Minimizing Radiation Exposure in Minimally Invasive Spine Surgery

Lessons Learned from Neuroendovascular Surgery

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KEYWORDS

• Radiation exposure • Radiation avoidance • As low as reasonably achievable
• Neuroendovascular surgery • Spine surgery • Minimally invasive spine surgery

KEY POINTS

- Increased radiation exposure is largely due to increased used of radiation for therapeutic and diagnostic purposes.
- Minimizing radiation exposure can be achieved by controlling radiation doses, limiting time of exposure, maintaining distance from the source, shielding, and appropriate engineering.
- Minimally invasive spinal surgery is associated with high levels of radiation exposure, which warrants abiding by radiation exposure precautions.
- Cone beam computed tomography reduces the surgeon's exposure while increasing the patient exposure.
- Neuronavigation is an increasingly popular radiation-free technique, which can be used in certain cases of minimally invasive spinal procedures.

INTRODUCTION

Radiation use for diagnostic and therapeutic purposes has significantly increased over the past several decades. Techniques that rely on radiation for image guidance such as minimally invasive spine surgery and neurointerventional surgery have resulted in less morbidity and improved outcomes for select patients, but the issue of operator and personnel exposure remains a concern.[1,2] Protective technologies and policies continue to evolve to meet the protection needs. Incorporating these policies and technologies into practice is a challenge.

In light of the available data regarding radiation exposure, national and international organizations

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have recognized radiation risk from occupational exposure as a significant hazard to health care professionals. Particularly in specialties such as spine surgery and neurointerventional surgery, operators who are susceptible to increased radiation exposure consider that the large number of procedures they perform can benefit from other experiences in the operative field or the angiography suite.[3] Knowledge acquired in one field or the other can help promote radiation safety among neurosurgeons in general and make the operative setting a safer environment for the patient, the surgeon, and the operating room (OR) personnel (**Box 1**).

REGULATORY PROCESSES IN RADIATION PROTECTION

An increasing number of radiation-related procedures as well as an increasing number of involved personnel led to the institution of federal and international regulations aiming to control radiation exposure. As a result of international collaboration, the International Commission on Radiological Protection issued the As Low As Reasonably Achievable (ALARA) principle, which is a regulatory requirement aiming to minimize radiation exposure by using all reasonable methods. All operators using ionizing radiation are advised to abide by this principle.

Box 1
Summary of general recommendations for radiation exposure reduction

Wear protective devices (lead apron, thyroid shield, leaded glasses, leaded gloves)

Use the hands-off technique

Keep X-ray tube under the patient table

Use time-distance-shielding principle: minimize time, maximize distance, use shielding

Stand by the detector opposite to the X-ray source

Wear dosimeter

Use fluoroscope in automatic mode

Establish a radiation exposure profile of your operating room and take advantage of the room design when feasible

Use shielding even when using cone beam computed tomography scan

Beware of a false sense of safety while wearing protective equipment

KEY CONCEPTS IN RADIATION PHYSICS

Radiation comprises energetic particles or energy waves traveling in space. When these particles or waves have enough energy to liberate electrons from atoms or molecules, this is known as ionizing radiation. Radiation propagates in a forward linear direction in air. At the air-matter interface, physical phenomena such as absorption, reflection, refraction, and scattering may occur, possibly leading to secondary sources of radiation. Many variables can be used to quantify radiation exposure. The most common methods of measuring radiation in medicine include absorbed dose and equivalent dose, which are measured in Gray and Sievert, respectively. One Gray and 1 Sievert both correspond to the absorption of 1 J of energy per kilogram of matter. However, the Sievert is corrected to express the equivalent dose for a fixed mass of biological tissue.

BIOLOGICAL EFFECTS OF RADIATION

Ionizing radiation damages cells by incurring direct injuries to DNA molecules or by inducing free radicals, which may affect DNA as well as other cellular structures. Low-dose radiation is usually believed to cause stochastic effects such as mutations, which may result in cancer, and hereditary diseases. However, data regarding low-dose radiation exposure remain limited because most low-dose human ionizing radiation risk estimates come from studies conducted on atomic bomb survivors in Japan.

Large doses of radiation might also cause stochastic effects; however, they are more likely to induce direct necrosis or fibrotic changes. Documented radiation effects range from skin irritation to instantaneous death. Mild radiation sickness necessitates a dose that is 10 times higher than US radiation workers' annual limit.[4] Organs that are particularly sensitive to radiation include skin, the eyes, and most mucosal membranes. Acute radiation doses delivered to skin during a single procedure or closely spaced procedures may induce skin erythema at a dose of 2 Gy, permanent epilation at a dose of 7 Gy, and delayed skin necrosis at 12 Gy. Secondary ulceration may occur at 24 Gy.[5–7] Eye exposure may cause cataract if 2 Gy of radiation is received in a short period or if 4 Gy is received in less than 3 months. Cataract may occur as a delayed effect if 5.5 Gy is received in more than 3 months.[5–7]

SOURCES OF RADIATION

In its 2008 report to the United Nations General Assembly, the United Nations Scientific Committee