gap technique can be considered, provided a small focal spot is used for cine recordings.

Use of the air gap technique, however, can limit the effects of scattered radiation on image quality without the increased dose from the grids.[79] With the image receptor moved approximately 15 cm from the patient, most of the scattered x-rays emitted from the patient bypass the receptor and, do not degrade image quality.[79] All the unscattered x-rays reach the receptor when the grids are removed; this increased dose to the receptor allows the automatic exposure control system to decrease the dose rate delivered. The air gap technique has the added benefit of creating geometric magnification of the image without increase in dose. Fifteen centimeters of air gap approximates a 1-step increase in electronic magnification. It is important to recognize though that the air gap technique can increase patient entrance dose if it is achieved by bringing the patient closer to the x-ray tube. Also, the air gap technique should not be used with the antiscatter grids in place, as this redundancy increases the overall dose.[79]

11.4.3. Best practices of operator conduct. Even though operator conduct forms a crucial pillar of radiation dose optimization, it is important to emphasize that staff plays an equally vital role in radiation dose optimization, and in alerting the operator when suboptimal settings and practices are being used for a procedure.

Prior to and during each case, the operator should employ the following strategies to decrease dose to the patient and medical personnel:

Selecting protocols and settings:

- The operator should select the proper patient size and type of exam to bring forth the configured parameters for dose and image quality optimization that include frame rates for fluoroscopy and cine acquisition, as well as fluoroscopy mode.
- Lower frame rates for both fluoroscopy and cine acquisition translate into lower doses at the expense of temporal resolution. Because the eye has fewer frames to integrate temporally, the noise level appears to increase at lower frame rates. Some systems automatically adjust for this by increasing the dose per frame slightly to maintain a constant level of perceived noise. Therefore, the dose rate reduction may not be directly proportional to the frame rate reduction on all systems.
- Pulsed fluoroscopy should not exceed 15 pulses/second, and acquisition frame rates should not exceed 30 frames/second.[79] Lower frame rates can be used for patients with slower heart rates or when imaging slow-moving structures, such as during venography or balloon inflation.[79]
- Modern x-ray systems also allow the operator to select from a number of fluoroscopy dose rate modes (usually 3-4 modes, such as low/medium/high). The mode determines the radiation dose rate at the image receptor and affects the amount of noise in the image.
- A lower detector dose translates into a lower patient dose but with greater image noise. Using a lower dose mode can potentially reduce radiation exposure by as much as 50% or even more, and, as such, it is recommended to start in the low dose mode and only increase if needed for image quality.

Assess need for antiscatter grids and table/patient distance to tube and detector:

- Remove the antiscatter grids during procedures on small patients (<20 kg) or when the image receptor cannot be placed close to the patient (geometric magnification technique).
- Position the patient at the imaging isocenter and raise the table to increase the distance from the tube to the patient. Table height may be limited by the lateral detector positioning, but increasing the distance between the x-ray tube and the patient decreases dose to the patient's skin by the inverse square law.[79]
- Unless an air gap is being used to mitigate scatter, decrease the distance between the patient and the image receptor.

Use the lowest acceptable electronic magnification:

- The field of view (FOV) is the area of the x-ray field at the entrance plane of the detector. When not using magnification, the x-ray beam irradiates the entire surface of the detector. In electronic magnification modes, there are successively smaller areas of beams to the receptor, which magnifies the image anatomy on the monitor and therefore may improve perceived image resolution. For image intensifiers, the dose rate to the patient increases with a smaller FOV proportionally to the inverse of the FOV change. For example, when the FOV is halved, the patient dose is doubled. While this may not have a significant impact on DAP in pediatric patients, it is an important consideration for tissue effects in larger patients.

Collimate the image:

- Collimation reduces the volume of tissue exposed to the primary beam, thereby sparing the surrounding tissue and organs from direct irradiation (and reducing the DAP in the process), and it also reduces scatter. The reduction in scatter at the detector leads to improved image contrast, which helps to visualize small stents, for instance. Exclusion of radiolucent lung tissue also improves image contrast, due to the automatic brightness control feature of the fluoroscopy unit.[84] Collimators should always be visible within the field.

Dim the room lights:

- Dimmer ambient lighting improves contrast perception and makes the monitors appear brighter.

Limit excessively oblique imaging angles:

- These angles require the beam to pass through more tissue, degrading the image quality and increasing the dose to the patient.[79]

Ensure that the patient's arms are not in the x-ray beam:

- Arms in the beam increase the x-ray path length through the patient, resulting in an increase in patient dose rate. Also, the arms of adult patients can be very close to the lateral plane X-ray tube, resulting in an unnecessary risk of skin injury to the arm.

Limit fluoroscopy time:

- Radiation dose increases with longer fluoroscopy times, and, therefore, the beam should only be on when the operator is looking at the image.

Use saved fluoroscopy, instead of cine acquisition, when appropriate:

- Stored fluoroscopy significantly decreases dose, as the dose rate per frame during acquisition is 6 to 10 times greater than during fluoroscopy.[79]

Alternating beam angulation:

- During long procedures, consider altering the beam angulation to change the area on the patient's skin that is in the direct x-ray field. This is particularly important in larger patients who are at increased risk of tissue effects.