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## Six to ten slice CT scanner comparison report version 13

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# Six to ten slice CT scanner comparison report version 13

**David Platten, Nicholas Keat**
**Maria Lewis, Sue Edyvean**

ImPACT
Bence Jones Offices
St George's Hospital
London SW17 0QT

Tel: 020 8725 3366
Fax: 020 8725 3969

e-mail: impact@impactscan.org

For more information on ImPACT visit www.impactscan.org

# Contents

# Introduction

## Purpose of this report

The primary aim of these reports is to aid the equipment selection process by providing comparisons of CT scanners that are currently on the market. There are separate reports for six to ten, sixteen, and 32 to 64 slice CT scanners, as well as a report on wide bore systems.

This report features CT scanners that are capable of acquiring between six and ten sets of attenuation data per tube rotation.

## Comparison method

There are two main areas for comparison of the scanners: performance and specification. The data given in this report are representative of the scanners as of July 2005, and are liable to change as the performance of individual scanner models is changed and upgraded. In particular, optional features listed in the specification section such as workstations and software packages may be listed as standard, but may not be included in specific purchases.

### Scanner performance

This section presents the results of ImPACT's imaging and dose performance assessment of each of the scanners. Although manufacturers generally publish image and dose characteristics of their scanners, different measurement techniques and phantoms often make it very difficult to compare results from one scanner against another. The ImPACT performance assessments utilise standard techniques, and allow a fair, like-with-like comparison.

### Specification comparison

The specification comparison is presented as a side-by-side summary comparison of the specification of each scanner, workstation and related equipment. It is grouped into a series of sub-sections relating to different aspects of the scanner, such as gantry, tube and detectors etc. Manufacturers supplied the specification data in response to a template issued by ImPACT. The data has not been verified by ImPACT.

## Scanners covered in this report

At the time of writing, there are four manufacturers of medical CT scanners that sell their systems in the UK (in alphabetical order); GE Medical Systems, Philips Medical Systems, Siemens AG and Toshiba Medical Systems. The systems capable of imaging between 6 and 10 slices per gantry rotation are listed in Table 1.

**Table 1: Scanners covered in this report**

| Manufacturer | Scanner model |
|---|---|
| GE | LightSpeed Ultra [8] |
| Philips | Brilliance CT 6 |
| Philips | Brilliance CT 10 |
| Siemens | Somatom Emotion 6 |
| Toshiba | Aquilion 8 |

The GE LightSpeed Ultra is based upon the same design as the four slice LightSpeed Plus. In particular, the gantry, tube and detector layouts are identical. The most obvious difference between the two is the ability of the LightSpeed Ultra to acquire eight slices of data per gantry rotation.

The Philips Brilliance range of scanners are an update on the previously available Mx8000 range.

The Philips Brilliance CT 10 is based on the 16-slice Brilliance CT 16. It features the same detector array, but is only capable of acquiring 10 slices per rotation.

The Philips Brilliance CT 6 is also based on the 16-slice Brilliance CT 16. It features the same detector array, but is only capable of acquiring 6 slices per rotation.

The Siemens Somatom Emotion 6 features a detector array that has a total z-axis coverage of 18 mm.

The Toshiba Aquilion 8 is based on the Aquilion 16-slice scanner, with the ability to acquire 8 slices of data per rotation.

ImPACT has assessed the imaging and dosimetry of the GE LightSpeed Ultra and Siemens Emotion 6 scanners.

# Scanner performance

## Introduction

The results of ImPACT's CT scanner assessments are presented in this section. In order to compare the performance of CT scanners, the ImPACT evaluation programme has developed a range of assessment techniques. These were first described in detail in MDA/98/25, 'Type Testing of CT Scanners: Methods and Methodology for Assessing Imaging Performance and Dosimetry'. Since the publication of MDA/98/25 ImPACT's scanner testing methods have evolved, in particular those relating to the measurement of dose. Our approach to testing remains the same, but the more recent publication, 'Report no. 32, part III, computed tomography x-ray scanners 2nd edition', IPEM, ISBN 0 904181 76 6, better reflects current testing methods.

The dose and image quality section looks at the overall image quality of the scanner relative to the radiation dose delivered to the patient, for both head and body scanning. It includes a graphical representation of the relationship between noise and spatial resolution, and the ImPACT Q value.

The spatial resolution section compares the ability of the scanners to reproduce fine detail within an image, usually referred to as the high contrast spatial resolution. This is characterised by the spatial frequencies where the modulation transfer function reaches 50% and 10% (known as $MTF_{50}$ and $MTF_{10}$) for the clinical filters with highest resolution. As well as the in-plane resolution, this report also details the spatial resolution along the z-axis.

Geometric efficiency is a measure of x-ray dose utilisation along the z-axis. ImPACT now quotes the geometric efficiency figure as specified by the IEC CT safety standard, 60601-2-44 Ed.2 (2001) Amendment 1 (2003). This defines geometric efficiency as the ratio of the integral of the dose profile falling within the nominal detector width to the integral of the dose profile along its total length. In general, beam collimations with a lower geometric efficiency will lead to higher patient doses. The lowest geometric efficiency tends to occur at narrow beam collimations.

Clinical scan tables list the measured image quality and dose parameters for the standard ImPACT clinical scans.

**All results tables list scanners in alphabetical order.**

# Dose and image quality

In this report, image quality is assessed in terms of objective measurements of image noise, scan plane spatial resolution and imaged slice width. The radiation dose used to acquire these images is given by the $CTDI_{vol}$ measured on the standard head and body phantoms. These parameters can be presented graphically, or combined into a single number, the Q value.

## Noise and resolution

The following graphs show image noise plotted against spatial resolution for the available convolution filters on each scanner. Resolution is characterised by the mean of the $MTF_{50}$ and $MTF_{10}$ values. Patient dose and slice width are adjusted to a $CTDI_{vol}$ of 50 mGy for head scans and 15 mGy for body scans, and a 5 mm slice. The spatial resolution (4.7 lp/cm) at which $Q_2$ is defined is marked with a vertical line.

It is important to note that the data for each scanner is obtained using scan parameters that can be selected in ‘standard’ imaging mode, and may exclude high resolution filters when they are reserved for imaging with narrow slices. For information about the limiting (highest) resolution of the scanners, see the spatial resolution section of this report.

In some cases, scanners have edge enhancing reconstruction filters available in standard scanning modes. These result in data points that lie outside the trend of the rest of the filters.

