Automatic Tube Current Modulation and Dose Reduction

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INTRODUCTION – As awareness increases regarding the risks associated with radiation exposure the need to ensure the lowest possible dose to patients from Computed Tomography (CT) examinations whilst maintaining high diagnostic quality increases. CT accounts for 5% of radiological examinations in the world but contributes 34% of the collective effective dose to patients (Soderberg and Gunnarson 2010). Developments aimed at dose reduction in CT include automatic tube current modulation (ATCM), automatic selection of tube voltage, selective organ protection, adaptive collimation and iterative reconstruction (Calzado et al 2013). When other factors are held constant radiation dose has a linear relationship with the tube current value (Lee et al 2011). For the purpose of the poster we will be taking a closer look at ATCM. Looking at how ATCM works and how the user can affect the degree of dose reduction and image quality achieved with these systems.

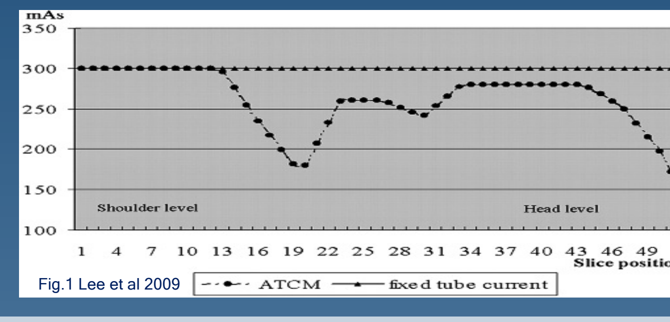

Fig.1 Lee et al 2009

TECHNOLOGY – Prior to the advent of ATCM a fixed tube current (FTC) set by the scanning radiographer was used (Khatonabadi et al 2012). Figure 1 demonstrates the difference in mAs at different slice positions between ATCM and FTC. With ATCM the dose changes along the z axis whilst the noise is kept relatively constant. FTC does not take into account patient size or changes in attenuation along the z-axis resulting in the patient receiving a higher dose than necessary during their scan (Livingstone et al 2009). ATCM now a standard on new scanners can be defined as a system that "manages the required image quality and radiation dose in a reproducible manner by adapting the tube current to the patients shape, size and attenuation" (Khatonabadi et al 2012). The figure 2. briefly describes the different range of ATCM available. Combined ATCM is seen as the most effective as it works in all planes.

Automatic Tube Current Modulation			
Parameter	Angular	Longitudinal	Combined
Principle	The tube current is adjusted during each gantry rotation according to the size, shape and attenuation of body region being scanned.	The tube current is adjusted along the scanning direction of the patient, according to the size and attenuation of the anatomic region being scanned and the predetermined image quality.	The tube current is adjusted both during each gantry rotation and for each slice position.
Direction	X,Y	Z	X,Y,Z

Fig.2 Soderberg & Gunnarsson 2011

ATCM AND NOISE – ATCM systems maintain image quality within patients and across populations by reducing dose whilst maintaining minimum levels of acceptable noise for any given scan protocol. Fig. 3 shows the relationship between dose and noise for FTC and ATCM. This shows that ACTM maintains a level of noise regardless of the attenuation of the subject and independent of dose (Peng et al 2009). Different manufacturers use different methods to standardise noise in their images. Fig.4 details these. The level of noise which is acceptable to the user has an influence on the dose received by the patient. Peng et al 2009 study involved 50 patients which found that increasing the acceptable level of noise by 5% resulted in a dose reduction of 10%. The study was limited to CT of the thorax and therefore lacked date for a wider range of examinations however the correlation between an acceptable increase in noise and reduction in dose is clear.

Fig.4 Ibrahim et al 2013

Manufacturer	Trade Name	Image Quality Reference	Principle
GE Healthcare	AutomA SmartmA	Noise Index	Maintain constant noise level defined by index.
Toshiba	Sure Exposure	Standard Deviation	Maintain constant noise level defined by standard deviation.
Siemens	CARE dose 4D	Quality Reference mAs	Maintain same image quality with reference to target effective mAs for standard sized patients.
Philips	Dose Right	Reference Image	Maintain the same image quality as reference image.

