Proposed Revisions to Digital Prime Image Quality Factors

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Given the changes brought on with the adoption of digital technology, it is clear that the four traditional primary image quality factors, which were identified as either photographic or geometric properties, are in need of revision. Photographic perspective is no longer pertinent, as it reflects film-based radiographic imaging. Therefore, we propose that photographic or visibility of detail properties be renamed *image signal*. Furthermore, digital image detail is controlled by much more than the geometry of the beam, and as such should be renamed *image resolution*. Revision to the prime quality factors that control image signal and image detail, as outlined in figures C and D are discussed in their respective sections below.

Image Signal. *Image signal* refers to the fact that the radiographic image is evident only when sufficient signal value (IR exposure) and signal differences (contrast) are received by the image receptor to permit the structural details to be perceived. Therefore, the two quality factors that control image signal are signal value and signal differences.

Signal value is the new term proposed to replace IR exposure and can be defined as total accumulated charge in the detector element that is dependent on the amount of exposure. When evaluating signal value (IR exposure) and critiquing technique exposure factors on a digital image, it is important for radiographers to realize that this process has changed and that older visual evaluation cues used with film-screen systems are no longer appropriate. Radiographers accustomed to film-based evaluation may be inclined to use monitor brightness to critique exposure factors.[1] However, brightness is a monitor control function that allows the radiographer to change the lightness and darkness of the image on a display monitor, but it is not related to IR exposure.[2] Unless a radiographer evaluates exposure indicator values, he or she may find images to be acceptable even when proper signal value is not achieved. Consequently, signal value must be evaluated using target exposure indicator values (EI_t). A wide variety of factors affect signal value (IR exposure). The mAs is still a primary influencing factor, along with a number of other factors that have not changed, including kVp, distance, filtration, beam restriction, anatomical part, and grid. Furthermore, fill factor and detector sensitivity need to be considered as additional influencing factors. *Fill factor* refers to the sensing area of the detector element compared to the non-sensing area, and is expressed as a percentage. The fill factor has a direct relationship with both the spatial resolution and the contrast resolution. A higher fill factor percentage results in increased detector sensitivity.[2,4] *Detector sensitivity* can be "defined in terms of the charge produced by the detector (before any external amplification) per incident x-ray quantum of a specified energy".[3] Both of these new factors are inherent to the detector and cannot be changed by the technologist.

Signal differences (contrast) can be described as the range of signal values, from highest to lowest. Because signal differences (contrast) consist of various signal values (IR exposures), any change in overall signal value (IR exposure) will affect signal differences (contrast). The influencing factors that affect signal differences (contrast) still include mAs, kVp, filtration, anatomical part, and grid construction. In addition, detector dynamic range needs to be considered as an influencing factor.[2] *Detector dynamic range* is the spectrum of signal values (IR exposures) that an image receptor can detect and use to form an image.[1] Digital image receptors can respond to a wide range of exposures, from as low as 0.01 mR up to 100 mR.[2]

Image Resolution. *Image resolution* is the amount of detail a digital image can contain. Good detail exists even when it is not evident due to poor image signal, which occurs when the signal value (IR exposure) and/or signal differences (contrast) are poor. We propose that the first of the two original geometric properties, spatial resolution, be revised and now include the second original geometric property, distortion. In addition, *contrast resolution* is proposed as the second image resolution property.

Spatial resolution still describes the ability of an imaging system to accurately display objects in two dimensions. Spatial resolution is higher when two objects can be demonstrated to be smaller or closer together. The original factors that affected spatial resolution, beam geometry, image receptor, and motion[2] should be replaced by beam geometry, temporal resolution, and IR resolution. *Beam geometry* has been revised as an influencing factor for spatial resolution and is now affected by the focal spot, distance, and distortion. *Temporal resolution* is the relationship between the duration of signal acquisition (exposure time) and dynamic motion of the anatomy. As acquisition time increases, temporal resolution decreases, which impacts spatial resolution. *IR resolution* reflects the properties of the detector. It is controlled by the detector matrix size, detector element (DEL) size, fill factor, DEL pitch, and sampling frequency for digital radiography (DR) systems. *Detector matrix* is an array of elements laid out in rows and columns. The individual matrix elements are known as DELs. DELs are charge- collecting elements of the digital detector and are positioned in a matrix. *DEL size* is defined as the size of the detector element. *DEL pitch* is defined as the physical distance between DELs and is generally measured from center to center. *Sampling frequency* is the rate at which signal is sampled from the exposed detector.[2,3,4]