**Figure 1: Image noise vs. spatial resolution for head scanning at a $CTDI_{vol}$ of 50 mGy**

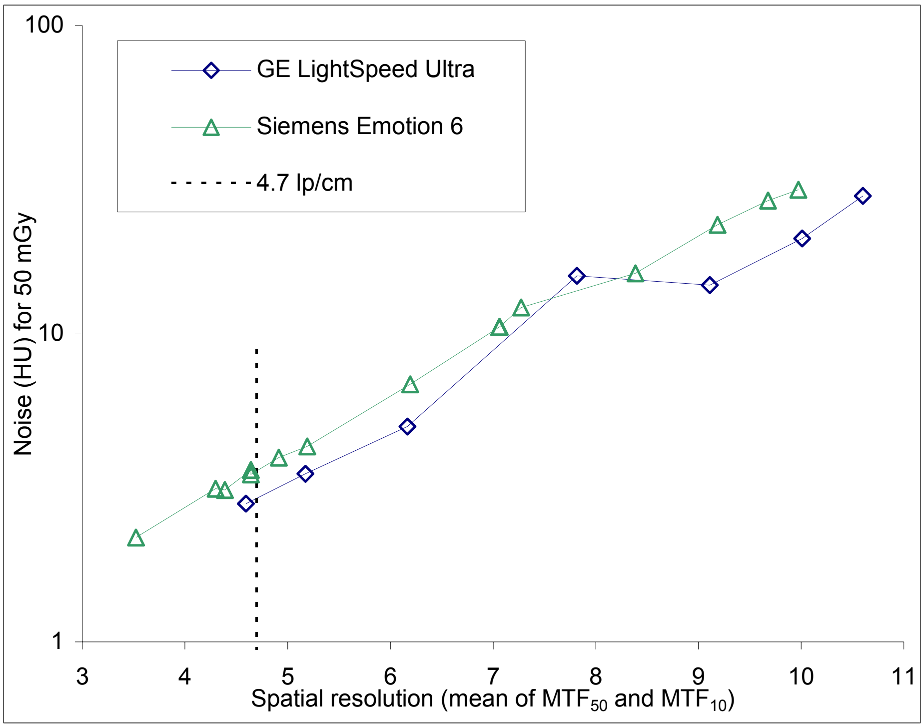
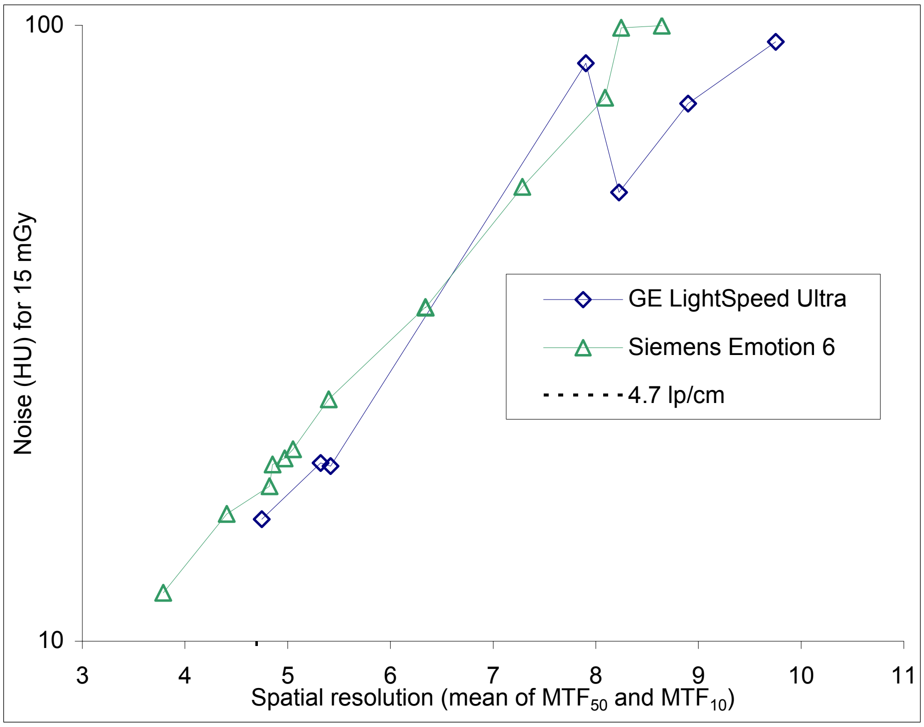



**Figure 2: Image noise vs. spatial resolution for body scanning at a $CTDI_{vol}$ of 15 mGy**



## Q value

The parameters in the noise and resolution section can be combined into a single numerical figure, a Q value, which reflects quantifiable aspects of image quality when taking into account radiation dose. Scanners with higher Q values will produce images with lower noise at a set spatial resolution, when slice thickness and dose are taken into account. Appendix 2 describes the approach in more detail.

Q factors are specific to the phantom used, since noise and dose are phantom dependent. Q values are presented in this section for head and body sized phantoms. A subscript is used to identify the Q value quoted ($Q_2$), reflecting the way that performance parameters are measured and quoted.

### Calculation of $Q_2$

The imaging parameters used for these scans are chosen to minimise slight variations that occur for different kV, slice thicknesses, scan times and reconstruction filters, by using standard values where possible. These are indicated below:

- Tube voltage: 120 kV or 130 kV when this is the 'standard' operating kV for the scanner
- Collimation: 20 mm, or the closest available setting
- Image width: 5 mm, or the closest available setting
- Scan time: as recommended by the manufacturer, sub-second for body scanning and 1 s or greater for head scanning
- Reconstruction filter: the filter chosen for each scanner is the one that most closely matches the average 'standard' head and body spatial resolution ($MTF_{50}$ of 3.4 lp/cm, $MTF_{10}$ of 6.0 lp/cm)
- Reconstruction field of view: 250 mm (head) and 380 mm (body).

The mAs setting that would result in a $CTDI_{vol}$ of 50 mGy for head and 15 mGy for body scanning is listed. Z-sensitivity and MTF values, together with image noise at these dose levels are also shown.

### Interpretation of the $Q_2$ factor

The noise and resolution relationship is measured at certain discrete values, governed by the reconstruction filters available on each scanner. $Q_2$ quantifies the relative positions of the scanners on the noise and resolution graphs at one particular spatial resolution. The filter chosen is the one that most closely matches that of the 'standard' head filter on a range of four slice scanners, with mean $MTF_{50}$ and $MTF_{10}$ values of 4.7 lp/cm.

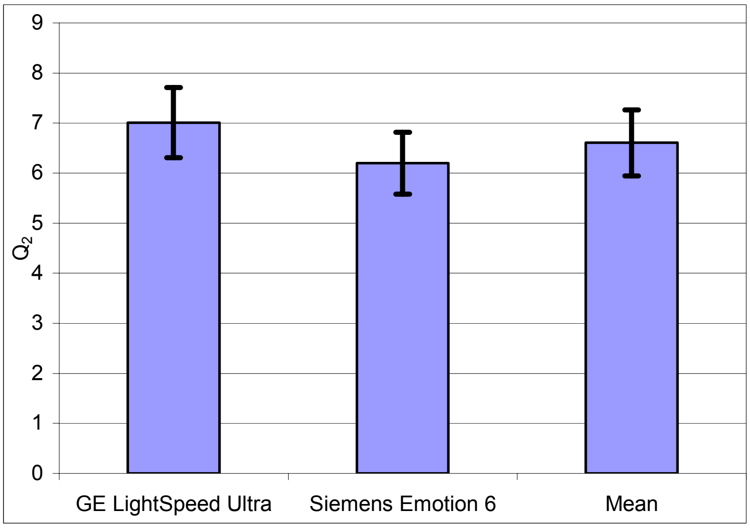
### Table 2: $Q_2$ figures for head scanning

| Scanner | Recon filter | mAs for 50mGy | z-sens (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) | $Q_2$ |
|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | Soft | 256 | 4.9 | 2.8 | 3.3 | 5.9 | 7.0 |
| Siemens Emotion 6 | H31s | 259 | 4.9 | 3.3 | 3.2 | 6.1 | 6.2 |
| *Mean* | | *258* | *4.9* | *3.1* | *3.2* | *6.0* | *6.6* |

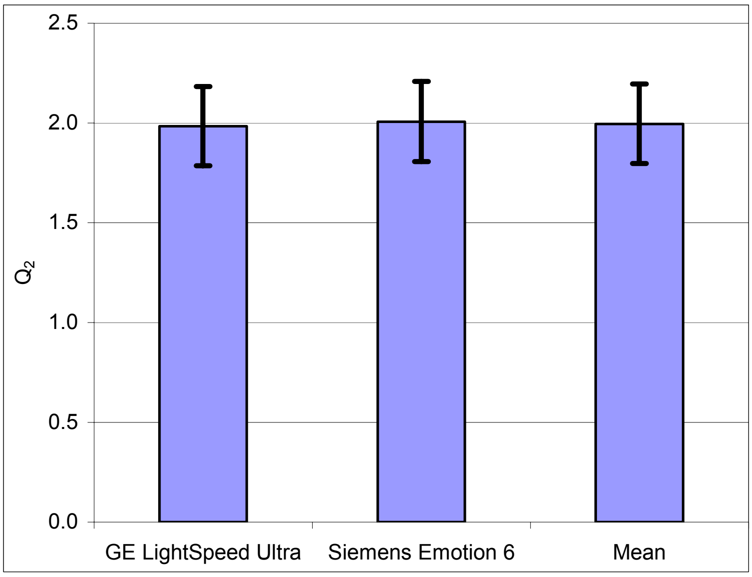
### Table 3: $Q_2$ figures for body scanning

| Scanner | Recon filter | mAs for 15mGy | z-sens (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) | $Q_2$ |
|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | Soft | 130 | 4.9 | 19 | 3.5 | 5.9 | 2.0 |
| Siemens Emotion 6 | B30s | 157 | 4.9 | 20 | 3.7 | 6.0 | 2.0 |
| *Mean* | | *144* | *4.9* | *19* | *3.6* | *5.9* | *2.0* |

### Figure 3: $Q_2$ figures for head scanning



## Figure 4: $Q_2$ figures for body scanning



## Spatial resolution

The spatial resolution figures given below show the capabilities of the scanners to reproduce fine detail within an image.

