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Wide bore CT scanner comparison report version 14

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Wide bore CT scanner comparison report version 14

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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.

The scope of this report is limited to CT scanners that have a gantry bore wider than a standard system. These systems have been developed primarily for applications in radiotherapy treatment planning.

Comparison method

There are two main areas for comparison of the scanners: performance and specification. Two of the scanners in this report have been tested by ImPACT, the GE LightSpeed RT and the Siemens Sensation Open. For the remaining scanners the scope of this report is restricted to a comparison of system specifications.

The data given in this report are representative of the scanners as of February 2006, and are liable to change as the performance of individual scanner models is changed and upgraded. In particular, for the specification sections optional features 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 quality and radiation 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. This report covers systems with a gantry bore that is wider than a standard diagnostic scanner (Table 1).

Table 1: Scanners covered in this report

Manufacturer	Scanner model
GE	LightSpeed RT
Philips	Brilliance CT Big Bore
Siemens	Somatom Sensation Open
Toshiba	Aquilion LB

The GE LightSpeed RT is a 4-slice system based on the existing GE LightSpeed range. It features a detector layout consisting of 16 x 1.25 mm rows, with a z-axis coverage of 20 mm. The gantry opening has a diameter of 80 cm, with a maximum standard image size of 50 cm available. Use of the system's extended field of view reconstruction allows the image size to be increased to 65 cm by extrapolating existing data. However, the image quality in this extended region will be reduced compared to that found in the standard sized region.

The Philips CT Big Bore scanner is a 16-slice system based on the Brilliance CT 16 scanner. The detector layout has 16 x 0.75 mm rows in the centre, surrounded by 4 x 1.5 mm on either side, producing a total z-axis coverage of 24 mm. The Big Bore has an increased focus to detector distance to accommodate the 85 cm gantry aperture. To enable image sizes up to 60 cm to be acquired and reconstructed directly, the number of elements in each detector row has been increased from the 690 found in the Brilliance 16, to 816 in the Big Bore.

The Siemens Somatom Sensation Open is a 3rd generation 24 or 40 slice helical CT scanner, with a wider than usual gantry opening. It features a Straton x-ray tube, and a fastest gantry rotation time of 0.5 seconds. The 24-slice option has a routine beam collimation of 24 x 1.2 mm. The 40 slice version uses a flying focal spot along the z-axis to produce 40 x 0.6 mm data sets per rotation, and can also acquire 24 x 1.2 mm data sets per rotation. The z-axis detector bank length is 28.8 mm. The gantry bore has an opening of 82 cm, and the systems are capable of acquiring images up to 50 cm directly. In addition, an extended field of view technique can be applied that reconstructs images beyond 50 cm, up to 82 cm. Special techniques are used for this, and result in

reduced image quality within the extended field of view compared to that found in the standard sized region.

The Toshiba Aquilion LB is a 3rd generation, 16-slice scanner based largely on the Toshiba Aquilion 16 slice system. The z-axis detector layout has16 x 0.5 mm rows in the centre, with 12 x 1.0 mm rows on either side. It has an increased focus to detector distances to accommodate the 90 cm gantry aperture. To enable image sizes of up to 70 cm to be acquired and reconstructed directly, the number of elements in each detector row has been increased from 896 to 994 and the scanner operates with an asymmetric fan beam when in body mode. Work is in progress to provide an extended field of view of up to 85 cm.

ImPACT have assessed the imaging and dosimetry performance of the GE LightSpeed RT and Siemens Somatom Sensation Open systems.

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 filter 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 Consolidated Edition 2.1 (incl. am1) (2002-11). 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

