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Abdominal CT at Low Peak Tube Potential Settings Brings Promises, But New Rules Apply

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What would happen if you clicked that often-ignored button over there on the CT console? Is it possible that the adjustment of one setting may bring many benefits to abdominal CT? Data are emerging to suggest that there may be such a button.

The speed and robustness of modern CT certainly impress, but concerns remain regarding the associated exposure of patients to ionizing radiation and contrast material. In particular, during recent years radiation exposure and patient safety at clinical imaging have assumed a central place in the minds of the public and physicians and are the drivers for many innovations in imaging safety. Risk reduction without loss of diagnostic image quality is our new focus.

Since the early days of contrast material use with planar radiography, we have known that lower peak tube potential settings exponentially decrease radiation dose and improve contrast material conspicuity by up to 70%. Historically, when CT x-ray tubes were not as powerful as those currently available, higher peak tube potential settings, such as 120 or 140 kVp, were chosen as a compromise to provide diagnostic CT images with a reasonably short scan exposure time. Unfortunately, low-kVp settings were largely impractical because of the associated low x-ray flux that did not provide reliable penetration of many body parts.

Ironically, because CT x-ray tubes were engineered to accept higher tube currents to generate greater x-ray flux, the possibility to use reduced-radiation-dose, low-kVp settings has been realized for an increasingly broad array of applications—most notably, in brain perfusion scanning and scanning pediatric patients where the girth of the imaged anatomy is relatively small. Application of low-kVp imaging in the adult abdomen has lagged because the abdomen is typically the physically thickest section of the human anatomy and hence requires the greatest x-ray penetration.

In this issue of the American Journal of Roentgenology, Nakaura et al. [1] and Yanaga et al. [2] present two reports about the use of low CT tube potential settings at clinical abdominal

CT and help address the relative paucity of studies in the literature on this technique in abdominal imaging. Nakaura et al. report how a low-radiation-dose, low-kVp CT protocol improves portal venous phase CT image quality, and Yanaga et al. report that a liver CT protocol using a low-radiation-dose, low-kVp setting and a low contrast material dose improves CT image quality and hepatocellular carcinoma conspicuity when compared with a more conventional CT protocol. Notably, these studies are of Asian populations with lower mean abdominal girths than are seen in many Western countries—an important consideration even with our more powerful modern scanners. Indeed, Nakaura et al. describe the need to use the maximum allowable tube current at the low-kVp settings for most patients to make such imaging feasible and images sufficiently low noise for diagnostic interpretation.

When evaluating low-kVp studies, it is critical to consider image noise. Rather than looking at mere increases in IV contrast enhancement in simple Hounsfield units that result from the use of lower kVp settings, one must see whether the contrast-to-noise ratio or figure of merit (an assessment of contrast-to-noise ratio relative to the effective radiation dose) actually points to an improvement in image quality. Future studies will need to address whether better image quality and lesion conspicuity actually result in improved lesion detection and specificity of diagnoses.

Regarding subjective assessments of image quality, it is inappropriate to use identical window and level settings to view different kVp images, even though this method is commonly reported in the radiology literature. When viewed with identical window and level settings, images obtained at higher kVp settings invariably look “washed out” compared with those obtained at lower settings. For the latter, the effective range of contrast enhancement is much wider—the fat is much lower and calcium and iodine much higher in CT number—and often undervalues the low noise that is usually present in high-kVp images. Ideally, window level settings should be tailored for every scan to highlight relative contrast material enhancement in that particular scan. At daily readout, the level should be set dynamically at the mean CT number of the tissue of interest and the width should be set to encompass the range of CT numbers in the tissues of interest.

Questions also arise regarding prior established diagnostic standards that rely on hard CT Hounsfield unit thresholds, such as for the diagnoses of fatty liver and adrenal adenomas, which were largely based on a 120-kVp setting. When lower or higher peak potentials are used, the older thresholds no longer hold true and new diagnostic standards will need to be set.

A tantalizing aspect of lower-kVp CT is the potential reduction in required contrast material doses, which may improve patient comfort and reduce the risk of contrast-induced nephropathy. However, the benefit is not only smaller doses, as Yanaga et al. [2] report, but also the potential ability to deliver a tighter contrast bolus with a shorter injection time. For the liver, a tighter bolus allows one to better separate the arterial phase from portal venous inflow contamination that may reduce the conspicuity of liver lesions. Of course, to reap this benefit, one also must accurately time the scan because the window of opportunity for an optimized scan becomes less forgiving. We know that patients vary widely in their cardiac

output, even from day to day, and clearly further research is needed to determine patient-specific scan delays in the modern era.

Finally, the biologic effect of radiation at different energy spectra is still poorly understood. What is the relative biologic effect of 80-kVp energy spectra versus that delivered at 140 kVp? At first glance, a reduction in radiation dose should be beneficial. However, we know that lower-energy x-rays are more completely absorbed, rather than scattered, and may be more ionizing than higher-energy x-rays. Is the use of lower CT tube potential settings more harmful despite the delivery of a lower dose?

No single article will answer all of these intriguing questions and we can look forward to unraveling the puzzles that improved CT technology brings. However, one thing is clear: As CT technology advances, the safety of the CT examination is dramatically improving. It is up to us to learn to use CT wisely and to educate our colleagues regarding the rapidly diminishing risks involved with CT.

References

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