Effective dose for CT head scans with a modulated tube current

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Introduction

- The use of modulated tube current in CT
- Dose audit pre and post mA modulation
- Effective dose calculations with a modulated tube current
- Study conclusions
- Study limitations and further work
Tube current modulation in CT

- All major manufacturers of CT scanners now offer automatic tube current modulation (ATCM)
- All adopt slightly different approaches
- The aim is to reduce unnecessary radiation for any given slice
A literature search on CT tube current modulation returns numerous scientific publications mostly from quite recent work. Those that quote 'dose' reductions do not explicitly specify what measure of dose is being used. Closer scrutiny suggests that it is absorbed dose. Absorbed and effective dose may not be proportional when tube current is modulated.
Tube current modulation in CT

Anatomical image courtesy of Wikimedia Commons, Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist
Dose audit results with and without tube current modulation

- Caldicott approval has been granted to download patient images for our routine dose audits.
- Custom java code is used to extract the mA curves and these are used to determine the mean mA for the scan.
- The effective dose is estimated using the IMPACT CT dose calculation spreadsheet with the mean mA.
Dose audit results with and without tube current modulation

- Results agreed with literature values of approximately 10% dose reduction with modulation on as opposed to a constant current technique.
- The reduction was reflected in the DLPs for the scans.
The end?
Variation of risk of radiation damage with z position in the MIRD mathematical phantom
Tube current modulation in CT

Anatomical image courtesy of Wikimedia Commons, Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist
Effective dose calculations with a modulated tube current

- Is there another way to calculate the effective dose for a modulated scan?
Effective dose calculations with a modulated tube current

- Ensure a constant scan range using anatomical markers (top of skull to base of posterior fossa)
- Re-bin the data to match the smallest collimation available in the IMPACT spreadsheet (5mm)
- Calculate the effective dose in IMPACT on a slice by slice basis and sum the results
Effective dose calculations with a modulated tube current

- Study involved 300 patients scanned within the last three months
- 49 were discarded due to unusual positioning or insufficient scan range
- 251 patients were in the final analysis
Effective dose calculations with a modulated tube current

- Plots of effective dose using mean mA and effective dose using modulated method

Fit gives mean $E$ of 1.5 with reduced chi square statistic of 0.99

Fit gives mean $E$ of 1.6 with reduced Chi square statistic of 1.1
Effective dose calculations with a modulated tube current

- Difference in absolute value is quite small... could it simply be overscan?
- Repeated all measurements of effective dose using the mean mA with the slice by slice methodology.
- The maximum percentage difference was $6.7 \times 10^{-14}$
Effective dose calculations with a modulated tube current

- Using the mean mA suggested a dose reduction of 4.4% with modulation as opposed to without
- Using the DLPs suggested a dose reduction of 4.2%
- Using a modulated analysis on a slice by slice basis suggested a small dose increase of 1.9%
Study conclusions

- The mA modulation had not been suitably optimised
- If the image quality was acceptable at 180mA then, for an average patient, there should be no need to exceed this for any slice
- The mean maximum mA was 210 +/- 4 mA with 3 sigma confidence
- Suggests could reduce the mean max mA to 184
- Then the average patient will receive at least a max mA of 180 with 3 sigma confidence
Study conclusions

- A significant effective dose reduction is possible
- DLP is not a good indicator of effective dose for modulated scans
- CTDIvol may be a more appropriate optimisation parameter
Further incidental conclusion

- Overscanning may be falsely increasing DLP values
Study limitations and further work

- **Limitations**
  - Only one make and model considered
  - Modulation possible during rotation as well as along z-axis
  - Minimum slice available in IMPACT
  - Very time consuming process
  - Uncertainties

- **Further work**
  - Include uncertainty calculations
  - Develop tests of mA modulation from a QC perspective
  - Investigate other scan regions (potentially much harder to match mA curve to anatomical regions in MIRD phantom)
Questions and feedback?