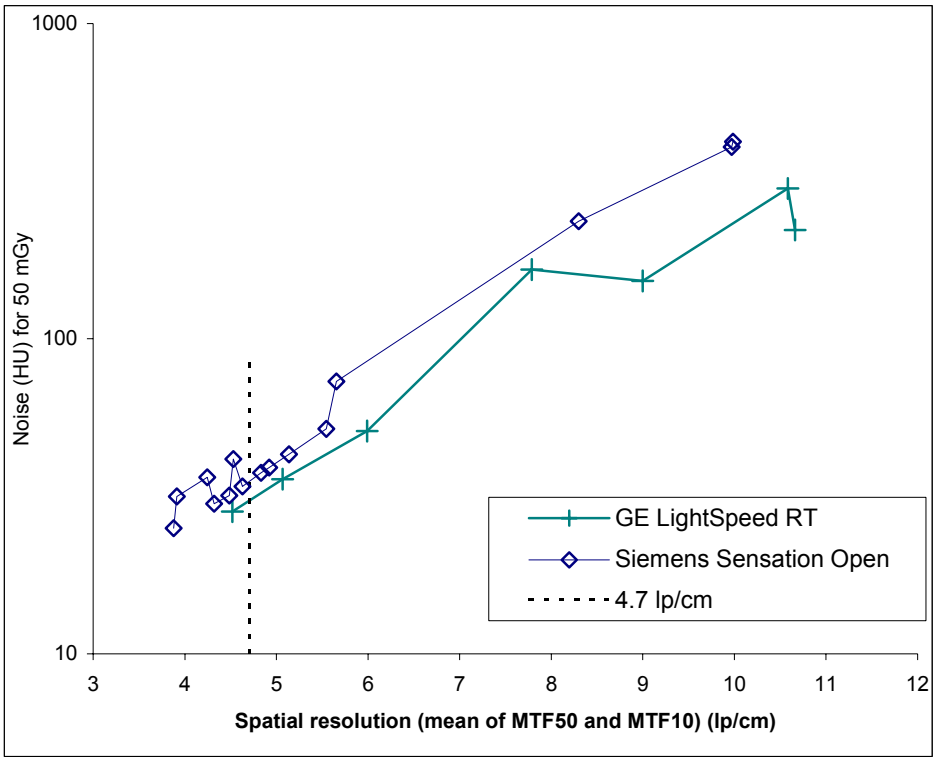
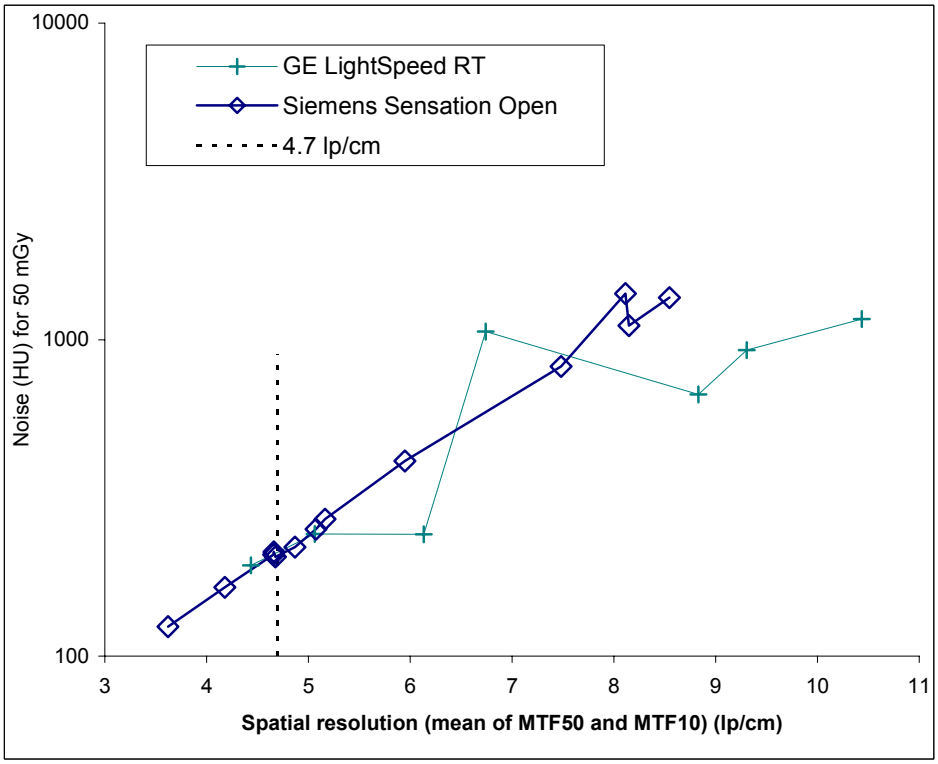


Figure 2: Image noise vs. spatial resolution for body scanning at a $CTDI_{vol}$ of 15 mGy



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 1 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)
- Small focal spot
- 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 RT	SOFT	253	4.7	34	3.2	5.8	5.9
Siemens Sensation Open	H30	277	4.7	35	3.3	6.0	5.9
Mean		265	4.7	34	3.2	5.9	5.9

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 RT	SOFT	151	4.7	200	3.5	6.0	2.0
Siemens Sensation Open	B31	173	4.7	213	3.2	6.1	1.8
Mean		162	4.7	207	3.4	6.1	1.9

