October 2003

MHRA

Evaluation Report MHRA 03122

Four Slice CT Scanner Comparison Report Version 9

ImPACT report

MHRA Evaluation Report

MHRA 03122

£100 (Free to the NHS)

WHAT YOU CAN EXPECT FROM MHRA EVALUATION REPORTS

The Device Evaluation Service (DES) aims to provide independent and objective evaluations of medical devices available on the UK market. Specialist centres, mainly in NHS Trusts, do the evaluations under long-term contract to, and in accordance with protocols approved by, the MHRA. The evaluations are usually of a unit supplied by the manufacturer. We would expect this unit to be representative of the product on the market but cannot guarantee this. Prospective purchasers should satisfy themselves with respect to any modifications that might be made to the product type after MHRA's evaluation. The reports are intended to supplement, not replace, information already available to prospective purchasers.

ImPACT – Imaging Performance Assessment of CT Scanners

Four Slice CT Scanner Comparison Report

Version 9, October 2003

A report comparing the specification and imaging performance of the following CT scanners:

Manufacturer	Scanner model
GE	LightSpeed QX/i Advantage
GE	LightSpeed Plus Advantage
Toshiba	Aquilion 4

Compiled and prepared by members of the ImPACT group

www.impactscan.org

Table of contents

Introduction

Purpose of this report

In May 2003 the UK Government announced a £90 million fund to replace all CT and MRI scanners installed before 1997 as part of the NHS Cancer Plan.

ImPACT will be producing comparison reports for each phase of the purchase program. 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.

This report is for phases 2 and 3 of the Cancer Plan funding. There are separate reports for single, dual, four, six to ten and sixteen slice CT scanners.

The scope of this report is limited to CT scanners that are capable of acquiring four sets of attenuation data per tube rotation.

Comparison methods

The data given in this report are representative of the scanners as of October 2003, and are liable to change, as the performance of individual scanner models is changed and upgraded. In particular, optional features such as workstations and software packages may be listed as standard for the scanner replacement programme, but may not be included in other, separate scanner purchases.

There are two main areas for comparison of the scanners, performance and specification.

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; (in alphabetical order) GE Medical Systems, Philips Medical Systems, Siemens AG and Toshiba Medical Systems. Of these, GE and Toshiba currently produce four slice scanners. The scanner models in this report are listed in the table below.

Manufacturer	Scanner model
GE	LightSpeed QX/i Advantage
GE	LightSpeed Plus Advantage
Toshiba	Aquilion 4

The GE LightSpeed QX/i Advantage and LightSpeed Plus Advantage models are grouped together in the specification section of this report, as the majority of their specifications are the same. Where there are exceptions to this, such as the LightSpeed Plus' faster scan speeds, these are indicated in the tables. The LightSpeed QX/i is a replacement for the LightSpeed scanner. The performance of the LightSpeed QX/i is expected to follow that of the LightSpeed Plus, with the exception of the availability of 0.5 second scan times.

The Toshiba Aquilion 4 is an update to the Aquilion Multi. There are two versions available, one of which has a shorter table making it suitable for installation in smaller rooms. ImPACT has yet to assess the Aquilion 4.

Scanner performance

Introduction

In order to compare the performance of CT scanners, the ImPACT evaluation programme has developed a range of assessment techniques. These were described in detail in MDA/98/25, *Type Testing of CT Scanners: Methods and Methodology for Assessing Imaging Performance and Dosimetry*. The results of this testing are presented in this section, which consists of data regarding different aspects of scanner performance.

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. This is presented using graphical representation of the relationship between noise and spatial resolution, and the ImPACT Q value.

Spatial resolution 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 limiting clinical resolution of the scanner.

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). 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, scanners with a high geometric efficiency will not produce large patient doses, particularly for narrow slice thicknesses, where geometric efficiencies are normally lowest.