Limiting resolution is the highest spatial resolution that can be achieved with the scanner, using a clinical reconstruction filter.

**Table 4: Limiting in-plane spatial resolution**

| Scanner | Recon filter | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) |
|---|---|---|---|
| GE LightSpeed Ultra | EDGE | 9.3 | 14 |
| Siemens Emotion 6 | U90s | 8.1 | 14 |
| Mean | | 8.7 | 14 |

The scan parameters used for the in-plane limiting resolution results are those that produce the highest spatial resolution i.e. small focal spot, long (>1 s) scan time, sharpest reconstruction filter and small reconstruction field of view.

**Table 5: Limiting z-axis spatial resolution**

| Scanner | Pitch | Collimation (mm) | Slice width (mm) Nominal | Slice width (mm) Measured | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) |
|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | Data not currently available | | | | | |
| Siemens Emotion 6 | 1 | 6 x 0.5 | 0.63 | 0.77 | 5.2 | 11 |

The scan parameters used for the z-axis limiting resolution result are those that produce the highest z-axis spatial resolution whilst still using a routine multi-slice collimation i.e. low pitch, many sub-millimetre data-sets per rotation and narrow reconstructed slice. The FWHM data was measured in helical mode using a 6 mm diameter 0.1 mm thickness tungsten disc.

## Geometric efficiency

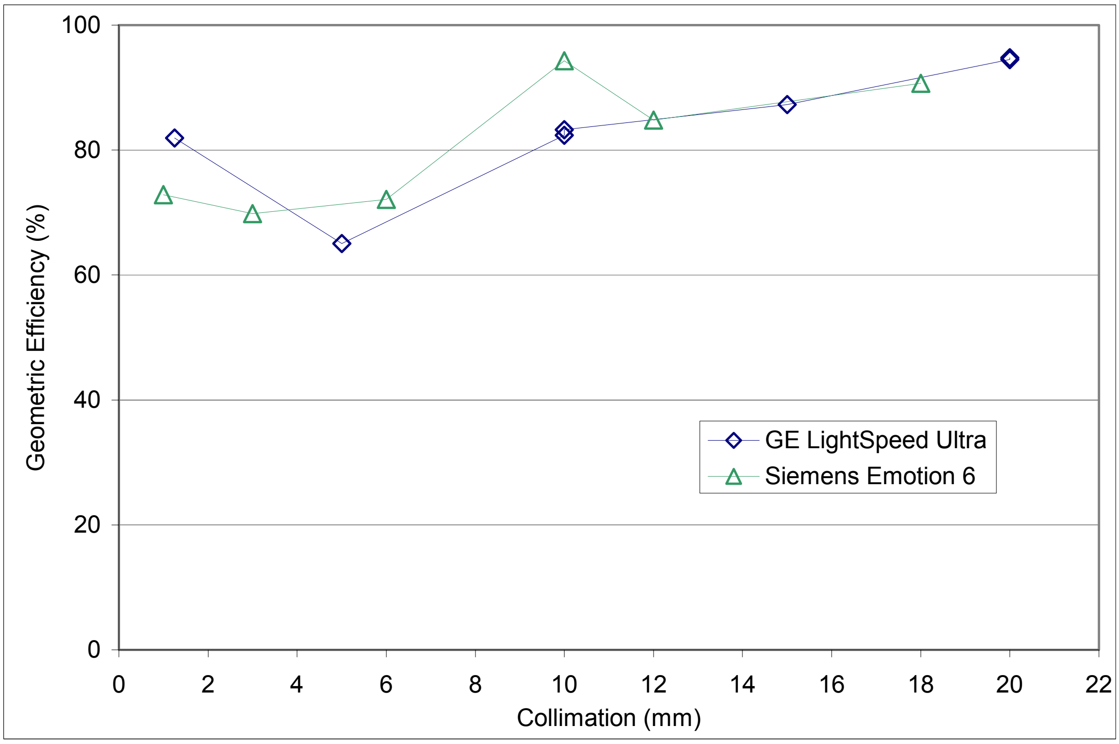
Geometric efficiency is a measure of x-ray dose utilisation along the z-axis. ImPACT now uses the geometric efficiency figure as specified by the IEC CT safety standard, 60601-2-44 Ed.2 (2001) Amendment 1 (2003). Geometric efficiency has been calculated from this definition as the ratio of the integral of the dose profile falling within the active detector width to the integral of the dose profile along its total length.

For multi-slice scanners, geometric efficiency tends to increase as the x-ray beam collimation is increased. This is due to the fixed size x-ray beam penumbra becoming less significant as the overall beam width is increased.

Data are presented for the scan mode that produces the maximum number of images per rotation for each collimation. All data obtained using the small focal spot unless otherwise indicated.

In some cases, single or dual slice beam collimations are available which tend to have higher geometric efficiency than multi-slice collimations at similar beam widths.

**Figure 5: Geometric efficiency**



# Clinical scan tables

These are a sub-set of the standard clinical scan tables for a range of examination types as defined and measured by ImPACT. It should be noted that the exposure parameters listed were those suggested by the manufacturer, but in practice they will vary from site to site. In particular, the settings for mA and scan time, which define patient dose, may vary widely from one centre to another. Results are presented in alphabetical order.

### Table 6: Standard brain

| Scanner | kVp | mAs | Scan time (s) | Slice (mm) | FOV (mm) | Recon filter | $CTDI_W$ (mGy) | z-sens. (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | 120 | 280 | 2 | 4 x 5 | 250 | Soft | 55 | 4.9 | 2.7 | 3.3 | 5.9 |
| Siemens Emotion 6 | 130 | 185 | 1.5 | 2 x 5 | 250 | H31s | 36 | 4.9 | 3.8 | 3.2 | 6.1 |
| MEAN | | | | | | | 45 | 4.9 | 3.3 | 3.2 | 6.0 |

### Table 7: Axial inner ear

| Scanner | kVp | mAs | Scan time (s) | Slice (mm) | FOV (mm) | Recon filter | $CTDI_W$ (mGy) | z-sens. (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) | $MTF_{10}$ as mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | 140 | 120 | 0.8 | 2 x 0.63 | 120 | Bone+ | 48 | 0.89 | 60 | 9.3 | 11 | 0.44 |
| Siemens Emotion 6 | 130 | 180 | 1.5 | 6 x 1 | 120 | U90s | 46 | 1.1 | 82 | 7.6 | 12 | 0.40 |
| MEAN | | | | | | | 47 | 0.98 | 71 | 8 | 12 | 0.42 |

### Table 8: Axial abdomen

| Scanner | kVp | mAs | Scan time (s) | Slice (mm) | FOV (mm) | Recon filter | $CTDI_W$ (mGy) | z-sens. (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | 120 | 176 | 0.8 | 4x5 | 380 | Std | 18 | 4.9 | 22 | 3.9 | 6.5 |
| Siemens Emotion 6 | 130 | 100 | 0.8 | 2 x 5 | 380 | B31s | 10 | 4.9 | 23 | 3.3 | 6.2 |
| MEAN | | | | | | | 14 | 4.9 | 22 | 3.6 | 6.4 |

### Table 9: Helical abdomen

| Scanner | kVp | mAs | Scan time (s) | Slice (mm) | Pitch | Recon filter | $CTDI_W$ (mGy) | z-sens. (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | 120 | 120 | 0.5 | 5 | 1.35 | Std | 8.9 | 5.9 | 26 | 3.9 | 6.5 |
| Siemens Emotion 6 | 130 | 95 | 0.6 | 5 | 1.19 | B31s | 8.2 | 5.1 | 20 | 3.3 | 6.3 |
| MEAN | | | | | | | 9 | 5.5 | 23 | 3.6 | 6.4 |

## Table 10: High resolution spine

| Scanner | kVp | mAs | Scan time (s) | Slice (mm) | FOV (mm) | Recon filter | $CTDI_W$ (mGy) | z-sens. (mm) | Noise (HU) | $MTF_{50}$ (lp/cm) | $MTF_{10}$ (lp/cm) | $MTF_{10}$ as mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GE LightSpeed Ultra | 120 | 320 | 2 | 8 x 2.5 | 120 | Bone+ | 32 | 2.5 | 133 | 9.4 | 12 | 0.42 |
| Siemens Emotion 6 | 130 | 300 | 1.5 | 6 x 1 | 120 | U90s | 39 | 2.2 | 202 | 7.8 | 14 | 0.37 |
| MEAN | | | | | | | 35 | 2.3 | 167 | 8.6 | 13 | 0.39 |

# Specification comparison

In order to limit the number of columns in the following comparison scanners with similar specifications have been listed together. Where differences exist, square brackets are used to denote the specification of the second system. This is the case for the following system:

- Philips Brilliance CT 6 and CT 10 models, where the 10-slice system is in brackets.