Figure 3: Q_2 figures for head scanning

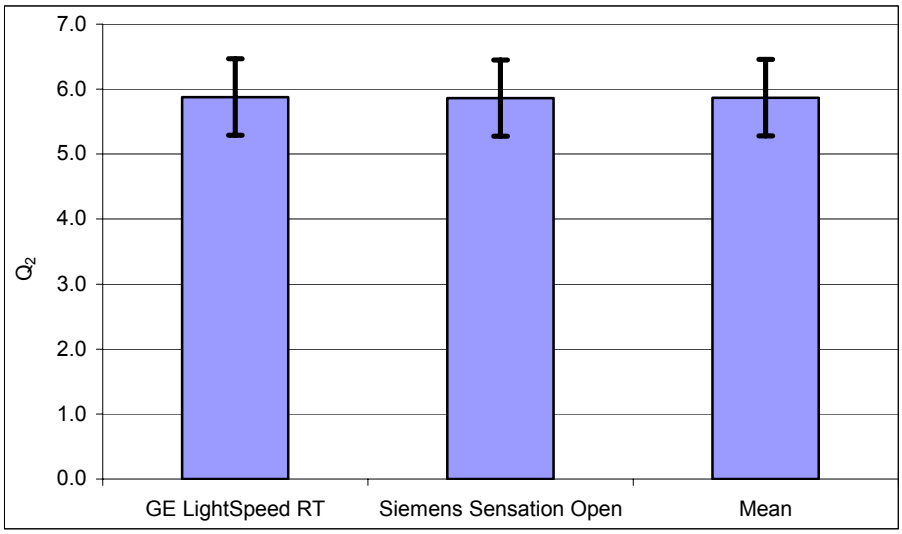
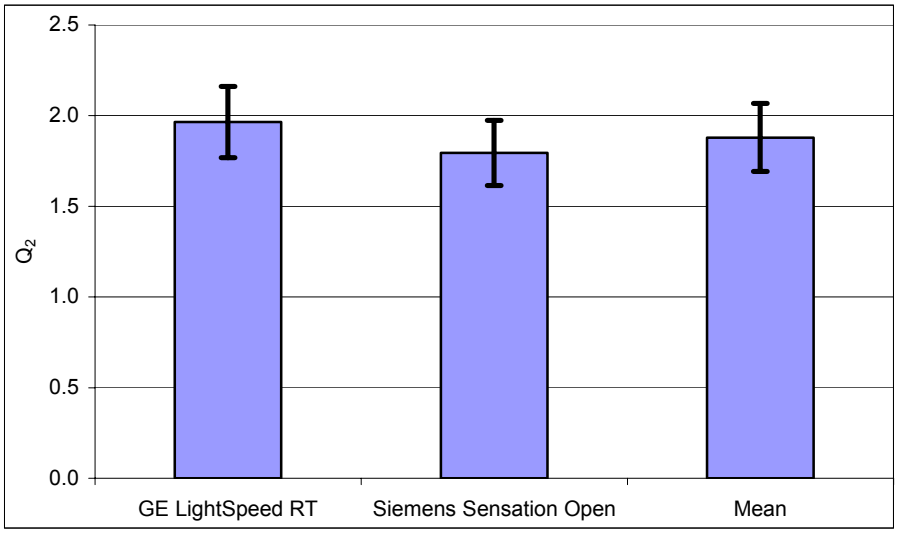


Figure 4: Q_2 figures for body scanning



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.

Scan-plane spatial resolution

Table 4: Limiting scan-plane spatial resolution

Scanner	Recon filter	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
GE LightSpeed RT	EDGE	8.6	13.2
Siemens Sensation Open	H80h	8.6	12.0
Mean	-	8.6	12.6

The scan parameters used for the scan-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.

Z-axis spatial resolution (helical)

Table 5: z-axis spatial resolution

Scanner	Pitch	Collimation (mm)	Slice width (mm)		MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
			Nominal	Measured		
GE LightSpeed RT	0.75	4 x 1.25	1.25	Results not available		
Siemens Sensation Open	0.45	40* x 0.6	0.6	0.63	5.6	13.1
Mean				0.63	5.6	13.1

Geometric efficiency

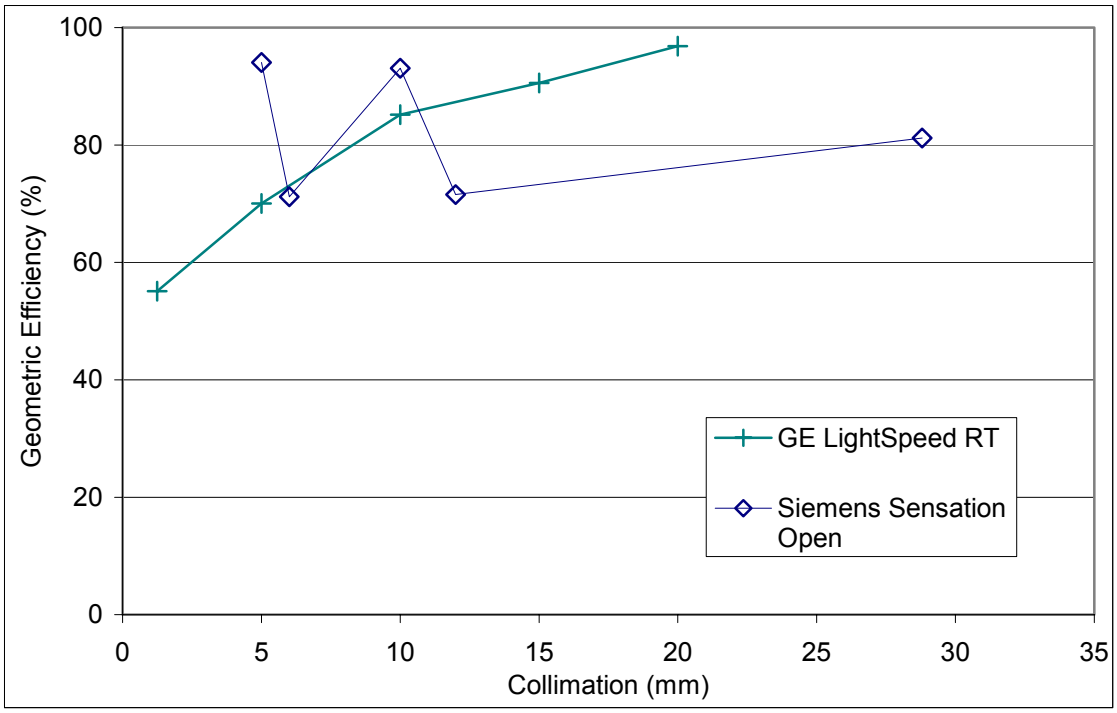
Geometric efficiency is a measure of x-ray dose utilisation along the z-axis. ImPACT now uses the geometric efficiency figure as specified by the IEC CT safety standard, 60601-2-44 Consolidated Edition 2.1 (incl. am1) (2002-11). Geometric efficiency has been calculated from this definition as the ratio 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	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
GE LightSpeed RT	120	320	1	5 (4 x 5)	250	SOFT	57	4.7	2.6	3.1	5.7
Siemens Sensation Open	120	320	1	3 (20 x 0.6)	250	H30	70	3.0	4.0	3.3	6.0
Mean							64	3.8	3.3	3.2	5.9

