The Correct Selection of Pitch for Optimal CT Scanning: The Big Misconception

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Introduction

In this poster we wish to provide information leading to correct guidance in the proper selection of pitch and rotation time for optimal CT imaging with multi-slice scanners with single tube technology.

Pitch: Single Slice to Multi-slice

There exists a widespread misconception concerning the role of pitch in patient dose with modern multi-slice scanners, particularly with the use of mA modulation techniques. We investigated the relationship of pitch and rotation time to image quality, dose, and scan duration, with CT scanners from different manufacturers in a way that clarifies this misconception. This source of this misconception may concern the role of pitch in single slice CT scanners

When helical/spiral CT was first introduced using single slice CT scanners, the selection of pitch typically did not affect the image noise. As long as the same interpolation algorithm (180 LI vs. 360 LI) was used in the image reconstruction, the image noise was independent of the pitch. This resulted from 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. In the 1990's there was a general consensus that the best compromise in patient dose, slice sensitivity profiles, and artifacts for most exams was a pitch of 1.3 to 1.4. Thus increasing the pitch from lower pitches up to about 1.4 was considered a good way to reduce patient dose, without increasing the image noise, since the dose was inversely proportional to the pitch.

However with multi-slice scanners the situation has very much changed. The dose remains inversely proportional to the pitch, but the image noise does increase significantly as the pitch increases. The CTDI dose measure that takes into account the effects of pitch is $CTDI_{vol} = CTDI_W / pitch$. A similar equation provides a parameter that is also proportional to patient dose: **effective mAs = mAs / pitch = mA * rotation time / pitch**. The important additional fact to note is that that for multi-slice scanners, the image noise IS NOT independent of pitch but is generally proportional to the inverse of the square root of the effective mAs: $$\text{Image Noise} \propto 1/\sqrt{\text{effective mAs}}$$

Note that on some scanners the "effective mAs" is called the "mAs per slice". Some scanners do not use this terminology at all in their user interface but rather refer separately to the mA, rotation time, and pitch.

Current Misconceptions Concerning Pitch & Dose

When using the CT scanner in a manual exposure mode, either manually selecting the effective mAs or the mA:

It is true that increasing the pitch will lower the dose when all other scan parameters on certain CT scanners are kept constant (kV, mA, rotation time). With other scanners, on which you select the manual effective mAs, **increasing the pitch will have no effect on the dose**. For these latter scanners when you increase the pitch, the mA is increased in the background to keep the effective mAs constant. Thus the dose and image noise remain constant.

With scanners in which you select the mA and rotation time rather than the effective mAs, when increasing the pitch you can increase the mA or the rotation time by the same factor to keep the dose constant. Conversely if you lowered the pitch you could keep the same dose by reducing the mA or the rotation time by the same factor.

When using an Automatic Exposure Mode (AEC) that modulates the mA in response to patient size:

Changing the pitch on any type of CT scanner will not change the dose. If the pitch is increased, the AEC system on the scanner will simply increase the mA to keep the dose constant - as determined by the selection in the AEC system of Noise Index, Standard Deviation (SD), or reference effective mAs. Since much CT scanning is now performed using the AEC system, it is important that the dose is affected by the AEC system selection and not by the pitch.

Current Misconceptions Concerning Pitch & Dose

A major misconception concerning pitch and dose is that pitches less than one over-irradiate the patient due to "overlap" of the x-ray beam irradiation the patient. It is true that all helical scanning at almost any pitch will result in a non-uniform irradiation of the patient, with either "overlaps" or "gaps" in the primary radiation beam. Whatever the pitch, however, all of the radiation exposing the patient is used to create the CT image. A pitch less than one simply delivers more dose to the CT detectors. Reducing the pitch by a factor of 2 will deliver twice the dose to the patient, averaged over tissues, and will therefore have the same net effect on patient dose and image quality as doubling the mA. The overlapping radiation IS NOT wasted and is not providing unnecessary radiation to the patient.

