The Correct Selection of Pitch for Optimal CT Scanning: Avoiding Common Misconceptions

Frank N. Ranallo, PhD, Timothy Szczykutowicz, PhD

Today's state-of-the-art CT scanners include many features that aid in the selection of optimal technique parameters. Vendors offer solutions for choosing the optimal beam energy (tube voltage), automatic exposure control (AEC) via tube current modulation control, patient positioning within the gantry, and patient-specific contrast injection protocols. The trend seems to be leading to a "push button" CT scanner in which only the dose, noise level, and image sharpness, determined by the clinical indication, need to be prescribed. This trend will likely decrease the frequency of nondiagnostic CT scans. However, it should not mitigate the need to understand some of the fundamental relationships between acquisition parameters and dose. We illustrate the most common misconceptions concerning the selection of pitch in this article.

What are these misconceptions? There are 2 major ones: (1) a good way to reduce patient dose is to increase the pitch, and (2) pitches < 1 overirradiate the patient because of "overlap" of the x-ray beam irradiating the patient.

MISCONCEPTION 1: A GOOD WAY TO REDUCE PATIENT DOSE IS TO INCREASE THE PITCH

With modern CT scanners using AEC, patient dose and image noise are not affected by the pitch, so trying to decrease dose by increasing the pitch is completely ineffective. The dose and noise are determined by the setting of specific AEC parameters depending on the manufacturer of the CT scanner. If the pitch is increased, the AEC system on the scanner will simply increase the tube current to keep the dose and noise constant, as determined by the parameter selection in the AEC system. For GE and Toshiba, this parameter is the noise index, or the standard deviation (SD), and indicates the amount of image noise that is selected for the CT images. For Siemens and Philips, it is the quality reference tube current-time product (mAs), or the mAs per slice, which are "effective mAs" values that would be used for a reference size patient. (See the American Association of Physicists in Medicine's CT lexicon for a complete listing of vendor terminology related to AEC [1].) For all vendors' AEC systems, patient dose will increase as patient size increases.

When using AEC, the following steps should be used to reduce patient dose:

- Adjust the AEC by either increasing the noise index or SD or by decreasing the target effective mAs or mAs per slice, depending on the type of scanner used.
  - For scanners using the noise index or SD for AEC control, to decrease the dose by a certain factor, increase the noise index or the SD by multiplying it by the square root of that factor. For example, if the dose should be reduced by a factor of 2, multiply the noise index or SD by $\sqrt{2}$.
  - For scanners using the target effective mAs or mAs per slice for AEC control, to decrease the dose by a certain factor, decrease the target effective mAs or mAs per slice by dividing it by that factor. For example, if the dose should be reduced by a factor of 2, divide the target effective mAs or mAs per slice by 2.
- Finally, reduce the rotation time by the amount allowed by the scanner tube limits. This last step will not affect the dose but will automatically increase the tube current, shorten the examination time, and improve image quality. Care should be taken to avoid reaching the tube current ceiling when reducing the rotation time.

When using a CT scanner in a manual exposure mode (ie, manually selecting either the effective mAs or the tube current), note the following:

- With scanners on which the tube current and rotation time are selected rather than the effective mAs, increasing the pitch will decrease the dose. The same decrease in dose can be achieved by decreasing the tube current or the rotation time by the same factor as the increase in pitch. Conversely, if the pitch is lowered, the dose is affected in the same way as by increasing the tube

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current or the rotation time by the same factor as the decrease in pitch. Reducing the rotation time is a much better option than increasing the pitch because it results in improved rather than degraded image quality.

- With scanners on which the manual effective mAs (or mAs per slice) is selected, changing the pitch will have no effect on the dose. For these scanners, when the pitch is increased, the tube current is increased automatically by the scanner to keep the effective mAs constant. Thus, the dose and image noise both remain constant.