Contrast resolution refers to the ability to distinguish between very subtle differences in signal values and differentiate them from the noise in the image.[4] Low-contrast resolution is a characteristic of contrast resolution that deals with the ability to visualize subtle energy differences, particularly in soft tissues. Contrast resolution is impacted by the *image receptor (IR) contrast* and *subject contrast*. *IR contrast* is the range of signal values acquired by the image receptor. It is controlled by the detective quantum efficiency (DQE), bit depth, and dynamic response of the detector. *DQE* is a measure of the sensitivity and accuracy by which the image receptor converts the incoming data to the output viewing device. *Bit depth* is defined as the number of shades of gray in each detector element.[1,2,4] *Dynamic response* deals with the ability of a detector material to sense the incoming energy. Since the primary interaction with the detector material is photoelectric absorption, the DEL material needs to be able to function at a k-edge value that is consistent with the energy value striking its surface. Energy values that are outside the k-edge response of the detector will not be measured, as they do not create enough accumulated electrical charge in the DEL to generate a signal. Consequently, the response is not there. Manufacturers design detectors to have a wide detector response range, so terms *dynamic response* and *detector dynamic range* are closely related, but not interchangeable. *Subject contrast* is the range of differences in the intensity of the x-ray beam after it has been attenuated by the subject, but before it has been detected. This range of differences is the result of the differential attenuation by the tissues in the body. It is dependent on kilovoltage and the amount and type of irradiated material. Unlike image contrast, subject contrast cannot be manipulated with post-processing because it is directly influenced by the attenuation properties of the tissues.[1,2] Therefore, subject contrast is still controlled by the kVp and irradiated material.[2]

Figure A. Revisions to "Visibility of Detail"