### Table 11: Couch

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Couch top material | Carbon fibre | Carbon fibre | Carbon fibre | Carbon fibre |
| Couch top length and width (cm) | 239 x 42 | 243 x 41 | 222 x 43 (just for cradle) | 219 (std) or 189 (short) x 47 |
| Horizontal movement range (cm) | 170 | 200 | 153 | 219 (std) 189 (short) |
| Horizontal movement speeds (mm/sec) | up to 100 | 0.5 - 100 | 1 - 100 | 10 or 130 |
| Accuracy/reproducibility of table positioning (mm) | ± 0.25 | ± 0.25 | ± 0.25 | ± 0.25 |
| Scannable horizontal range without table top extension (cm) | 170 (Axial), 160 (Helical & Scout) | 162 | 153 | 180 (std) 150 (short) |
| Scannable horizontal range with table top extension(s) (cm) | 170 (Axial), 160 (Helical & Scout) | 192 | 153 | 180 (std) 150 (short) |
| Vertical movement range out of gantry (cm) | 51 - 99 | 52-104 | 45 - 83 | 31 - 95.4 |
| Vertical movement range in gantry (cm) | 88 - 99 | 85 - 104 | 64 - 83 | 77.9 - 95.4 |
| Minimum couch top height outside gantry (cm) | 51 | 52 | 45 | 31 |
| Maximum weight allowed on couch (kg) | 205 | 204 | 200 | 205 |
| Maximum weight on couch which still achieves stated performance specifications (kg) | 180 (±0.25mm) 205 (±1mm) | 204 | 200 | 205 |

## Table 12: Scanner gantry

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Generation | 3rd | 3rd | 3rd | 3rd |
| Slipring | Low voltage | Low voltage | Low voltage | Low voltage |
| Aperture (cm) | 70 | 70 | 70 | 72 |
| Scan fields of view (cm) | 25 and 50 | 25 - 50 | 50, extended 70 option | 18, 24, 32, 40, 50 |
| Tilt range (degrees) | ± 30 | ± 30 | ± 30 | ± 30 |
| Type of positioning lights | Laser | Laser | Laser | Laser |
| Accuracy of positioning lights (mm) | ± 1 at any laser to patient distance | ± 0.5 at centre of gantry | ± 1 | ± 1 |

## Table 13: X-ray generator

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Type | High frequency | High frequency | High frequency | High frequency |
| Location | Rotation assembly | Rotation assembly | Rotation assembly | Rotation assembly |
| Power rating (kW) | 53.2 | 60 | 50 | 60 |
| kV settings available | 80, 100, 120, 140 | 90, 120, 140 | 80, 110, 130 | 80, 100, 120, 135 |
| mA range and step size | 10 - 440 (5mA steps) | 30 - 500 (1mA steps) | 20-345 (1mA steps) | 10 - 50 (5mA steps) 50 - 500 (10mA steps) |
| Max. mA allowed for each kV | 80kV: 400mA<br>100kV: 420mA<br>120kV: 440mA<br>140kV: 380mA | 90kV: 500mA<br>120kV: 500mA<br>140kV: 430mA | 80 kV: 345 mA<br>110 kV: 345 mA<br>130 kV: 345 mA | 80 kV: 500mA<br>100 kV: 500mA<br>120kV: 500mA<br>135kV: 430mA |

## Table 14: X-ray tube

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Type and make | GE Performix | Philips MRC | Siemens Dura 422MV | Toshiba Megacool |
| Focal spot size(s) (mm), quoted to IEC 336/93 standard | 0.6 x 0.7<br>0.9 x 0.9 | 0.5 x 1.0<br>1.0 x 1.0 | 0.5 x 0.8<br>0.7 x 0.8 | 0.9 x 0.8<br>1.6 x 1.4 |
| Settings at which focal spot changes.<br>kW = kV x mA / 1000 | 24KW | Small focus in high res. mode, not kW limited | Change automatically; small 28 kW large 45kW | 80kV : 36kW<br>100kV : 35kW<br>120 kV : 36kW<br>135 kV : 33.8kW |
| Total filtration (inherent + beam shaping filter) at central axis (mm Al equivalent) | 4.75 (70kV,head)<br>5.65 (70kV,body) | 7 | 6.3 (140kV) | > 1 (inherent)<br>1.5 - 10 (wedge dependent) |
| Anode heat capacity (MHU) | 6.3 | 8 | 5 | 7.5 |
| Maximum anode cooling rate (kHU/min) | 840 | 1608 | 810 | 1386 |
| Method of cooling | Oil to air | Oil to air | Oil to air | Oil to forced air |
| Guaranteed tube life | 1 year unlimited guarantee | 1 year unlimited guarantee | 200,000 scan seconds | 300,000 rotations |

## Table 15: Detection system

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Detector type | Solid state (HiLight / Lumex) | Solid state (High speed ceramic) | Solid state (Ultra Fast Ceramic) | Solid state |
| Number of detectors per row | 888 (plus 18 reference detectors) | 690 | 736<br>(1472 channels) | 896<br>(plus 2 reference detectors) |
| Number of elements along z-axis | 16 | 24 | 16 | 40 |
| Effective length of each element at isocentre (mm) | 16 x 1.25 | 16 x 0.75<br>8 x 1.5 | 8 x 0.5, 4 x 11,<br>2 x 2, 3 x 3 | 16 x 0.5<br>24 x 1.0 |
| Total effective length of detector array at isocentre (mm) | 20 | 24 | 18 | 32 |
| Option for more slices / rotation | 16 slices | Upgradeable to all Brilliance levels | Yes | 16 slice |

## Table 16: System start-up and calibration

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Power-on to warm-up time from fully off (mins) | 2 | 2 | 11 | 2 |
| Tube warm-up time from 'cold' to operating temperature (mins) | 0.75 | 2 - 3 | 1 | 2 (0 in an emergency) |
| Time to perform detector calibrations at warm-up (mins) | Included in tube warm-up | Part of warm up procedure | 5 | 1 |
| Recommended frequency for any additional calibration by the radiographer | Once every 24 hours | 1 every 3 weeks | Advised 2 hrs post switch on | Not required |
| Time to perform these additional calibrations (mins) | 15 | 2 | 2 | Not required |
| Total time from fully off to scanning in an emergency (mins) | < 3 | 2 | 4<br>(without check up) | 2 |

## Table 17: Scan parameters

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| kV settings available | 80, 100, 120, 140 | 90, 120, 140 | 80, 110, 130 | 80, 100, 120, 135 |
| mA Range and Step size | 10 - 440<br>(5mA steps) | 30 - 500<br>(1mA steps) | 20-345<br>(1mA steps) | 10 - 50<br>(5mA steps)<br>50 - 500<br>(10mA steps) |
| Max. mA allowed for each kV | 80kV: 400mA<br>100kV: 420mA<br>120kV: 440mA<br>140kV: 380mA | 90kV: 500mA<br>120kV: 500mA<br>140kV: 430mA | 80 kV: 345 mA<br>110 kV: 345 mA<br>130 kV: 345 mA | 80 kV: 500mA<br>100 kV: 500mA<br>120kV: 500mA<br>135kV: 430mA |
| Maximum continuous scan time (s) | 120 | 100 | 100 | 100 |

