Key Points

- **Intraoperative fluoroscopy is not a substitute** for direct visualization of limb alignment using anatomical landmarks.
- **Exposure to radiation** is a risk associated with intraoperative fluoroscopy and should be kept to a minimum.
- **Safer use of IO fluoroscopy** includes avoiding direct and indirect (scatter) exposure to X-ray beam, wearing protective gears including full body lead apron, thyroid guard, lead goggles and attenuating surgical gloves.
- **Monitoring of exposure is essential**

Any move towards less invasive surgery, with smaller incisions and surgical exposures, creates the problem for the surgeon that the dimensions, location and orientation of the bone, fracture and joints can no longer be directly and comprehensively inspected during the surgical procedure. While this could mean that there is less damage to the soft tissue envelope, we need to use other methods to ensure that fracture alignment or reduction, and implant placement are accurate. During surgery, reference to palpable anatomical landmarks and a good knowledge of normal ranges of joint mobility are invaluable. However the use of fluoroscopy to allow intra-operative inspection of the bone, joints and implants can be invaluable to achieve an acceptable degree of accuracy. There are some major difficulties with using intra-operative fluoroscopy to obtain useful images, while minimizing exposure of the patient and surgical personnel to ionizing radiation.

To safely acquire useful images, the surgeon must be prepared to plan and practice the use of intra-operative fluoroscopy. At the same time, it is important not to be overly reliant on this technology, and be willing to resort to direct visualization if the intra-operative fluoroscopy is not working out, so that personnel are not exposed to unacceptably high doses of radiation.

The major piece of equipment that is needed to effectively perform intra-operative fluoroscopy is a C-arm. The semi-circular C-arm has an X-ray source fixed at one end, and an image intensifier fixed to the other end. The output is shown on one or two display screens. The X-rays absorbed by the image intensifier cause it to fluoresce and therefore low intensity X-rays are amplified, the result being less radiation emission. The C-arm is designed to have a great deal of mobility so that it can be positioned in various horizontal or vertical orientations as needed. The X-ray beam needs to be perpendicular to the bone or joint being imaged, with the image intensifying screen as close to the patient as possible. The minimum distance from the X-ray source to the patient should be 38 cm. In order to facilitate imaging, and certainly to get two orthogonal views, it is necessary to have a radiolucent table surgery table. Not only does this allow imaging of the patient through the table, but their cantilevered design allows the C-arm to move easily under the table top.

The main uses for intra-operative fluoroscopy are pre-operatively prior to draping the patient to confirm the appropriate positioning and localization of the region of interest, then intra-operatively to guide reduction and fixation, and then post-operatively to check final fixation.

Surgeons using intra-operative fluoroscopy must be well acquainted with the dangers of radiation exposure. There are three units of measurements for describing the exposure to
radiation: 100 milirem = 1 mGy = 1 mSv (= 1000 μSv). Normal exposure rates for humans from natural background radiation are 0.01 mSv/day. This is increased by up to twenty fold by exposure to cosmic rays at high altitude flights to 0.001 to 0.01 mSv/hour. Medical exposure of humans undergoing chest x-ray is 0.1 mSv, and whole body CT is 9.9 mSv. For accidental exposure such as from nuclear bomb, the level is 500-1000 mSv which is sufficient to produce radiation sickness. Late effects of ionizing radiation are leukemia, thyroid cancer and cataracts. These can result from cumulative damage that is not determined by dosage. In human orthopedic surgery, the main dangers for radiation exposure of the patient and surgery team are with intramedullary nailing, percutaneous K wire fixation, vertebroplasty and MIPO. For example one study found that exposure of the surgeons hands with intramedullary nailing was 0.0042 mSv.

To reduce exposure of the patient and surgeon, it is important to avoid the primary beam exposure, minimize scatter and employ protective measures for the surgery team. About 10% of the x-ray beam is scattered, mainly back towards the source. Scatter is greater with uncollimated primary beam, larger patients, and decreased tube – patient distances. Surgeons standing closer to the patient will receive more scattered radiation. Protection for surgical personnel that is effective in reducing exposure includes goggles, thyroid collar, apron and special surgery gloves. In addition, the intra-operative fluoroscopy should be performed using pulsed acquisition to allow viewing on the display of saved images, rather than performing continuous screening. It is important that radiation monitors be used to document cumulative exposure levels.

Provided appropriate guidelines are followed intra-operative fluoroscopy can be very valuable in improving the accuracy of reduction and implant placement in performing minimally invasive surgery.