Table 7: Axial inner ear

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)	MTF_{10} as mm
GE LightSpeed RT	140	120	1	0.63 (2 x 0.63)	120	EDGE	43	0.9	97	7.8	13.4	0.4
Siemens Sensation Open	Axial inner ear not routine (thin slices available in helical mode)											
Mean							43	0.93	97	8	13	0.4

Table 8: Helical inner ear

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	Pitch	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)	MTF_{10} as mm
GE LightSpeed RT	140	70	1	0.63	1	EDGE	25	1.0	111	6.3	11.9	0.4
Siemens Sensation Open	120	96	1	0.6 (40* x 0.6)	0.8	H60	24	0.6	130	7.5	9.6	0.5
Mean							25	0.82	120	6.9	11	0.5

Table 9: Axial abdomen

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
GE LightSpeed RT	120	190	1	5 (4 x 5)	380	STANDARD	16	4.7	22	3.9	6.3
Siemens Sensation Open	120	105	1	4.8 (24 x 1.2)	380	B31	9	4.7	27	3.2	6.1
Mean							13	4.7	25	3.5	6.2

Table 10: Helical abdomen

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	Pitch	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
GE LightSpeed RT	120	250	1	5 (4 x 5)	1.5	STANDARD	15	6.4	20	3.8	6.5
Siemens Sensation Open	120	144	0.5	5 (24 x 1.2)	1.2	B31	10	5.1	23	3.1	6.1
Mean							13	5.8	22	3.5	6.3

Table 11: Low noise spine

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)
GE LightSpeed RT	120	290	1	2.5 (4 x 2.5)	120	STANDARD	30	2.3	26	3.5	6.1
Siemens Sensation Open	120	180	1	3 (20 x 0.6)	120	B31	18	3.0	28	3.2	6.2
Mean							24	2.7	27	3.4	6.1

Table 12: High resolution spine

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon filter	$CTDI_{vol}$ (mGy)	z-sens. (mm)	Noise (HU)	MTF_{50} (lp/cm)	MTF_{10} (lp/cm)	MTF_{10} as mm
GE LightSpeed RT	120	200	1	1.25 (4 x 1.25)	120	BONE+	24	1.1	257	7.8	10.8	0.5
Siemens Sensation Open	120	180	1	3 (20 x 0.6)	120	B60	18	3.0	157	7.1	9.3	0.5
Mean							21	2.0	207	7.5	10	0.5

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:

- Siemens Sensation Open 24 and Sensation Open 40 models, where the Open 24 is in brackets.

Table 13: Couch

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Couch top material	Carbon fibre	Carbon fibre	Carbon fibre	Carbon fibre
Couch top length and width (cm)	239 x 42	244 x 41	243 x 40	219 (std) or 189 (short) x 47
Horizontal movement range (cm)	170	201	200	219 (std) 189 (short)
Horizontal movement speeds (mm/sec)	up to 100	0.5 - 100	1 - 150	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	157	180 (std) 150 (short)
Scannable horizontal range with table top extension(s) (cm)	170 (Axial), 160 (Helical & Scout)	192	157	180 (std) 150 (short)
Vertical movement range out of gantry (cm)	51 - 99	53 - 105	53 - 102	31 - 95.4
Vertical movement range in gantry (cm)	73 - 99	79 - 104	82.5 - 102	66.9 - 95.4
Minimum couch top height outside gantry (cm)	51	52	53	31
Maximum weight allowed on couch (kg)	205	204	200 (280 kg option)	205
Maximum weight on couch which still achieves stated performance specifications (kg)	180 (±0.25mm) 205 (±1mm)	204	200 (280 kg option)	205