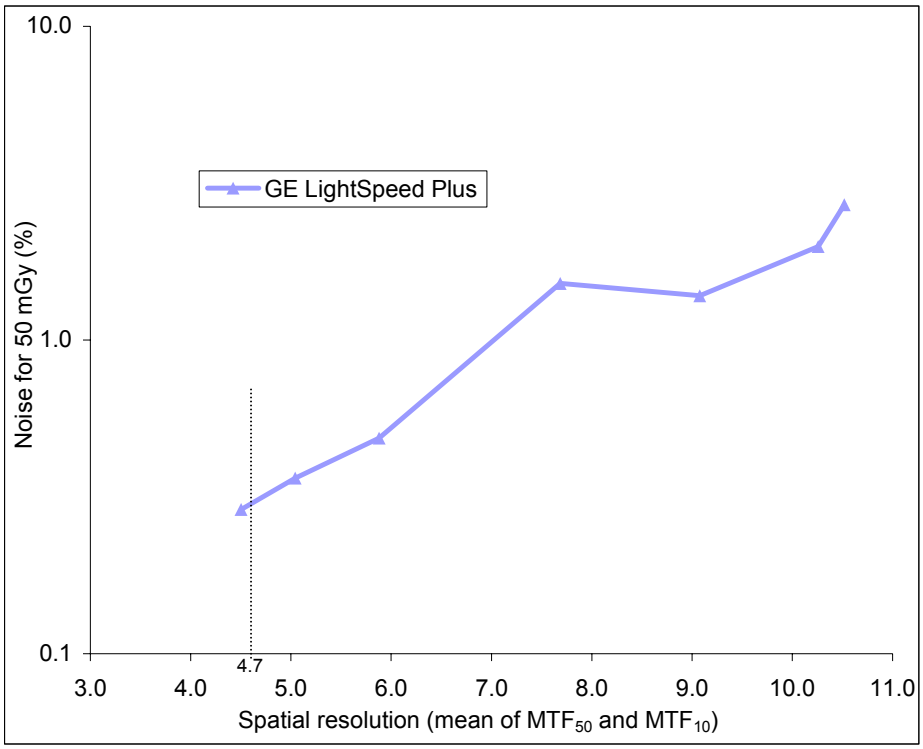
Clinical scan tables lists the measured image quality and dose parameters for the standard ImPACT clinical scans.

Dose and Image Quality

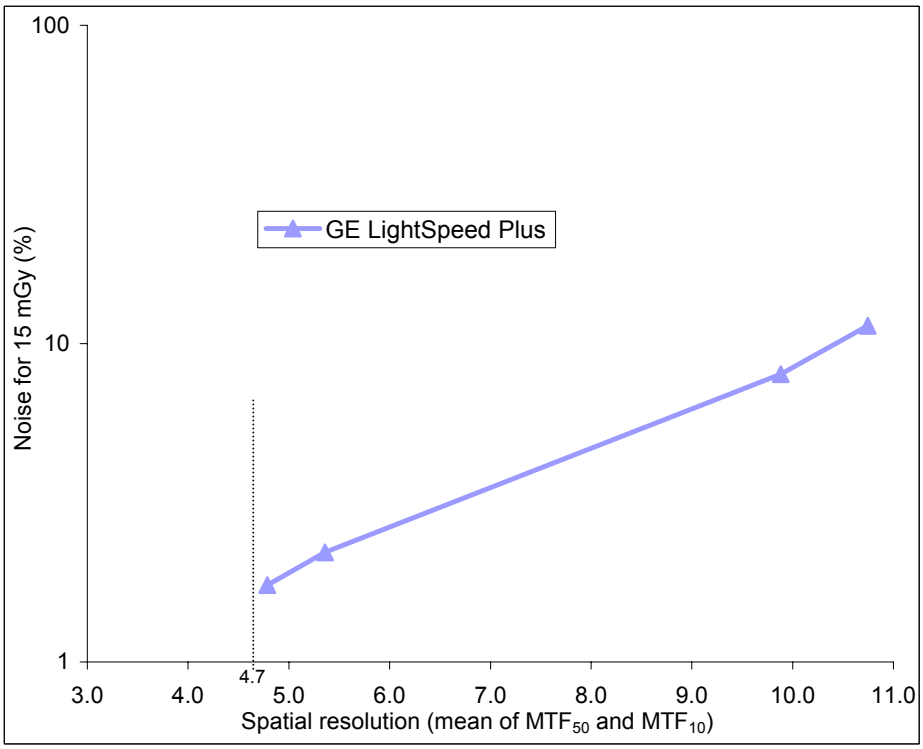
In this report, image quality is assessed in terms of objective measurements of image noise, scan plane spatial resolution and imaged slice width. The radiation dose used to acquire these images is given by the $CTDI_{vol}$ measured on the standard head and body phantoms. These parameters can be presented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

Noise and resolution

The following graphs show image noise plotted against spatial resolution for the available convolution kernels on each scanner. Resolution is characterised by the mean of the MTF_{10} and MTF_{50} 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 c/cm) at which Q_2 is defined is marked with a vertical line



Noise vs. resolution for head scanning



Noise vs. resolution for body scanning

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 algorithms, 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 algorithm: the algorithm chosen for each scanner is the one that most closely matches the average 'standard' head and body algorithm (MTF_{50} of 3.4 c/cm, MTF_{10} of 6.0 c/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, image noise at 50 or 15 mGy and MTF values 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 spatial resolution chosen is the one that most closely matches that of the 'standard' head algorithm on a range of four slice scanners, with mean MTF_{50} and MTF_{10} values of 4.7 c/cm.