## Table 18: Helical and axial scanning

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Rotation times for axial scaning (s)<br>* = Partial scans | 0.3*, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4 (360° rotation) | 0.3*, 0.5, 0.75, 1, 1.5, 2 (0.4 option) | 0.53*, 0.6, 0.8, 1, 1.5 (0.4* option) | 0.32*, 0.5, 0.75, 1, 1.5, 2, 3 (0.25* , 0.4 option) |
| Rotation times for helical scanning (s) | 0.5, 0.6, 0.7, 0.8, 0.9, 1 | 0.5, 0.75, 1, 1.5 (0.4 option) | 0.6, 0.8, 1, 1.5 | 0.5, 0.75, 1, 1.5 (0.4 option) |
| Axial slice widths (number x width, mm) | 2x0.625, 1x1.25, 4x1.25, 8x1.25, 4x2.5, 8x2.5, 4x3.75, 4x5 | 2x0.6, 6x0.75, 6x1.5, 5x3, 4x4.5 [2x0.6, 10x0.75, 10x1.5, 5x3, 4x4.5] | 1x1, 6x1, 6x2, 6x3, 3x4, 2x5, 3x6, 2x9, 1x10 | 4x0.5, 4x1, 4x2, 4x3, 4x4, 4x6, 4x8 |
| Helical acquisition widths (number of channels x width, mm) | 2x0.625, 4x1.25, 4x2.5, 4x3.75, 4x5, 8x1.25, 8x2.5 | 6x0.75, 6x1.5, 4x6, 4x4.5 [10x0.75, 10x1.5, 8x3, 4x4.5] | (6x0.5 option), 1x1, 6x1, 6x2, 6x3, 3x4, 2x5, 3x6, 2x9, 1x10 | 8x0.5, 8x1, 8x2, 8x3, 8x4 |
| Pitches available for routine scanning (range and increment) | 2-slice: 1<br>4-slice: 0.75, 1.5<br>8-slice: 0.625, 0.875, 1.35, 1.675 | 0-1.7 freely selectable | 0.416 - 1.8 freely selectable | For TCOT: 0.625 - 1 / 1.125 - 1.625<br>For MUSCOT: 0.625 - 1.5 (except 1.0, increment 0.0625) |
| Recommended pitches for optimal image quality | 2 slice: 1<br>4 slice: 0.75, 1.5<br>8 slice: 0.625, 0.875, 1.35, 1.675 | 0 -1.7 freely selectable | 0.416 - 1.8 freely selectable | 0.6875, 0.9375, 1.375 |
| Helical interpolation algorithms available | SmartHelical & MDMP Algorithm | Cobra - Cone Beam Reconstruction | SureView (Adaptive spiral interpolator) | TCOT and MUSCOT |
| Maximum number of rotations in one helical run at standard abdomen parameters | 70 (300mA)<br>90 (270mA)<br>110 (250mA) | 200 | 125 (100mA)<br>100 (184mA)<br>at 0.8 s | 200 at 0.5s (250 at 0.4 option) |
| Starting with a cold tube, the maximum helical scan distance using a 1 mm imaged slice thickness and a pitch of 1.5 (mm) | 1600 | 1920 | 1500 | 1750 (std)<br>1450 (short) |
| Gantry tilt range for helical scanning (degrees) | ± 30 | ± 30 | ±30 | ± 30 |

## Table 19: Scanned projection radiography (SPR)

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Maximum SPR length (mm) | 1600 | 1500 | 1530 | 1800 (std)<br>1500 (short) |
| SPR field dimensions (mm x mm) | 500 x 1600 | 500 x 1500 | 512 x 1500 | width:<br>240, 400, 500<br>length:<br>200 - 1800 (std),<br>1500 (short) |
| Angular positions of X-ray tube available for SPR | 0 - 359°<br>(1° steps) | 0°, 90°, 180° | AP, PA, LAT | 0°, 90°, 180°, 270°, and any angle in 5° steps |
| Real time image | No | No | Yes | Yes |
| Accuracy of slice prescription from the scanogram (mm) | ± 0.25 | ± 0.25 | ± 0.5 | ± 0.25 |
| Accuracy of distance measurements from SPR's taken at isocentre (lateral and axial directions) (mm) | < 2 x image pixel size | ± 0.25 | Lateral accuracy<br>± 1.0<br>axial accuracy:<br>info. not available | < ± 0.5 |

## Table 20: Image reconstruction

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Reconstruction fields of view (cm) | 9.6 - 50 | 5 - 50 | 5 - 50 | 0.05 - 50 |
| Extended scan field of view (cm) | Option to 65 | Not available | 70 option | Not available |
| Reconstruction matrix | 512 | 512, 768, 1024 | 512 | 256, 512 |
| Minimum reconstruction interval in helical scanning (mm) | 0.1 | 0.1 | 0.1 | 0.1 |
| Reconstruction time from the start of data acquisition to the appearance of the 30th image of a series for a standard axial brain scan (s) | 30 (with IBO) | 7<br>[6.2] | 9 | 20 |
| Reconstruction time from the start of data acquisition to the appearance of the 30th image of a series for an axial spine scan (s) | 11 | 7<br>[6.2] | 9 | 20 |
| Reconstruction time from the start of data acquisition to the appearance of the 30th image of a series for a helical abdomen scan (s) | 11 | 7<br>[6.2] | 8 | 2.5 (real time)<br>5 (after scan completion) |
| Simultaneous scanning and reconstruction | Yes | Yes | Yes | Yes |
| Any delay in either scanning or reconstruction when performed concurrently | No | No | No | No |
| Simultaneous scanning and routine analysis | Yes | Yes | Yes | Yes |
| Simultaneous scanning and archiving and/or hard copying | Yes | Yes | Yes | Yes |
| Simultaneous scanning and transfer to second console/workstation | Yes | Yes | Yes | Yes |

## Table 21: Factors affecting image quality and dose

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Post-patient collimation for narrow slices | No | No | No | No |
| Automatic mA control (AEC / mA modulation) software | SmartmA | Doseright ACS and DOM + cardiac | Yes (CAREDose 4D) | SureExposure |
| - mA adjustment for patient size | Yes | Yes | Yes | Yes |
| - mA adjustment along the z-axis | Yes | Yes | Yes | Yes |
| - mA modulation during rotation | No | Yes | Yes | No |
| Number of helical gantry rotations required at each end of total imaged volume. | Info. not available | 0.5 | Info. not available | 3.3 max |
| Adaptive filtration for noise reduction | Low signal correction | Adaptive image enhancement or smoothing for three density ranges | Yes (automatic) | Yes (user programmable) |
| Quarter detector shift | Yes | Yes | Yes | Yes |
| Moving (dynamic/flying) focal spot, xy plane | No | Yes | Yes, for all scan times | No |
| Number of imaging detectors per row | 888 | 672 | 736 (1472 channels) | 896 |
| Sampling frequency (Hz) | 1640 | 4640 | 1250 | 1800 (0.5s scan) 1200 (>0.5s) |
| Artefact reduction algorithms | Iterative Bone Option (IBO), Motion correction Reconstruction of thick slices from thinner ones to reduce partial volume effects | Iterative bone correction, COBRA cone beam reconstruction, combined slice | Modified beam hardening (abdomen, pelvis, shoulder), Motion correction (sequential modes), Posterior Fossa optimisation | Beam hardening correction Raster Art. Suppression Protocol (RASP) Stack scanning Automatic patient motion correction |
| Cone beam correction | GE Proprietary algorithms (SmartHelical & MDMP Algorithm) | Cone beam reconstruction (COBRA) | Not needed with less than 8 slices per rotation | TCOT (modified Feldkamp method) |

