

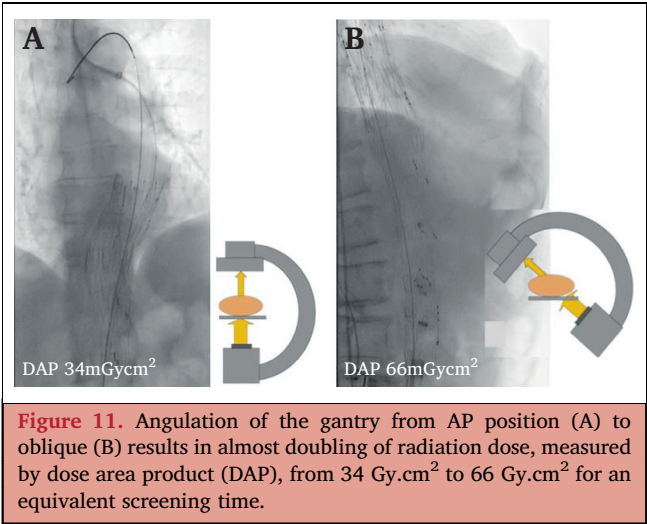
reaching a maximum at full lateral projection;¹⁶⁵ and (3) steeper angles place the Xray source closer to the patient increasing skin dose and deterministic injury risk, one study reporting 83% of all radiation skin injuries occurring with steep angulation.^{111,139,145,150,171} It is advisable that whenever possible, the operators should maintain maximum distance from the radiation source.

On a phantom model, AP projections resulted in 5 mSv/hr operator exposure increasing to 11 mSv/hr at a 45 degree projection, and 69 mSv/hr at 90 degrees.¹⁷¹ Steep angulation such as that required during complex aortic repairs results in higher scatter to the operator, particularly at head level,¹²⁰ with operator radiation exposure being six times higher if they are on the same side as the Xray source (Fig. 11).⁶² Cranial left anterior oblique projections cause the most exposure^{6,120,147,160,165,232} because the radiation source is usually on the same side as the operator in this configuration leading to maximum backscatter towards the operator.^{165,176} If possible, the Xray beam should always be positioned on the opposite side from the endovascular operator.

In prolonged cases, frequent alterations in gantry angulation have been recommended to reduce skin dose,^{112,146,233} but steep cranial and lateral angles should never be used for this purpose.²³³ In obese patients steep angulation compounds the risks and should be used very sparingly.^{26,145} When steep angulation is essential, it should be used for the shortest period of time with adequate collimation applied.¹³⁸

Recommendation 26		
Prolonged use of steep gantry angulation is not recommended during endovascular procedures.		
Class	Level	References*
III	B	Durán <i>et al</i> (2013), ¹⁴⁷ Haqqani <i>et al.</i> (2013) ¹⁷¹

*Physics principle



5.11.3. The inverse square law and stepping away. Scatter radiation comprises the main source of radiation exposure to staff, and by minimising patient dose, scatter consequently is reduced. However further steps can be taken to reduce exposure to scatter, the most fundamental is to observe the inverse square law ($X = 1/d^2$, X = exposure, d = distance). As scatter exits and moves away from the patient there is an exponential reduction in the number of photons per unit area, and hence potentially harmful ionising energy. Doubling the distance from the patient quarters exposure and tripling distance reduces it nine fold. This simple but highly effective act of stepping away from the patient during DSA can considerably reduce personal radiation dose and is a cornerstone technique to lower exposure.^{7,145,147,165,173,176} If there is no need to be in close proximity to the Xray source or patient, particularly during high dose acquisitions (DSA runs), then staff should step away as far away as is practical or even exit the room.¹⁶⁵ Indeed it has been suggested that this should be mandatory behaviour if it does not compromise the safety of the patient. A relatively safe distance is considered to be 1 – 2 m,⁷ and at 5 m operator dose is effectively eliminated.¹⁶⁶ Whenever possible, personnel should aim to increase their distance from the radiation source because even moving away by a small distance can have a substantial effect on the amount of exposure. Standing closer to the feet of the patient rather than the abdomen during pelvic interventions has also been shown to be beneficial.¹⁷²

5.11.4. Positioning around the table. The highest intensity of scatter is located on the Xray beam entrance side of the patient,¹⁴⁷ usually under the table or in left anterior oblique (LAO) projections with the operator standing on the right of the patient. Generally, doses are much higher for primary operators compared with assistants and scrub nurses.^{114,165} During complex aortic repairs the principal operator can receive twice the dose of the first assistant standing next to them.⁵ The person standing at the opposite side of the table, typically the second assistant standing at the patient's left groin or arm, will receive the next highest dose. The third assistant and scrub nurse position receives undetectable levels for most cases. Linked to gantry position, the variable radiation dose received at different table positions is the result of an asymmetric scatter cloud created by interaction of scatter with the complex infrastructure of an angiographic table. Rather than scatter decreasing in predictable concentric circles according to the inverse square law, which governs radiation behaviour in a vacuum, non-conforming patterns of scatter are created around the table.¹⁷⁶ Lateral projections were associated with seven times higher exposure than 45 degree projections, with maximum exposure at the operator and assistant positions if on the same side as the emitter.¹⁷¹ While this should in no way derogate the advice to step away whenever possible, it emphasises the need to move personnel away from the patient when standing on the emitter side of the table during DSA runs, as this is where the highest radiation doses are observed. It is vital to also convey this message to