MISCONCEPTION 2: PITCHES < 1 OVERIRRADIATE THE PATIENT DUE TO "OVERLAP" OF THE X-RAY BEAM

It is true that helical scanning at almost any pitch will result in nonuniform irradiation of the patient, with either "overlaps" or "gaps" in the primary radiation beam. However, whatever the pitch, all of this radiation (except for any of the usual overscan at the ends of the scan range) is used to create the CT image. The overlapping radiation is not wasted and does not provide unnecessary radiation to the patient. As far as both patient dose and image noise are concerned, increasing the pitch by a certain factor has the same effects as decreasing the tube current by the same factor [2,3].

These misconceptions have led, in particular, to recommendations that pediatric scans always be performed at high pitch to reduce the dose to the patient [4]. As previously explained, there are many other ways to reduce patient dose, and frequently the use of high pitch values is not the best option.

What could be the source of the misconception that raising the pitch is a key to lowering patient dose? It may come from the introduction of helical and spiral scanning to single-slice CT scanners. With these scanners, the selection of pitch typically did not affect image noise. As long as the same interpolation algorithm (180 vs 360 LI) was used in the image reconstruction, image noise was independent of the pitch. This was due to the same amount of CT data being used to reconstruct the image, independent of the pitch. Increasing the pitch simply used data farther from the actual slice position, thus degrading the slice sensitivity profile and increasing helical artifacts [2,3,5,6]. In the 1990s, the general consensus was that the best compromise in patient dose, slice sensitivity profiles, and artifacts for most exams was a pitch of 1.3 to 1.5 [7]. Thus, increasing the pitch from lower pitches up to about 1.5 was considered a good way to reduce patient dose, without increasing image noise, because the dose was inversely proportional to the pitch.

However, with multislice scanners, these relationships have changed. The dose remains inversely proportional to the pitch, but image noise does increase significantly as the pitch increases. This is a result of the different types of helical interpolation algorithms that can be used in multislice CT that reduce helical artifacts and the degradation of the slice thickness.

CONCLUSIONS

Increasing the pitch should not be thought of as the proper method or the only method to reduce patient dose. It is a misconception that the use of a lower pitch overirradiates patients by wasting dose. The use of lower pitch values can provide images of equal or better image quality at the same patient dose, whether using manual or automatic tube current modulation techniques. By decreasing the pitch and the rotation times by equal amounts, both helical and patient motion artifacts can be reduced without increasing the examination time. The use of lower helical pitch also can provide better imaging of larger patients by allowing the use of a larger effective mAs if the examination time can be extended without compromising the examination. However, low pitches may not be appropriate for all examination types. This is especially true if the length of the scan time cannot be made short enough with a low pitch. For example, low pitches may not be appropriate in chest imaging because of respiratory motion or for runoffs because of contrast timing constraints.

REFERENCES

1. American Association of Physicists in Medicine. AAPM CT lexicon version 1.3. Available at: http://www.aapm.org/pubs/CTProtocols/documents/CTTerminologyLexicon.pdf. Accessed January 15, 2015.
2. Hsieh J. Computed tomography: principles, design, artifacts, and recent advance. 2nd ed. Bellingham, Washington: SPIE; 2009.
3. Kalender WA. Computed tomography. 3rd ed. Erlangen, Germany: Publicis Publishing; 2005.
4. Strauss KJ, Goske MJ, Kaste SC, et al. Image Gently: ten steps you can take to optimize image quality and lower CT dose for pediatric patients. AJR Am J Roentgenol 2010;194:868-73.
5. Crawford CR, King KF. Computed tomography scanning with simultaneous patient translation. Med Phys 1990;17:967-82.
6. Hui H, Fox SH. The effect of helical pitch and beam collimation on the lesion contrast and slice profile in helical CT imaging. Med Phys 1996;23:1943-54.
7. Wang G, Vannier MW. Optimal pitch in spiral computed tomography. Med Phys 1997;24:1635-9.

Frank N. Ranallo, PhD, and Timothy Szczykutowicz, PhD, are from the Departments of Medical Physics and Radiology, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin.

Frank N. Ranallo, PhD: Wisconsin Institutes for Medical Research, Medical Physics Department, 1111 Highland Avenue, Room 1173, Madison, WI 53705-2275; e-mail: ranallo@wisc.edu.