Table 14: Scanner gantry

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Generation	3rd	3rd	3rd	3rd
Slipring	Low voltage	Low voltage	Low voltage	Low voltage
Aperture (cm)	80	85	82	90
Scan fields of view (cm)	25 and 50	5 - 60	50	24, 32, 40, 55, 70
Tilt range (degrees)	± 30	± 30	± 30	Not available
Type of positioning lights	Laser	Laser	Laser	Laser
Accuracy of positioning lights (mm)	± 1	± 0.5 at centre of gantry	± 1	± 1
Focus-isocentre distance (mm)	606	645	570	712
Focus-detector distance (mm)	1059	1183	1040	1275

Table 15: X-ray generator

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
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, 100, 120, 140	80, 100, 120, 135
mA range and step size	10 - 440 (5mA steps)	30 - 500 (1mA steps)	28 - 400 (1mA steps)	10 - 50 (5mA steps) 50 - 500 (10mA steps)
Max. mA allowed for each kV	80kV: 400 mA 100kV: 420 mA 120kV: 440 mA 140kV: 380 mA	90kV: 500mA 120kV: 500mA 140kV: 430mA	80 kV: 400mA 100kV: 400mA 120kV: 400mA 140kV: 360mA	80 kV: 500mA 100 kV: 500mA 120kV: 500mA 135kV: 430mA

Table 16: X-ray tube

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Type and make	GE Performix Pro	Philips MRC	Siemens Straton	Toshiba Megacool
Focal spot size(s) (mm), quoted to IEC 336/93 standard	0.6 x 0.7 0.9 x 0.9	0.5 x 1.0 1.0 x 1.0	0.7 x 0.7 0.8 x 1.1	0.9 x 0.8 1.6 x 1.4
Settings at which focal spot changes. kW = kV x mA / 1000	24 kW	Small focus in high res. mode, not kW limited	Change automatically; medium up to 55kW; large up to 60 kW	80kV : 36kW 100kV : 35kW 120 kV : 36kW 135 kV : 33.8kW
Total filtration (inherent + beam shaping filter) at central axis (mm Al equivalent)	6.8 (70kV, head) 9.5 (70kV, body)	8.8	6.8	> 1 (inherent) 1.5 - 10 (wedge dependent)
Anode heat capacity (MHU)	7.5	8	0.6, equiv to 30	7.5
Maximum anode cooling rate (kHU/min)	840	1608	5000	1386
Method of cooling	Glycol to air	Oil to air	Oil to air	Oil to forced air
Guaranteed tube life	1 year unlimited guarantee	1 year unlimited guarantee	1 year unlimited guarantee	300,000 rotations

Table 17: Detection system

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Detector type	Solid state (HiLight / Lumex)	Solid state (High speed ceramic)	Solid state (Ultra Fast Ceramic)	Solid state
Maximum number of simultaneously acquired data sets (no. of slices)	4	16	40 [24]	16
Number of detectors per row	888 (plus 18 reference detectors)	816	672 (1344 channels)	994 (plus 2 reference detectors)
Number of elements along z-axis	16	24	40	40
Effective length of each element at isocentre (mm)	16 x 1.25	0.75 1.5	32 x 0.6, 8 x 1.2	16 x 0.5 24 x 1.0
Total effective length of detector array at isocentre (mm)	20	24	28.8	32
Option for more slices / rotation	No	No	Yes	No

Table 18: System start-up and calibration

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Power-on to warm-up time from fully off (mins)	2	4	4	2
Tube warm-up time from 'cold' to operating temperature (mins)	0.5	2 - 3	0	2 (0 in an emergency)
Time to perform detector calibrations at warm-up (mins)	Included in tube warm-up	3 min or less	5	1
Recommended frequency for any additional calibration by the radiographer	Once every 24 hours	Not required	Not required	Not required
Time to perform these additional calibrations (mins)	13 (inc warm-up)	Not required	Not required	Not required
Total time from fully off to scanning in an emergency (mins)	< 3	Info.not available	4	2

Table 19: Scan parameters

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
kV settings available	80, 100, 120, 140	90, 120, 140	80, 100, 120, 140	80, 100, 120, 135
mA Range and Step size	10 - 440 (5mA steps)	30 - 500 (1mA steps)	28 - 400 (1mA steps)	10 - 50 (5mA steps) 50 - 500 (10mA steps)
Max. mA allowed for each kV	80kV: 400 mA 100kV: 420 mA 120kV: 440 mA 140kV: 380 mA	90kV: 500mA 120kV: 500mA 140kV: 430mA	80 kV: 400mA 100kV: 400mA 120kV: 400mA 140kV: 360mA	80 kV: 500mA 100 kV: 500mA 120kV: 500mA 135kV: 430mA
Maximum continuous scan time (s)	120	100	100	100