## Table 22: Manufacturer's performance data

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| In plane spatial resolution (lp/cm) for sharpest clinical algorithm. Acquisition parameters in brackets. | MTF0: 15.4<br>MTF10: 13.0<br>(10cm DFOV, Edge alg, Small Focus) | MTF0: 24<br>(0.75 s, 2.5 mm slice, 25 cm scan FOV, E alg) | MTF0: 17.5<br>(0.8 / 0.6 s, 1 mm, U90S) | MTF2: 21.4<br>(120 kV, 200mA, 2 mm slice width, 1s, 240 mm FOV, FC90 alg, small focus) |
| Contrast resolution: smallest rod size (mm) discernable at given parameters in 20 cm CATPHAN | 5mm @ 0.3% @ 13.3 mGy: 120kVp, 100mAs, 10mm, Std alg | 4.0 mm @ 0.3% 120 kVp, 248 mAs, 10 mm, EB filter, 27 mGy at phantom surface | 5 mm @ 0.3% @15.8 mGy 130kV, 90 mAs, 0.8 sec, 10 mm | 2 mm @ 0.3% @ 26.7 mGy: 120kV, 240 mAs, 8 mm, FC41 with adaptive filter |
| CT number accuracy (HU) | Water : ± 3 | ± 4 | Air: ± 10<br>Water: ± 4 | Water: ± 3 |
| CTDI settings for std head | 120 kVp, 20 mm | 120kV, 24 mm | 130 kV, 10 mm | 120kV, 16 mm |
| CTDI (mGy/100mAs), centre of head phantom | 18 | 12.3 | 20 | 10.0 (Wedge 1)<br>18.4 (Wedge 2) |
| CTDI (mGy/100mAs), periphery of head phantom | 18.3 | 13.1 | 20.7 | 11.1 (Wedge 1)<br>21.5 (Wedge 2) |
| CTDI settings for std body | 120 kVp, 20 mm | 120kV, 24 mm | 130 kV , 10 mm | 120kV, 16 mm |
| CTDI (mGy/100mAs), centre of body phantom | 5.5 | 4.2 | 6.3 | 3.5 (Wedge 1)<br>6.6 (Wedge 2) |
| CTDI (mGy/100mAs), periphery of body phantom | 11.3 | 7.7 | 11.7 | 7.3 (Wedge 1)<br>14.8 (Wedge 2) |
| Dose profile FWHM (mm) (focal spot size in brackets) | 20: 20.6(l)<br>15: 16.5 (s)<br>10: 11.5 (s)<br>5: 6.7 (s)<br>1.25: 3.5 (s)<br>2 x 0.63:1.9 (s) | ± 10% for all collimations | 18 : 19.6 (l)<br>12 : 13.8 (l)<br>10 : 10 (l)<br>6 : 8.1 (l)<br>3 : 4.1(l)<br>1 : 1.2 (s) | 32 : 38 ± 9.5 (s)<br>24 : 28 ± 6.0 (s)<br>16 : 20 ± 5.0 (s)<br>8 : 12 ± 3.6 (s)<br>4 : 8 ± 2.4 (s) |

## Table 23: Main console

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Diagonal dimension of image screen (inches) | 20 | 19 | 19 | 18 (LCD) or 21 (CRT) |
| Number of monitors at console (functions of each if > 1) | 2 (acquisition / review and processing) | 2 (acquisition / review and processing) | Up to 6 (shared database) | 2 (acquisition/ review and processing) |
| Image area matrix dimensions | 512 x 512, 768 x 768, 1024 x 1024 | 1024 x 1024 | 1024 x 1024 | 512 x 512, 640 x 640, 1024 x 1024 |
| Usual range of CT Number displayed (HU) | -1024 to +3071 | -1024 to + 3094 | -1024 to +3071 (-10,240 to 30,710 if metal implants) | -1024 to +8191 |
| Accuracy of distance measurements in x-y plane (mm) | < 2 times image pixel size | ± 0.25 | depends on pixel size | < 1 |
| Weighted CTDI (CTDIw or CTDIvol) displayed on console | Yes | Yes | Yes | Yes |
| Dose Length Product (DLP) displayed on console | Yes | Yes | Yes | Yes |
| Geometric Efficiency displayed on console when <70% | Yes | Yes | >70% for all collimations | Yes |
| Control methods | Mouse, trackball, keyboard | Mouse, keyboard | Mouse, keyboard | Mouse, keyboard |

## Table 24: Main computer

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Make and model | HP XW8000 | Dell Xeon | Siemens PC compatible with array processors | 2 x Dual Processor |
| Operating system | Linux RedHat 7.3 | Windows XP | Windows XP | Windows |
| Type and speed of CPU | 2 x 2.66 GHz | 2 x 3.06 GHz | Pentium Xeon 3.6 GHz | 3.06 Ghz (scan console and display console) |
| Amount of computer RAM supplied as standard (Gbytes) | 2 | 2 | 4 | 1.5 (scan)<br>3.0 (display) |
| Maximum amount of computer RAM (Gbytes) | 12 | 4 | 4 | 1.5 (scan)<br>3.0 (display) |

## Table 25: Image storage

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Total standard hard disk capacity (Gbytes) | 254 | 392 | 328 | 450 |
| Maximum hard disk capacity (Gbytes) | 254 | 392 | 328 | 450 |
| Hard disk capacity for image storage (Gbytes and no. of uncompressed 512x512 images) | 146 (250,000 images) | 146 (257,000 images) | 146 (260,000 images) | 200,000 images |
| Hard disk capacity for storage of raw data files (Gbytes and no. of data files) | 72 (5000 8 slice axial raw data files) | 110 (30,000 data files) | 146 | 144 (3600 rotations) |
| Archive options | MOD (images) & DVD (scan data, protocols) (standard) | MOD and CD writer (standard) | MOD and CD-R (standard) | MOD (standard) DICOM Media CD-ROM (option) |
| Capacity of a single archive disk (Gbytes and no. of images) | 4.6 (9400 losslessly compressed 512x512 images or 700 raw data files) | 9.1 (39,000 losslessly compressed 512x512 images. Factor 2-3 compression) | MOD: 4.1GB (26,000 lossless images), CD-R: 0.65GB (4100 lossless images) 512 x 512 | 4.8 (16,000 images 140 rotations raw data) |
| Time to mount an archive disk or tape (s) | 5-6 in background operation | Info. not available | Approx 30 for full disk | Less than 20 |
| Archive data transfer rate (images / s) | 1 (read) 0.7 (write) | > 1 | 2 - 3 | Info. not available |

## Table 26: Independent workstation

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Is a workstation provided? | Yes | Yes, Brilliance Extended Workspace | No, option (LEONARDO) | Yes |
| Computer make and model | HP XP8200 | Dell Xeon | Siemens Fujitsu Xeon | Dual processor |
| Operating system | Linux RedHat 7.3 | Windows XP | Windows XP | Windows |
| Type and speed (GHz) of CPU | 2 x 3.4 | 2 x 3.06 | 2 x Xeon 3.2 | 3.06 |
| Amount of computer RAM supplied as standard (Gbytes) | 2 | 2 | 2 | 3 |
| Maximum amount of computer RAM (Gbytes) | 4 | 4 | 3 | 3 |
| Total hard disk storage capacity supplied as standard (Gbytes) | 180 | 146 | 147 | 153 |
| Maximum total hard disk storage capacity (Gbytes) | 180 | 438 | 147 | 153 |
| Archive options | CD-R standard<br>MOD optional | CD-R standard<br>EOD option | CD-R standard<br>MOD option | MOD standard |
| Capacity of a single archive disk (Gbytes) | 4.6 | 9.1 | MOD: 4.1<br>CD-R: 0.65 | 4.8 |
| Environmental requirements (max/min temperature, humidity) for workstation | 10-40 °C, 20-80 % relative humidity | 0-40 °C | 10-35 ºC, 20-80% relative humidity | 18-28 ºC, 40-80% relative humidity |

## Table 27: 3D reconstruction display (MC – main console, WS – workstation)

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| MIPs and MinIPs (maximum and minimum intensity projections) | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard |
| SSD (3D Shaded Surface Display) | MC-option<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard |
| 3D Volume rendering software | MC-option<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard |
| 3D Virtual endoscopy | MC-option<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-option<br>WS-standard |
| MPR (Multi-planar reconstruction) | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard | MC-standard<br>WS-standard |
| Planes available in MPR | Axial, para-axial, sagittal, coronal, oblique, curvilinear | All planes, any oblique (identical on console and workstations) | Axial, sagittal, coronal, oblique, curvilinear | Axial, sagittal, coronal, oblique, curved with cross cut through the curved reformat |

## Table 28: Optional facilities (MC – main console, WS – workstation)

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Contrast injector | Option | Option | Option | Option |
| Contrast media bolus tracking | Standard (SmartPrep) | Standard | Standard (CAREBolus) | Standard |
| CT fluoroscopy software and hardware | Option (SmartStep) | Option (Continuous CT Imaging) | Option (CAREVision with HandCARE) | Option |
| Hard-copy imaging device | Option | Option | Option | Option |
| Radiotherapy planning table top | Option (RT flat pad and Exact couch top) | Option (Exact table top) | Option | Option |
| Carbon fibre breast board | Option | Option | Option | Not available |
| Means for attaching patient immobilisation devices and a stereotactic frame to the end of the couch | Option (Exact couch) | Option | Option | Option |
| Bone Mineral Densitometry | MC-Not available WS-option (BMD) | MC-option WS-option | MC-option WS-option (Osteo CT) | MC-option WS-Not available |
| CT Angiography | MC-standard WS-standard AVA (Vessel Assessment) option on WS | MC-standard WS-standard | MC-standard WS-standard | MC-standard WS-standard |
| Dental | MC-option WS-option (Dentascan) | MC-option WS-option | MC-option WS-option (Dental CT) | MC-option WS-option |
| Radiotherapy CT simulation software | MC-Not available WS-option (CT sim) | MC-option WS-option | Coherence Dosimetrist (separate workstation) | MC-Not available WS-option |
| Prospective ECG-triggered cardiac software | MC-option WS-option (SmartScore) | MC/WS option (Prospective Gating) | MC-option WS-option (post-processing only) (HeartView CS) | MC-option WS-option |
| Retrospective ECG-gated cardiac software | MC-option (Snapshot) MC+WS-option (Cardiac Imaging) | MC/WS-option (Retrospective Tagging) | MC-option WS-option (post-processing only) (HeartView CI) | MC-option WS-option |
| CT Perfusion software | MC-option WS-option (CT Perfusion) | MC-option WS-option (head + body perfusion) | MC-option WS-option (Perfusion CT) | MC-option WS-Not available |

