.[2] The C-arm beam should be directed from medial to lateral rather than horizontal in order to avoid scatter radiation exposure to the surgeon which are maximum in the horizontal position.[26,27] The amount of radiation can be reduced by reducing the beam area and enhancing the contrast utilizing the concept of collimation.[27] The C-arm machine should have image capturing and storage capacity that would allow the operating surgeon to study intra operatively without re exposure.[2] The C-arm machines must have six monthly quality assurance technical review to monitor its radiation output and image resolution. Lead aprons and other protective shields should be stored properly by hanging them and not folding them and should be repaired or replaced if broken.[2] Lead boxes should be used for storage of monitoring dosimeters.[28] The use of mini C-arm fluoroscopy for extremity surgeries have been shown to cause less radiation hazards to the Orthopaedic surgeons than conventional standard C-arm machines.[29]

Every hospital should formulate Personalized Lead Protocol(PLP) and should employ at least one qualified radiation monitoring officer which would ensure that each and every Orthopaedic surgeon using C-arm should accurately place at least one dosimeter and checked regularly for radiation monitoring.[30] Miscommunication and confusion between the C-arm operator and the Orthopaedic surgeon leads to excessive and unnecessary radiation exposure. Development and implementation of a Standard Universal C-arm language or terminology however can minimize this hazard.[31] Post graduate training curriculum of Orthopaedic residents should include radiation safety and protection protocols. Regular radiation exposure and safety orientation sessions of Orthopaedic surgeons should be conducted on regular basis in every hospital which has C-arm fluoroscope. In fact the great hidden risk of radiation hazard due to C-arm fluoroscopy can not be reduced to zero but can be minimized if simple principal of As Low As Reasonably Achieved(ALARA) is strictly practised.[12]

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