DOSIMETRIC EVALUATIONS OF AUTOMATIC COMPUTED TOMOGRAPHY TUBE CURRENT MODULATION SYSTEMS

Elena Garelli
Servizio di Fisica Sanitaria Ospedale Molinette di Torino

Relatore: Dr. Ropolo
Contro relatore: Pr.ssa Peroni
Direttrice: Pr.ssa Ferrero

Abstract
The Computed tomography (CT) has devolved remarkably through device improvement and advancement of peripherals, including the computer. In 1999, multi detector-row CT (MDCT) appeared and made high-speed scanning possible. However, utility of clinical MDCT applications has not been gauged. Since CT examinations need a comparatively high dose, it is necessary to evaluate patient exposure prior to the introduction of the MDCT. The advantages of MDCT in clinical uses are that multiple slice data can be obtained by one scanning with multiple detectors and a thin slice image can be taken rapidly during one breath stop. As for CT, it has been conventionally thought that higher radiation exposure is delivered to the patient, compared with other X-ray diagnosis techniques. Since MDCT uses multi-detector rows at the same time, it was expected that exposure dose could be smaller in contrast to the conventional system and the reconstruction of the scan could be done with a low radiation dosage keeping the same image quality of the conventional CT. However, the exposed doses differed very much according to scanning method and technical conditions and it seems that dose reduction by MDCT has not been realized yet.

The greatly increased availability of CT, together with its value for an increasing number of conditions, has been responsible for a large rise in popularity. So large has been this rise that, in the most recent comprehensive survey in the United Kingdom, CT scans constituted 7% of all radiological examinations, but contributed 47% of the total collective dose from medical X-ray examinations in 2000/2001. Increased CT usage has led to an overall rise in the total amount of medical radiation used, despite reductions in other areas. In the United States and Japan for example, there were 26 and 64 CT scanners per 1 million population in 1996. In the U.S., there were about 3 million CT scans performed in 1980, compared to an estimated 62 million scans in 2006. The radiation dose for a particular study depends on multiple factors: volume scanned, patient build, number and type of scan sequences, and desired resolution and image quality. Additionally, two helical CT scanning parameters that can be adjusted easily
and that have a profound effect on radiation dose are tube current and pitch. The radiation from current CT-scan use may cause as many as 1 in 50 future cases of cancer.

Scanner manufactures have subsequently implemented several options to appropriately manage to reduce radiation from CT. Modulation of the x-ray tube current during scanning is one effective method of managing the dose. Automatic tube current modulation (ATCM) may be defined as a set of techniques that enable automatic adjustment of the tube current in the x-y plane (angular modulation) or along the z-axis (z-axis modulation) according to the size and attenuation characteristic of the body part being scanned and achieve constant CT image quality with lower radiation exposure. Hence ATCM techniques are analogous to the automatic exposure-control used in conventional radiography. Unfortunately, owing to rapid technologic advances, different vendors have developed different ATCM techniques and use proprietary nomenclature. Nevertheless, the introduction of ATCM techniques in modern CT scanners represents an important step toward standardization of tube current protocols, with elimination of arbitrary selection by radiologists and technologist. ATCM techniques allow maintenance of constant image quality at a required radiation exposure level because ATCM rapidly responds to large variations in beam attenuation. ATCM is based on the fact that image noise is determined by x-ray quantum noise in the transmitted beam projections. This technique aims to modulate tube current in the basis of regional body anatomy for adjustment of x-ray quantum noise to maintain constant image noise with improved dose efficiency.

The purposes of this study were to evaluate the consequences of different choices of acquisition parameters on the actual image noise and on the patient dose with an automatic tube current modulation system.

The CT investigated were a GE Lightspeed 16-slice and a Toshiba Aquilion 32-slice. An anthropomorphic phantom was used to simulate the patient. Several acquisitions were made varying noise index, kilovoltage and pitch values. Tube current values were compared for the different acquisitions. Patient dose was evaluated in terms of CTDIvol and also as effective dose. The noise actually present in the images was analyzed by a region of interest analysis considering representatively phantom sections in the regions of the shoulders, of the lungs and of the abdomen. The obtained results generally evidenced a good agreement between the noise index (NI) and the measured noise for the abdomen sections, whereas for the shoulders and the lungs sections the measured noise was respectively greater and lower of the NI. Varying the kV the automatic current modulation system provided images with a substantially constancy of the actual noise and of the patient dose. An increase of the pitch generally decreased the patient dose, whereas the noise was slightly greater for the lowest pitch and almost constant for the other pitch values. This study outlines some important relationships between an automatic tube current modulation system and other CT acquisition parameters, providing useful informations for the choice requested by radiologists in the task of optimization of the CT acquisition protocols. Unless there are other considerations in place, pixel pitches below 1.375 should be avoided, and kVp settings can be changed.
with no real impact on dose or image noise. The projection of the scout is another parameter to optimised the exam. In fact when two scout are required the GE system modulated the tube current based on the last scout projection. This study outlines a different in effective dose around the 26% if the last scout was the lateral instead the anteroposterior. For the Toshiba system this difference is less than 10 % in terms of effective dose.

The second aim of this study is to implement a useful dose evaluation model for exams with automatic tube current modulated CT once known the experimental parameters (kV, pitch, NI). In this way the specialist can roughly estimate the effective dose of the exam in analysis. To do this we use the multiple linear regression model, so we can find a relation that gives the effective dose as function of the exam parameters. The effective dose value found with the multiple model is compared with the effective dose calculated with the ImPACT software. The dependent variable, effective dose, will be described as function of three different independent variables: the NI, the kV and the pitch value. The ability to include several independent variables also provides a method to use when there is a need to avoid the risk of oversimplifying the effect of one independent variable on one dependent variable.

Real explanatory power comes from the way interpretations are made about the regression coefficients. Multiple regression lets you estimate the effect of an independent variable on a dependent variable and, at the same time, controls the effects of all the other independent variables in the model. In other words, since there are multiple independent variables in the model, you can compare their effects, and, in doing so, estimate which independent variable has the most explanatory power. Basically, multiple regression includes specifying the model, interpreting the regression statistic, comparing the independent variables, and interpreting the model.

All the multiple regression analysis is conducted with the help of software Statgraphics Centurion XV.

We analyzed the data collected with CT GE Lightspeed 16 and it is possible concluded that the linear hypothesis between the effective dose and the pitch and NI value is statistically significant in a confidence interval of 95%, while for the voltage parameter there isn’t statistical significance. In fact the effective dose means to be constant varying the voltage value. We applied this multiple regression model to another CT GE scanner (Lightspeed 16 Pro) and the agreement between the predicted E value and the observed is better than 6%. This difference is in the range of the error of the multiple regression model, in fact it is possible to estimate the intrinsic model error around the 7%.