LIMITATIONS OF ATCM

The effectiveness of ATCM is dependent to an extent on the user. Not all types of ATCM suffer from the same limitations.

Longitudinal ATCM is dependent on **accurate patient positioning**. Gudjonsdottir et al 2009 conducted a phantom study which found that off centring affected the function of ATCM devices resulting in increased image noise due to beam-shaping filter attenuation and furthermore increased the dose to parts of the patient that approached the isocentre. Toth et al 2007 demonstrated that off centring by as little as 30mm could result in an increase of 56% in surface dose. This research emphasises the importance of accurate patient positioning for CT. Angular modulation does not suffer from this problem to the same extent due to it constantly adjusted dose from each pervious gantry rotation.

Goo et al 2006 discussed the effect of **scan direction** on combined ATCM. There study using both date from patients and phantom scans concluded that differences in modulation dependent on direction of scan occurred at transition areas between higher and lower attenuating tissues. It was concluded that scanning in a direction from lower to higher attenuation areas resulted in the best dose reduction. This is not always possible in the clinical setting especially when using contrast and scanning organs in different phases.

Patient size can is a limiting factor of ATCM's ability to reduce patient dose in the individual. Lee et al 2011 reviewed the images of 100 patients who all had two scans of the abdomen and pelvis, one with ATCM and the second with FTC. They found that there was a cut off point for significant dose reduction at a body mass index (BMI) of 21.8 with ATCM. Therefore patients with a BMI of less than 21.8 benefit most from ATCM.

Moro et al 2013 evaluated in their phantom study that the ATCM was effected by the **scanogram position** on which the dose was modulated. Scan based on a posterior-anterior projection had a higher dose than those based on an anterior-posterior projection. They attributed this to the divergent beam magnifying structures closest to the x-ray tube in particular the spinal column. This means that the ATCM estimates higher patient attenuation values and therefore selects higher tube current values. It is therefore important to think about how you are positioning your patient and from what direction the scanogram is taken.

CONCLUSION – ATCM plays an important role in the reduction of dose within CT examinations. It has been demonstrated to significantly reduce dose despite difficulties in comparing different systems. ATCM allows for greater consistency in imaging both between a patients scans and amongst the patient population. There are limitations to this technology as described. Many of these can be combatted by proper and consistent use of ATCM systems.

ATCM AND PATIENT DOSE

There is a large body of research available investigating ATCM and its ability to reduce dose although as noted by Soderberg and Gunnarsson 2010 the aim of ATCM systems produced by some manufacturers is not for the primary aim of dose reduction. GE and Toshiba developed their systems with the aim to increase uniformity of image quality between anatomic regions in one patient. Siemens and Philips aim was to improve image quality be recognising that different sized patients require different levels of noise obtain adequate image quality.

Vollmar and Kalender 2008 state that ATCM reduces dose without a reduction in image quality and without additional preparation of the patient. Livingstone et al 2009 conducted a prospective study of 426 patients undergoing abdominal CT and reported dose reduction of 16-28% this was in comparison to weight based protocols which do not take into account patient shape or attenuation at different points in the scan.

Livingstone et al 2010 study which used date from 22 patients undergoing chest CT examinations reported dose reduction levels of 42.3% when using ATCM. They also reported an increase in signal to noise ratio of 29% indicating a degradation in image quality with ATCM.

Soderberg and Gunnarssons in 2010 conducted an extensive study comparing the ATCM systems available from the big four manufacturers. They found that the dose reducing capacity of the systems presented by different manufacturers were similar if used properly being in the range of 35/60%. However they also commented in the difficulty in comparing dose reduction values reported by diffident studies due to the figures dependence on scanning parameters, scanner model and specified image quality of the ATCM system.

Fig.3 Kalender 2014