## Table 29: Installation requirements

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Environmental requirements (max/min temperature, humidity) in scanner room | 15-26 ºC, 30-60% relative humidity | 15-24 °C, 20-75% relative humidity | 18-30 ºC, 20-85%, relative humidity | 18-28 ºC, 40-80% relative humidity |
| Environmental requirements (max/min temperature, humidity) in scanner control room | 15-26 ºC, 30-60% relative humidity | 15-28 °C, 20-75% relative humidity | 15-28 ºC, 20-85% relative humidity | 18-28 ºC, 40-80% relative humidity |
| Peak heat output from system during scanning (kW) | 7.1 (75 rot/patient, 4 patient/hour) | 5.9 | 5.5 (add 0.07 for CT fluoro) | 10.5 max |
| System cooling method | Output to air | Oil to air | Output to air | Output to air |
| Air conditioning requirements for scanner room of minimum floor area | Recommended | Not required, other than for patient comfort | None | Not necessary but recommended |
| Minimum floor area required for the system (m²) | 23 | 25 | 18 | 27 (std)<br>25 (short) |
| Gantry dimensions (H x W x D (mm)) and weight (kg) | 1887x2230x1007<br>1269kg | 2030x2290x940<br>1764kg | 1780x2300x680<br>1200kg | 1950x2330x960<br>1750kg |
| Couch dimensions (H x W x L (mm)) and weight (kg) | 1120x610x2387<br>340kg | 1010x690x2490<br>383 kg | 890x680x2260<br>400 kg | 450x630x2690<br>450kg(std)<br>450x630x2390<br>420kg(short) |
| Supplementary unit dimensions (H x W x D (mm)) and weight (kg) | Power unit:<br>1270x762x585<br>408kg | Power unit:<br>1120x560x530 | None | Power unit:<br>980 x 800 x 770,<br>550kg |
| Power supply requirements | 3 phase 380-480V, 90kVA | 3 phase 380-480V, 90kVA | 3 phase 380-480V, 70kVA | 3 phase 380-440V, 100kVA |

## Table 30: Image transfer and connectivity

| | GE LightSpeed Ultra | Philips Brilliance CT 6 [10] | Siemens Emotion 6 | Toshiba Aquilion 8 |
|---|---|---|---|---|
| Speed of scanner / workstation connections to local area networks (Mbits/s) | 100 | 100 or 1000 | 1000 | 100 |
| Remote PC access to images on workstation | Option | Option (Easyweb) | Option | Option |
| **DICOM services on Main Console** | | | | |
| Storage | SCU, SCP | SCU, SCP | SCU, SCP | SCU, SCP |
| Print | SCU | SCU | SCU | SCU |
| Query / retrieve | SCU, SCP | SCU, SCP | SCU, SCP | SCU, SCP |
| Modality worklist | Option | SCU | SCU | SCU |
| Performed procedure step | Option | SCP | SCU | SCU |
| Storage commitment | Yes | Not available | SCU | SCU |
| **DICOM services on Workstation** | | | | |
| Storage | SCU, SCP | SCU, SCP | SCU, SCP | SCU, SCP |
| Print | SCU | SCU | SCU | SCU |
| Query / retrieve | SCU, SCP | SCU, SCP | SCU, SCP | SCU, SCP |
| Modality worklist management | Yes | SCU | Not available | Not available |
| Performed procedure step | Yes | SCP | Not available | Not available |
| Storage commitment | Yes | Not available | SCU | Not available |

# Appendix 1: Manufacturer's comments

Manufacturers' comments included in this section were in response to version 9 of this report. Changes in the content of this report version may have affected the relevance of some comments.

Responses are included from the following manufacturers:

- GE Medical Systems
- Philips Medical Systems
- Toshiba Medical Systems

Where appropriate ImPACT have included a short reply.

A response was received from Siemens indicating that they did not wish to make any specific comments on the report.

*GE Medical Systems*
*General Electric Company*
*3200 N. Grandview Boulevard*
*Waukesha, Wi, 53188*

December 11, 2003

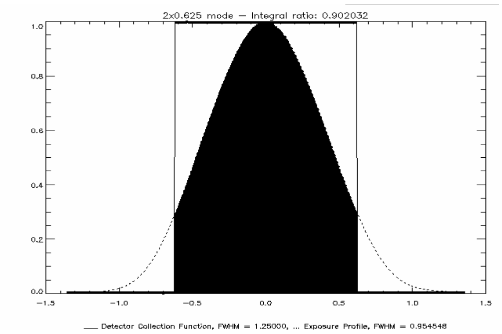
Dear Sir or Madam:

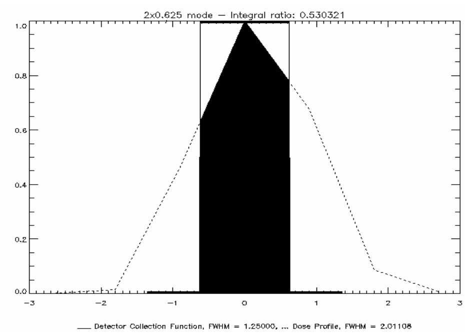
Thank you for giving GEMS an opportunity to review the preliminary drafts of the October 2003, Revision 9 ImPACT reports for CT Scanners. We are submitting these comments after reviewing the contents of each of the comparison reports. GEMS would appreciate consideration of our concerns prior to final release.

In summary our comments are:

1. Geometric Efficiency – While applauding the attempt to utilize the IEC CT 60601-2-44 Ed. 2 (2001) Amendment 1 (2003) definition of geometric efficiency, we believe that there are errors in the methodology used in ImPACT measurements. For this reason we are requesting that ImPACT returns to using earlier tabular and graphical data contained in Revision 6 until ImPACT and GEMS can agree on the details of methodology and calculations used to generate Geometric Efficiency via the IEC technique.

As an example, we reproduced the IEC geometric efficiency measurements of GEMS Thin-Twin (2 x .625mm) mode 1. Using an air scan and sweeping the detector in Z, and 2. Using TLD data from a CTDI phantom scan. Based on our results the IEC geometric efficiency of GEMS Thin-Twin mode is over 90% on our LightSpeed 16 scanner and should be even greater for the LS 4 and 8-slice scanners due to the use of the 1.25mm cells that afford even better focal spot tracking.




Integral ratio = area under exposure profile seen by detector/ area under exposure profile. Also, our nominal aperture is 0.48 at the collimator or 1.6 @ iso. From the exposure profile we measure equivalent values: 1.62mm @ 10% and 2.25 @ 1% (so we would be 100% for LightSpeed Plus and Ultra).

A second measurement was made using a TLD dose profile. The geometric efficiency done using this data is approximately 53% which agrees with the ImPACT Report, Revision 9 graph of Geometric Efficiency. **GEMS believed this is an incorrect determination of our Geometric Efficiency.**

2. Image Reconstruction

Please edit the Reconstruction Times table to include our XTream Console data:

Time(s) from the start of data acquisition (X-ray on) to the appearance of the 30th image of a series:

| | |
|---|---|
| (i) standard brain scan | 27 s |
| (ii) axial spine scan | 14 s |
| (iii) helical abdomen scan | 10 s |

3. Image Transfer and Connectivity

Please add Storage Commitment SCU to the list of DICOM Services on the Main Console.

4. Inner Ear Protocol for LS 16, Clinical Scan Tables

GEMS recommend a 16 x .625 helical scan of pitch .56 with a Bone+ filter for optimal inner ear scans.

Thank you for this opportunity to review the draft version of your report. Please contact me if you have any questions regarding this reply.