Table 20: Helical and axial scanning

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Rotation times for axial scaning (s) * = Partial scans	1, 2, 3, 4	0.3*, 0.4, 0.5, 0.75, 1, 1.5, 2	0.33*(option), 0.5 (option), 0.67* , 1.0s	0.32*, 0.5, 0.75, 1, 1.5, 2, 3
Rotation times for helical scanning (s)	1	0.4, 0.5, 0.75, 1, 1.5	0.5 (option), 1.0	0.5, 0.75, 1, 1.5
Axial slice widths (number x width, mm)	2 x 0.625, 1 x 1.25, 4 x 1.25, 1 x 2.5, 4 x 3.75, 4 x 5	2x0.6, 16x0.75, 16x1.5, 8x3, 4x4.5	12x2.4,4x3,1x5,1x10	4x0.5, 4x1, 4x2, 4x3, 4x4, 4x6, 4x8
Helical acquisition widths (number of channels x width, mm)	Info.not available	16x0.75, 16x1.5, 8x3, 4x4.5	24x1.2, 20x0.6, 40x0.6 [24x1.2, 20x0.6]	16x0.5, 16x1, 16x2
Pitches available for routine scanning (range and increment)	2 slice : 1 4-slice : 0.75 & 1.5	0.04-1.7 freely selectable	0.45 - 2.0 freely selectable	16-slice: 0.625 - 1 / 1.125 - 1.5 4-slice: 0.625 -1.5
Recommended pitches for optimal image quality	2 slice : 1 4-slice : 0.75 & 1.5	0.04-1.7 freely selectable	0.45 - 2.0 freely selectable	0.6875, 0.9375, 1.4375
Helical interpolation algorithms available	SmartHelical & MDMP, including CrossBeamTM & HyperplaneTM	Cobra - Cone Beam Reconstruction	SureView, AMPR cone-beam artefact reduction	TCOT and MUSCOT
Maximum number of rotations in one helical run at standard abdomen parameters	70s (350-440 mA) 90s (280-415 mA) 110s (240-345 mA)	200	160 (324mA, .5s) 176 (300mA, .5s) 200 (273mA, .5s)	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	1500	1570	1750 (std) 1450 (short)
Gantry tilt range for helical scanning (degrees)	± 30	Not available	Not available	Not available

Table 21: Scanned projection radiography (SPR)

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Maximum SPR length (mm)	1600	1500	1536	1800 (std) 1500 (short)
SPR field dimensions (mm x mm)	500 x 1600	500 x 1500	500 x 1536	width: 240, 320, 400, 500 length: 200 - 1800 (std), 1500 (short)
Angular positions of X-ray tube available for SPR	0 - 359° (1° steps)	0°, 90°, 180°	AP, PA, LAT (±1° accuracy)	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	±0.5	± 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	± 0.5	< ± 0.5

Table 22: Image reconstruction on main console

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Reconstruction fields of view (cm)	9.6 - 50	5 - 60	5 - 50	0.05 - 70
Extended scan field of view (cm)	65	Entire FOV uses standard reconstruction	51 - 82	85 (WIP)
Reconstruction matrix	512	512, 768,1024	512	256, 512
Minimum reconstruction interval in helical scanning (mm)	0.1	0.3	0.1	0.1
Time from start of scanning to appearance of 30th image for a standard axial brain scan (s)	30 (with IBO)	5.9	3 (up to 20 f/s)	20
Time from start of scanning to appearance of 30th image for an axial spine scan (s)	11	5.9	3 (up to 20 f/s)	20
Time from start of scanning to appearance of 30th image for a helical abdomen scan (s)	11	5.9	3 (up to 20 f/s)	2.5 (real time) 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 23: Factors affecting image quality and dose

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Post-patient collimation for narrow slices	No	No	No	No
Number of helical gantry rotations required at each end of total imaged volume.	Info.not available	0.5	Info. not available	1.3 max
Adaptive filtration for noise reduction	Low signal correction	Built-in in reconstruction	Yes (automatic)	Yes (user programmable)
Quarter detector shift	Yes	Yes	Yes	Yes
Moving (dynamic/flying) focal spot, xy plane	No	Yes	Yes	No
Number of imaging detectors per row	888	816	672 (1344 channels)	994
Sampling frequency (Hz)	984 @ 1s scan (hardware capable to 1760)	5280	Max. 2320	1800 (0.5s scan) 1200 (>0.5s)
Artefact reduction algorithms	Iterative Bone Option (IBO), Recon of thick slices from thinner ones	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, including CrossBeamTM & HyperplaneTM)	Cone beam reconstruction (COBRA)	Yes, SureView and AMPR cone-beam artefact reduction	TCOT (modified Feldkamp method)

Table 24: Automatic Exposure Control

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Automatic mA control (AEC / mA modulation) software	3D Dose Modulation	Doseright ACS and DOM + cardiac	CAREDose 4D	SureExposure
Method for operator control of AEC	Info.not available	Reference image	Reference mAs	Standard deviation
Method for system control of mA	Info.not available	Single scout	Single scout and online control	Scanogram (single)
- mA adjustment for patient size	Yes	Yes	Yes	Yes
- mA adjustment along the z-axis	Yes	Yes	Yes	Yes
- mA modulation during rotation	Yes	Yes	Yes	No