These misconceptions have led, in particular, to recommendations that pediatric scans should always be performed at high pitch to reduce the dose to the patient. A previously explained, there are many other ways to reduce the patient dose, and frequently the use of high pitch values is not the best option.
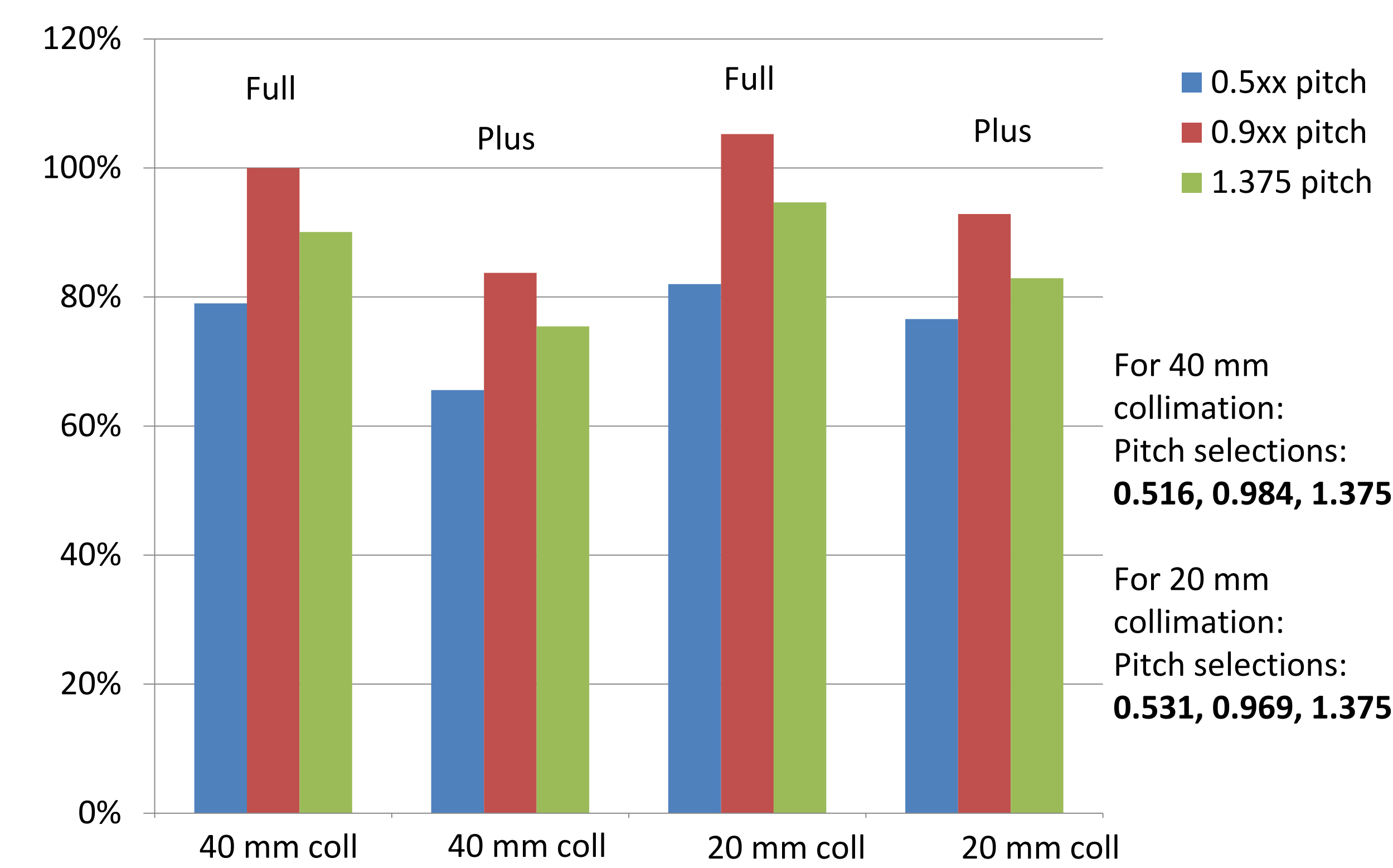
Recommendations for Correctly Selecting the Pitch

❖ Lowering the pitch and decreasing the rotation time by the same factor will keep the patient dose constant in either manual or AEC mode and will also keep the exam time constant, but frequently will provide improved image quality - *you can get something for nothing*!
  ❖ As an example :
  Change a 1.0 s rotation time and a pitch of 1.6 to
      a 0.5 s rotation time and a pitch of 0.8.
  ❖ The temporal resolution in this case is improved because of the faster rotation time reducing motion blurring and artifacts.
  ❖ The lower pitch value reduces helical artifacts.