Sincerely,

Thomas J. Myers, Ph.D.
GEMS CT Systems Engineering Manager

GE Medical Systems
3000 North Grandview Boulevard
W-1140
Waukesha, Wi 53188
USA

No method for measurement of geometric efficiency as defined in IEC CT 60601-2-44 Ed. 2 (2001) Amendment 1 (2003) is given in the standard, and ImPACT believes that the technique used to measure this quantity is in accordance with the definition. ImPACT has discussed this matter with GE, and both parties are now agreed on the method used, and that the results published in this report are correct.

The specification issues raised in points 2 and 3 have been updated.

The inner ear protocol listed in point 4 is a helical protocol, whereas the table in the report is an axial one. Future versions of this report will include a helical inner ear protocol in the clinical scan tables.

Philips Medical Systems would like to thank ImPACT for the hard work put into both the assessment and subsequent production of this report on the Philips Mx8000 IDT. However, it should be noted that as of the RSNA 2003 the Mx8000 system has been superseded by our new product line – the Brilliance CT range. This range has configurations ranging from 6 to 40 slices per configuration and offers a choice of tube (including our famous MRC) and reconstruction at rates of up to 40 images per second.

We are broadly in agreement with the results of the ImPACT report, but also appreciate this opportunity for review and so would like to make the following comments and observations:

The tests and results contained within this report were performed on and Mx8000 IDT 16 System with Release 2.5 software. An updated version R2.5.5 is now being installed on all systems, with a major new software Release – R 3.0, planned for early in 2004. This will substantially affect some of the results obtained in this assessment.

These evaluation reports focus upon the Q factor to allow comparison with other CT systems and we appreciate that there must be some method of enabling this analysis. However, as has been said before, we feel that for this figure to have relevance to the real diagnostic imaging situation, it is of paramount importance that real clinical scanning protocols are used for the evaluation. We note that whilst we have provided actual scan protocols including scan time, this may not be the case for all systems evaluated. For instance selecting a longer scan time for a particular scan may produce a better Q factor, but it would not be possible to reproduce this in a clinical situation. In addition this assessment has been performed on a machine in clinical use, not in a less realistic factory situation.

Further tests are being performed for limiting spatial resolution as, following discussion between ImPACT and PMS it was felt that the preliminary results did not accurately reflect the performance of the system. These results are awaited.

ImPACT would like to note that the Q values in this report are independent of scan time. Whilst it is true that for some scanners, the use of long scan times can increase spatial resolution, this effect is not apparent with the standard resolution kernels used for calculation of Q.

The updated resolution measurements are included in the limiting resolution section of this report.

TOSHIBA

**TOSHIBA** MEDICAL SYSTEMS CORPORATION
1385 SHIMOISHIGAMI, OTAWARA-SHI, TOCHIGI 324-8550, JAPAN
PHONE +81-287-26-6203 FAX +81-287-26-6028

Sue Edyvean
ImPACT
Medical Physics Department
Knightsbridge Wing
St. George's Hospital
London SW17 OQT
United Kingdom

Subject: Aquilion 16 assessment Our reference: MO/031210 Date: December 12, 2003

Dear Sue
Thank you for the assessment of our Aquilion 16 CT scanner.

We are glad that ImPACT recognizes the differences between Toshiba's reconstruction algorithms and those used by the other manufacturers. As pointed out in the graph: "Noise vs. Resolution in head scanning" and mentioned in the note in the paragraph on scanner performance, Toshiba reconstruction algorithms can generate better resolution values than achieved with the by ImPACT as "standard" perceived filter. This without suffering from a poorer signal to noise ratio. Consequently these algorithms lead to a much higher Q-value, which can be interpreted as a higher dose efficiency of these kernels. Next to the image impression given with these kernels, this higher dose efficiency is one of the reasons why our customers use these kernels (around FC22) instead of the for the assessment selected "standard" FC27.

During the assessment of the spatial resolution we noticed that ImPACT uses a phantom with a block of high dense material inside. The problem with scanning such a block is that the alignment of the phantom is rather critical. The slightest deviation of the scanned edge from the scan axis will generate a partial volume artifact in the slice, creating a fuzzy edge. Therefore it can be questionable if the MTF calculation from such a slice is accurate. To avoid any discussion when checking the spatial resolution of a scanner, our engineers use a phantom that contains a bead.

As previously discussed, we feel that the present ImPACT protocol mainly based on conventional axial scanning becomes gradually outdated. This because in modern multi slice CT scanners the majority of the scans are performed in a Helical scan mode whereby the resolution of the acquisition becomes isotropic. As there is a worldwide tendency towards these volumetric acquisitions and volumetric reconstructions, we would like to advice ImPACT to adapt the assessment protocol so that the scanner performance is reflected within this changed environment.

We appreciate the discussions between our organizations as these are not only beneficial to both our organizations but also to our customers and even more important their patients. The critical comments of ImPACT strengthen us to keep striving for development of the best possible CT scanner.

Yours sincerely,

Miwa Okumura
Group Manager Application & Research group
CT Systems Development Department
Toshiba Medical Systems Corporation

Whilst misalignment could potentially cause errors in measurement, the block used for resolution measurement is always aligned carefully in the scan plane. There are also advantages to the block method, as the number of pixels used to calculate the MTF from the block is greater than with a bead, resulting in an improved signal to noise ratio.

# Appendix 2: Image quality assessment and Q

Image noise, scan plane spatial resolution and imaged slice width are fundamental parameters describing the amount of object information retrievable from an image, or its image quality. Radiation dose can be regarded as a 'cost' of this information. In general, it is meaningless to quote any one of these measurements without reference to the others.

It is possible to incorporate dose, noise, spatial resolution and slice width into one number, using formulae derived from the relationships between image quality and dose. Figures of merit such as this can take a number of forms depending on how the various parameters are measured and quoted. ImPACT use the $Q_2$ value, whose formula and methods of measurement are given below.

High $Q_2$ values result from CT scanners that produce images with lower noise at a set spatial resolution, when dose and image width are taken into account.

The parameters used in Q are standard imaging performance parameters. However it should be noted that the quantification of perceived image quality is a complicated process and as such will not be fully described by the single descriptors used for each of the parameters.

Comparisons between scanners are more reliable when comparing scans reconstructed with similar convolution filters. The uncertainty in quoted values of $Q_2$ is up to about ± 15 %, with a conservative estimate of ± 10 %.

$Q_2$ is calculated as follows:

$$Q_2 = \sqrt{\frac{f_{av}^3}{\sigma^2 z_1 CTDI_{vol}}}$$

σ = image noise, expressed as a percentage (for water, standard deviation in HU divided by 10), for a 5 $cm^2$ region of interest at the centre of the field of view in the standard ImPACT water phantoms.

$f_{av}$ = spatial resolution, given as $(MTF_{50} + MTF_{10})/2$, where $MTF_{50}$ and $MTF_{10}$ are the spatial frequencies corresponding to the 50 % and 10 % modulation transfer function values respectively (in line pairs per cm). Reconstruction filters with standard spatial resolution values are chosen to minimise the dependency of $Q_2$ upon reconstruction filters. The reconstruction filter with $MTF_{50}$ and $MTF_{10}$ values as close as possible to 3.4 c/cm and 6.0 c/cm is used (c/mm used in the calculation for consistency of units with z-sensitivity).

$z_1$ = the full width at half maximum (FWHM) of the imaged slice profile (z-sensitivity). This is measured using the inclined plates method (mm).

$CTDI_{vol}$ = volume weighted CT dose index (mGy).

# Appendix 3: ImPACT

## ImPACT

ImPACT (Imaging Performance Assessment of Computed Tomography) is the Department of Health's CT evaluation facility. It is based at St George's Hospital, London, part of St George's Healthcare NHS Trust.

ImPACT has developed test objects and measurement procedures suitable for inter-comparing CT scanner performance. For each CT evaluation hundreds of images are obtained from the system under test and subsequently analysed using custom written software. Dose measurements are made using ion chambers, and x-ray film is used to obtain additional x-ray dose information.

## Support to purchasers and users

The ImPACT team is available to answer any queries with regard to the details of this report, and also to offer general technical and user advice on CT purchasing, acceptance testing and quality assurance.

ImPACT
Bence Jones Offices
St George's Hospital
London SW17 0QT

T: +44 (0) 20 8725 3366
F: +44 (0) 20 8725 3969
E: impact@impactscan.org
W: www.impactscan.org