Q.A. Collectible

Sponsored by CRCPD's Committee on Quality Assurance in Diagnostic X-Ray (H-7)

kVp Measurements

The voltage applied across an x-ray tube determines the quantity and energies (quality) of x-rays produced during an exposure. Peak kilovoltage (kVp) is the maximum voltage applied across the x-ray tube and governs the maximum energy of x-radiation produced. Accurately calibrated and consistent kVp's are important in diagnostic imaging to control both optical density and contrast of the x-ray image as well as radiation dose to the patient.

The operator's manual should be consulted for limitations and proper operation of the meter. Some instruments need a limited range of exposure or exposure rate for proper operation and may require reducing distance for measurements at a low kVp or mA. Others are sensitive to positioning and tilting with respect to the central ray. Still others may require additional correction factors for use with heavily filtered x-ray tubes or high frequency generators. It is essential that the user be aware of the potential problems that may be encountered, and skeptical of measurements that vary from expected results. Perhaps the best advice is to note the unusual reading and indicate that further investigation by service personnel appears warranted.

The most direct way of measuring kVp is by using a high voltage divider. This invasive test device is connected between the generator and the x-ray tube and provides isolated low level analog voltage signals proportional to the kilovoltage applied across the tube. The signal waveforms can be displayed and analyzed on an external oscilloscope or measured by a digital meter. The peak kilovoltage can be visually determined from the voltage waveform displayed on the oscilloscope. These devices are typically intended for calibration and analysis of x-ray generators.

Electronic, non-invasive kVp devices provide a measurement based on the change in x-ray transmission through varying thicknesses of filtration. These devices are accurate (if properly used) and widely employed for routine quality control due to their ease of use. However, it is important to understand how the meter works and what measurement variables may affect the accuracy of the results. These considerations may vary from one type of meter to the next and from one generator to another.

The kVp meter basically consists of a pair of matched, closely spaced diodes that are filtered by different thicknesses of material, e.g., copper. The ratio of the signals from the filtered diodes will depend on the energies of the x-ray beam (which are determined by the tube voltage). This ratio is electronically compared against an appropriate calibration "look-up" table to obtain the kVp.

Most non-invasive instruments do not measure true peak voltage, but rather a value that is integrated over exposure time and the ratio of the signals. This value is called effective kV (kV_{eff}) and is lower than the actual kVp. Knowing the amount of ripple in the waveform, the instrument can correct this

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value to provide an effective kVp (kVp_{eff}). Some instruments will automatically select the appropriate waveform calibration (e.g., single vs. three-phase) while others require the user to turn a knob to the appropriate setting.

On occasion, when using a kVp meter an abnormality may appear during a measurement in which an unusually high reading is observed, but cannot be reproduced. This may be due to a voltage spike, which is potentially damaging to the x-ray tube.

Many dental x-ray machines contain self-rectified x-ray tubes, which should not affect kVp measurements. However, generations in these units tend to have poorly regulated circuits that could allow the kVp to vary significantly during an exposure. Also, the preheat cycle for some dental x-ray tubes may generate sufficient x-rays to trigger the electronic kVp measurement, resulting in erroneous results. Accordingly, a single digital readout from a noninvasive kVp meter could be misleading. Unless the x-ray output waveform is viewed, the total kVp picture is not seen.

Measuring fluoroscopic kVp is a challenge due to the time necessary for the exposure to stabilize. Also, the low mA causes high voltage cable capacitance, which distorts the waveform, resulting in erroneous measurements.

High frequency generators may also cause problems in obtaining accurate kVp measurements. The x-ray pulse rate from the generator may change with different technique factors and may correspond to the sampling rate of the kVp meter. Therefore, the coincidence of the meter sampling rate versus the x-ray pulse rate, or lack thereof, may cause measurement errors.

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