Table 25: Manufacturer's performance data

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
In plane spatial resolution (lp/cm) for sharpest clinical algorithm. Acquisition parameters in brackets.	MTF0: 15.4 MTF10: 13.9 (10cm DFOV, Edge alg, Small Focus)	MTF0: 15	MTF0: 15.4 ±10% MTF2: 14.5 ±10% (1s, 160 mA, 120 kV, 1.2 mm)	MTF2: 21.4 (120 kV, 200mA, 2 mm slice, 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 with 95%CL: 120kVp, 135mAs, 10mm, Std alg	4.0 mm @ 0.3% 120 kVp, 248 mAs, 10 mm, EB filter, 27 mGy at phantom surface	Spiral: 5 mm @ 0.3% @ 21 mGy: 120 kV, 140 mAs 10 mm	4 mm @ 0.3% @ 11.9 mGy: 120kV, 150 mAs, 10 mm, FC41 with adaptive filter
CT number accuracy (HU)	Water : ± 3	± 4	Air: ± 10 Water: ± 4	Water: ± 3
CTDI100 settings for std head	120 kVp, 20 mm	120kV, 24 mm	120 kV, 24 mm	120kV, 16 mm
CTDI100 (mGy/100mAs), centre of head phantom	15.2	9.3	18.7	8.8 (Wedge 1) 15.1 (Wedge 2)
CTDI100 (mGy/100mAs), periphery of head phantom	16.9	10.6	19.8	9.5 (Wedge 1) 16.3 (Wedge 2)
CTDI100 settings for std body	120 kVp, 20 mm	120kV, 24 mm	120kV, 24mm	120kV, 16 mm
CTDI100 (mGy/100mAs), centre of body phantom	4.5	3.1	5.8	3.0 (Wedge 1) 5.6 (Wedge 2)
CTDI100 (mGy/100mAs), periphery of body phantom	10.5	6.3	11.1	6.5 (Wedge 1) 13.4 (Wedge 2)
Dose profile FWHM (mm) (focal spot size in brackets)	20: 20.6(l) 15: 16.5 (s) 10: 11.5 (s) 5: 6.7 (s) 1.25: 3.5 (s) 2 x 0.63:1.9(s)	± 10% for all collimations in air	20x0.6 : 6.7 (s) 40x0.6 : 15.8 (s) 4x3 : 17 (s) 24x1.2 : 34.3 (s) 12x2.4 : 34.3 (s) 1x5 : 5 (s) 1x10 : 10 (s) [As for 40-slice, without 20x0.6 & 40x0.6]	32 : 38 ± 9.5 (s) 16 : 20 ± 5.0 (s) 8 : 12 ± 3.6 (s)

The scanner performance data in the above table are supplied by the manufacturers. ImPACT measured data, where available, are given in the Scanner Performance section of the report.

Table 26: Main console

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Diagonal dimension of image screen (inches)	20	19	19	19 (LCD) or 21 (CRT)
Number of monitors at console (functions of each if > 1)	2 (acquisition / review and processing)	2 (acquisition / review and processing)	1, optional 1 x review and processing (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)	-31743 to +31743	-1024 to +3072	-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	±0.1	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 27: Main computer

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Make and model	HP XW8200	Dell Presision 670	Siemens PC compatible with array processors	2 x Dual Processor
Operating system	Fedora Linux Core 2	Windows XP	Windows XP	Windows
Type and speed of CPU	2 x 3.2 GHz	Xeon 2x3.4GHz	Pentium Xeon 3.6 GHz	3.06 Ghz (scan console and display console)
Amount of computer RAM supplied as standard (Gbytes)	2	4	18	1.5 (scan) 3.0 (display)
Maximum amount of computer RAM (Gbytes)	12	4	18	1.5 (scan) 3.0 (display)

Table 28: Image storage

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Total standard hard disk capacity (Gbytes)	291	392	627	450
Maximum hard disk capacity (Gbytes)	291	392	627	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)	36(2881) 4-slice axial raw data files)	110 (30,000 data files)	300	144 (3600 rotations)
Archive options	MOD [images] & DVD [scan data, protocols] (standard)	MOD and CD writer (standard)	MOD and CD writer (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	<15sec	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 29: Independent workstation