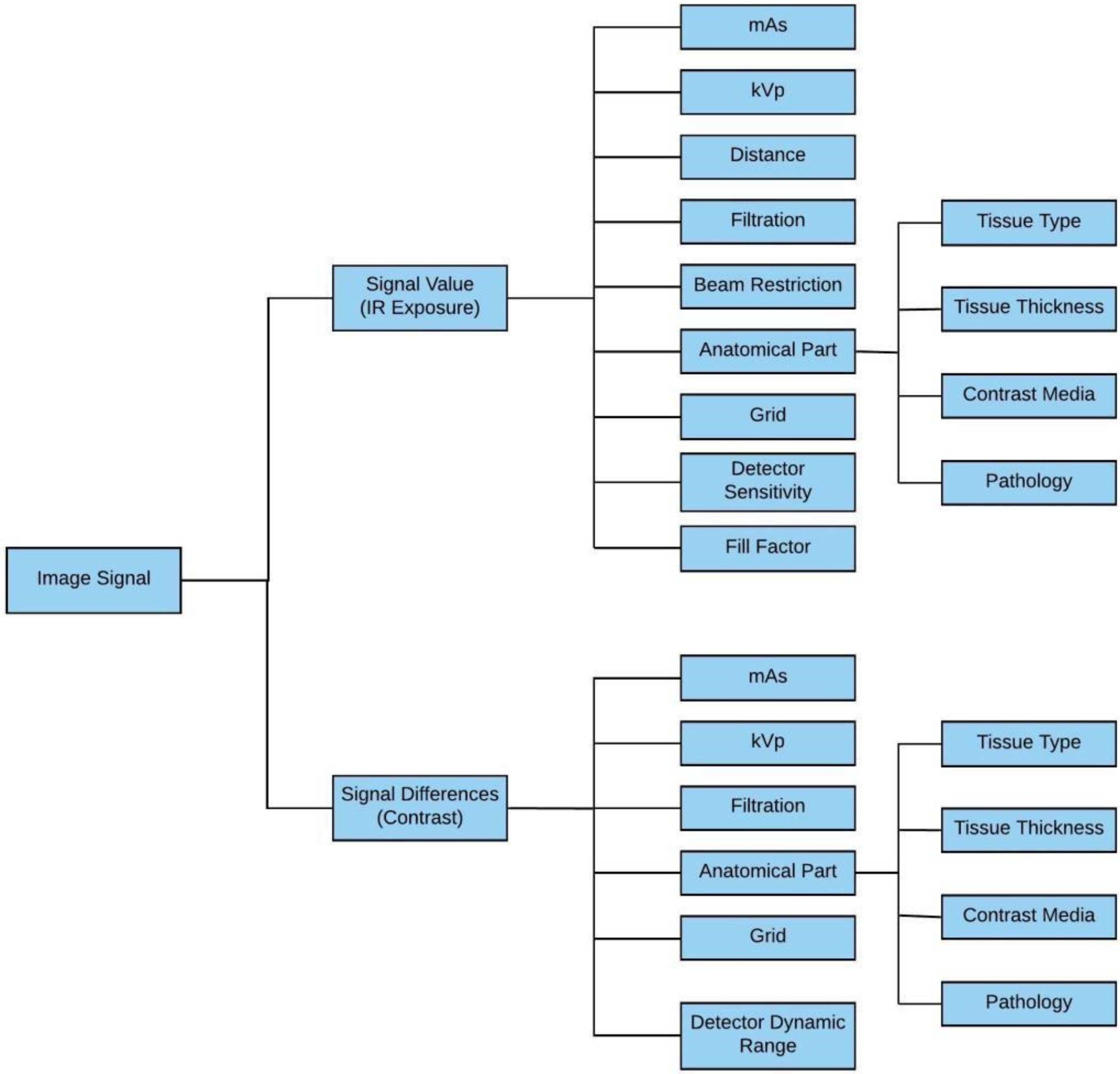
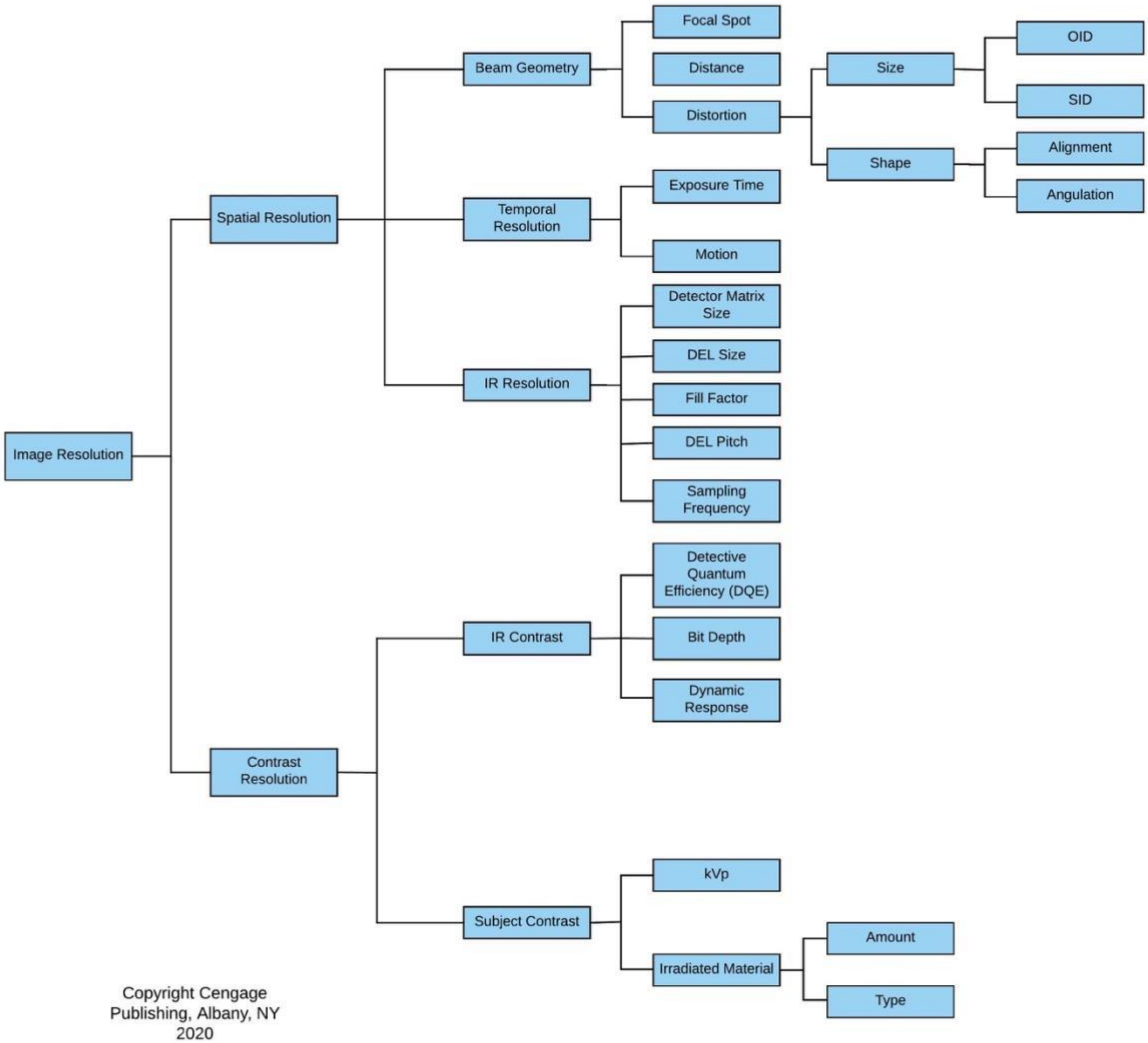


Figure B. Revisions to "Geometric Properties"



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2. Carlton R, Adler A, Balac V. *Principles of Radiographic Imaging.* 6th ed. Boston, MA: Cengage Publishing; 2019.

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