COMMENTARY

From Flatland to the Fourth Dimension

If this title evokes space travel rather than radiology, there is a parallel. How far we can go is in both cases limited by the effect of radiation on the human body.

Thirty years ago, radiology emerged from the flatland of 2D imaging when CT provided routine imaging with 3D spatial resolution. Multidetector CT now provides routine 4D imaging—by combining excellent 3D spatial with temporal resolution.

As a rough approximation, each new dimension has increased the patient dose penalty by an order of magnitude. Conventional radiographs are made with maximally exposed tissue doses in the 1–10-mSv range, but CT delivers a dose in the 10–100-mSv range. As an article by Cohnen[1] attests, dynamic imaging with multidetector CT is now pushing maximally exposed tissue doses into the 100–1000-mSv range. Although this is still below the dose range where threshold effects are observed (if the fetus is excepted), it is within the range where there is unquestioned epidemiologic evidence that exposure of many tissues to X-radiation is associated with increased cancer incidence.[2] At lower doses, cancer risk estimates are based on models that assume a linear relationship between risk and dose, which implies that the risk of any new exposure is independent of prior exposure. If so, there is no general need to consider past exposure to justify an additional low-dose procedure. The risk-dose models tend to depart from linearity in the higher dose range, however, and the potential for exceeding a dose threshold for a specific tissue as a result of repeated exposures is a concern if the accumulated dose is large enough and spread over a short enough time interval.

Cohnen's article reports the highest localized doses to cerebral tissues and skin of about 400 mSv in simulations of computed tomography perfusion (CTP). They cite another[3] article that associates the combination of CTP and angiography with observations of hair loss. It is most probable in the latter case that the greater part of the dose was received during angiography. Those who perform fluoroscopically guided interventional procedures are generally aware that localized skin doses may exceed 1000 mSv,[4] but, whereas fluoroscopy may deliver a large dose to skin, it gives less to the unseen deeper tissues. CT deposits relatively uniform doses to all tissues in each scan field and overlapping scan fields will be associated with larger tissue doses in the area of overlap.

The methods that are commonly used to describe dose have limited value if a specific tissue dose is a concern for an individual patient. Computed tomography dose index (CTDI) in its various forms characterizes dose to a centered plastic cylinder of fixed size. Its primary value is in comparing devices and techniques. CTDI values are commonly displayed on the console after a patient scan. While this is useful, the numbers so displayed are to a virtual phantom, and do not represent actual doses to the patient or to any specific tissue. Effective dose (the risk-weighted average dose to the body organs) is commonly used to compare diagnostic procedures to one another and to natural background exposures. Its validity rests on the questionable assumption that tissue risks are accurately known and are linearly related to dose. Its value is typically estimated from phantoms and mathematical models so it is only an approximate index of risk to an actual patient – and particularly so if specific tissues receive large doses. It would in fact be difficult to obtain information on dose to the specific tissues of specific patients in general, should medicine or society demand it.

Greater risks associated with higher tissue doses may well be justified if tangible medical benefits are realized by patients, but there are valid concerns about inappropriate use and repeated exposure of the same tissues. How the medical community deals with these issues may well determine how well society will accept the potential of the higher dose modalities. Educational programs should therefore re-emphasize both dose distribution and radiation biology if technology continues to push into the higher dose range. Curiously, such concepts may have been better instilled in the simpler technological days when training programs involved both the therapeutic and diagnostic applications of radiation, but the generations so trained are departing the scene, and a return to flatland is not an option.

References

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