❖ Some CT scanners allow a continuous selection of pitch values, while others (such as GE scanners) have a limited number of optimized pitch values that can be selected. With these latter scanners a different type of helical reconstruction is performed at pitches less than one (GE: interleaved) as compared to pitches greater than one (GE: interspaced). The pitches less than one provide better image quality due to the helical reconstruction than those greater than one, and are preferred when possible.

❖ For head imaging, and any high resolution imaging, always use a pitch less than one to improve image quality and reduce helical artifacts.

❖ For body imaging use a pitch of less than one whenever possible to improve image quality and reduce helical artifacts and to allow more total radiation to the CT detectors for the adequate imaging of larger patients.

  ❖ When selecting the pitch in body scans, you need to be aware of breath hold limitations and contrast timing considerations.

❖ One situation in which using pitches less than one can be unwise is in chest imaging, particularly the imaging of pulmonary embolisms (PE). In this case the overriding need for a short breath hold time recommends the use of a higher pitch to reduce the total scan time.

❖ Our recommendations for reducing the dose for a CT scan :

  ❖ Instead of just increasing the pitch :

  ❖ Reduce the rotation time (this will reduce dose in manual mode and is the first step in AEC mode). Reducing the rotation time improve image quality by reducing motion blurring and artifacts, while increasing pitch degrades image quality by increasing helical artifacts.

  ❖ Reduce the effective mAs (in manual or AEC mode); reduce the mA (in manual mode) or increase the noise index or SD (in AEC mode).

  ❖ Only then increase the pitch if required to reduce the total scan time.

Experimental Results leading to Some Special Considerations

As mentioned previously, some CT scanners allow a continuous selection of pitch values, while others (such as GE scanners) have a limited number of optimized pitch values that can be selected. With 64 slice GE scanners the pitch selections are 0.516, 0.984, and 1.375 when using a total beam collimation of 40 mm. The pitch selections are 0.531, 0.969, and 1.375 when using a total beam collimation of 20 mm.

These particular pitches are chosen to allow the use of specific reconstruction algorithms that optimize the image quality at those precise pitches. Because of the variation in the helical reconstruction algorithms used at different pitches, for the same image noise the dose will not necessarily be the same. We tested this hypothesis and found that the 3 different pitches at either collimation width did indeed provide different doses at the same image noise.

We performed this test using the GE LightSpeed VCT scanner using a 20 cm water phantom and the following techniques: Small Body SFOV, 25 cm DFOV, 120 kV, 5 mm slice thickness, and a Noise Index of 6.00. We performed 12 sets of scans by varying the Beam collimation from 40 mm to 20 mm, the reconstruction option between "Full" and "Plus", and the Pitch between the three available options. (The "Plus" reconstruction option allows one to reduce helical artifacts and decrease image noise while slightly increasing the effective slice thickness compared to using the "Full" option). We measured the actual noise in multiple images for each test, found the average noise and then adjusted the actual $CTDI_{vol}$ to reflect any slight variations in the measured noise. The resuts are given below:

For 40 mm collimation:
Pitch selections:
0.516, 0.984, 1.375

For 20 mm collimation:
Pitch selections:
0.531, 0.969, 1.375

Similar results were obtained using a 48 cm polyethylene phantom (thicker than the GE calibration phantom).

These results show that the use of a 0.5xx pitch allows a 21% dose reduction over the use of a 0.9xx pitch. Also the use of a 1.375 allows a 10% reduction over the use of a 0.9xx pitch. These results were independent of the choice of collimation width or the selection of "Full" or "Plus" reconstruction options. As a consequence of these results we have converted many of our original protocols which had used a pitch of 0.984 or 0.969 to using pitch values of 0.516 or 0.531. This reduced our patient doses by the expected 21%.

So in this one case, reducing the pitch by a factor of almost two actually provided a dose **decrease**!

References

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