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Is a workstation provided?	Yes	Yes, Extended Brilliance Workspace	No, option (Syngo Multimodality Workplace)	Yes
Computer make and model	HP XW8200	Dell Precision 670	Siemens Fujitsu Xeon	Dual processor
Operating system	Fedora Linux (Kernel 2.6)	Windows XP	Windows XP	Windows
Type and speed (GHz) of CPU	2 x 3.4	Xeon 2x3.4GHz	2 x Xeon 3.6	3.06
Amount of computer RAM supplied as standard (Gbytes)	2	2	6	3
Maximum amount of computer RAM (Gbytes)	4	4	6	3
Total hard disk storage capacity supplied as standard (Gbytes)	182	146	220	153
Maximum total hard disk storage capacity (Gbytes)	182	438	220	153
Archive options	CD-R standard MOD optional	CD-R standard EOD option	CD-R (DVD-R exp. Feb 06)	MOD standard
Capacity of a single archive disk (Gbytes)	4.6	9.1	CD-R: 0.65 DVD-R: 4.7	4.8
Environmental requirements (max/min temperature, humidity) for workstation	10-40 ºC, 20-80 % relative humidity	Temp: 0-35 °C Humidity: 25-75%	10-35 ºC, 20-80% relative humidity	18-28 ºC, 40-80% relative humidity

Table 30: 3D reconstruction display (MC – main console, WS – workstation)

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
MIPs and MinIPs (maximum and minimum intensity projections)	MC-standard WS-standard	MC-standard WS-standard (incl. Volume MIP)	MC-standard WS-option	MC-standard WS-standard
SSD (3D Shaded Surface Display)	MC-option WS-standard	MC-standard WS-standard	MC-standard WS-option	MC-standard WS-standard
3D Volume rendering software	MC-option WS-standard	MC-standard WS-standard	MC-option WS-option	MC-standard WS-standard
3D Virtual endoscopy	MC-option WS-standard	MC-standard WS-standard	MC-option WS-option	MC-option WS-standard
MPR (Multi-planar reconstruction)	MC-standard WS-standard	MC-standard WS-standard	MC-standard WS-option	MC-standard WS-standard
Planes available in MPR	Axial, para-axial, sagittal, coronal, oblique, curvilinear	All planes, any oblique/curve (both on MC and WS)	Axial, sagittal, coronal, oblique, curvilinear	Axial, sagittal, coronal, oblique, curved with cross cut through the curved reformat

Table 31: Optional facilities (MC – main console, WS –workstation)

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Contrast injector	Option	Option	Option	Option
Contrast media bolus tracking	Standard (SmartPrep)	Option	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)	Standard	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)	Not available
CT Angiography	MC-standard WS-standard AVA (Vessel Assessment) option on WS	MC-standard WS-standard	MC-standard basic package WS-option	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)	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 (HeartView CT and 0.5s rot time) [Not available]	MC-option WS-option
Retrospective ECG-gated cardiac software	MC-Not available MC & WS-option (Cardiac Imaging)	MC/WS-option (Retrospective Tagging)	MC-option (HeartView CT and 0.5s rot time) [Not available]	MC-option WS-option (Prospective Gating)
Prospective respiratory gating software	Info.not available	Standard	Yes	WIP
Retrospective respiratory gating software	Info.not available	Standard	Yes	WIP
Method of monitoring respiratory motion	Varian, Optical Sensor	Bellows/Varian	Pressure sensor	WIP
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 32: Installation requirements

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
Environmental requirements (max/min temperature, humidity) in scanner room	15-26 ºC, 30-60% relative humidity	18-24 °C, 35-75% relative humidity	15-28 ºC, 15-75% 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, 35-75% relative humidity	15-28 ºC, 15-75% relative humidity	18-28 ºC, 40-80% relative humidity
Peak heat output from system during scanning (kW)	15.3	5.9	1.53 (add 0.07 for CT fluoro)	10.5 max
System cooling method	Output to air	Oil to air	Water - water	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)	28	27	17.86	27 (std table) 25 (short table)
Gantry dimensions (H x W x D (mm)) and weight (kg)	1992x2439x1007 1701kg	2000x2515x945 2186kg	1990x2280x940 2000kg	1950x2330x960 1750kg
Couch dimensions (H x W x L (mm)) and weight (kg)	1121x610x2387 330kg	1010x690x2490 430 kg	1022x690x2430 500 kg	450x630x2690 450kg(std) 450x630x2390 420kg(short)
Supplementary unit dimensions (H x W x D (mm)) and weight (kg)	Power unit: 1067x711x559 350kg	None	Power unit: 1815 x 905 x 800, 550kg Cooling unit: 1815 x 905 x 860, 200kg	Power unit: 980 x 800 x 770, 550kg
Power supply requirements	3 phase 380-480V, 150kVA	3 phase 480V, 80kVA	3 phase 380-480V, 66-80kVA	3 phase 380-440V, 100kVA

Table 33: Image transfer and connectivity

	GE LightSpeed RT	Philips Brilliance CT Big Bore	Siemens Sensation Open 40 [24]	Toshiba Aquilion LB
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	SCU	SCU	SCU
Storage commitment	Yes	SCU	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	Not available	Not available	Not available
Performed procedure step	Yes	Not available	Not available	Not available
Storage commitment	Yes	SCU	SCU	Not available

Appendix 1: 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 lp/cm and 6.0 lp/cm is used (lp/mm used in the calculation for consistency of units with z-sensitivity).

z_1 = the full width at half maximum (FWHM), (mm), 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 2: 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 thousands 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.

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