Scanner performance

Head scanning

Scanner	Recon filter	mAs for 50mGy	z-sens (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)	Q_2
GE LightSpeed Plus	Stnd	278	4.9	0.37	3.5	6.6	6.3

Body scanning

Scanner	Recon filter	mAs for 15mGy	z-sens (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)	Q_2
GE LightSpeed Plus	Soft	175	4.9	1.8	3.6	6.0	2.2

Spatial resolution

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

Limiting resolution looks at the highest spatial resolution that can be achieved with the scanner, using a clinical reconstruction algorithm.

In-plane limiting resolution

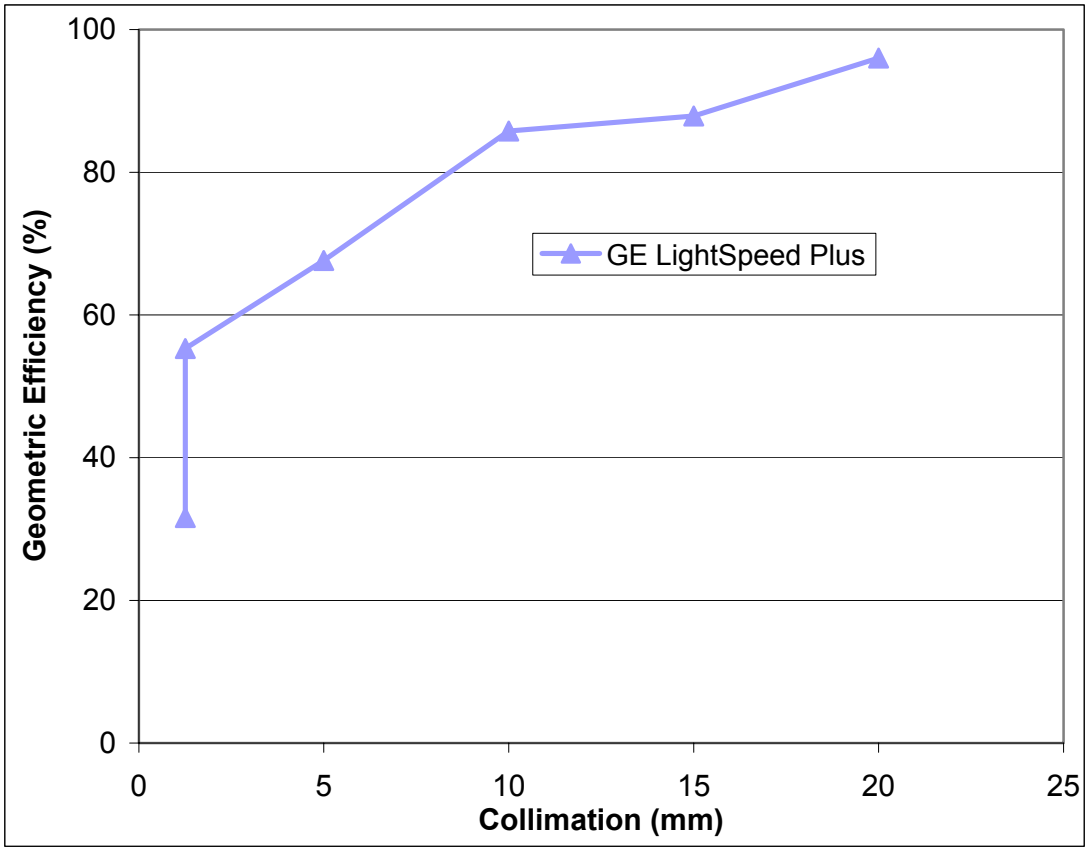
Scanner	Recon Filter	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus	EDGE	9.5	13.6

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

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 nominal total image width to the integral of the dose profile along its total length.

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.



Clinical scan tables

These are a sub-set of the standard ImPACT clinical scan tables for a range of examination types. 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.

Standard brain

Head scan reconstructed to show low contrast brain detail.

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon Filter	$CTDI_W$ (mGy)	z-sens. (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus	120	240	2	2 x 10	250	Soft	43	9.8	0.22	3.1	5.9

Standard abdomen

Axial abdomen scan.

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon Filter	$CTDI_W$ (mGy)	z-sens. (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus	120	80	0.8	2 x10	380	Stnd	7	9.8	2.4	4.0	6.7

Helical abdomen

Helical abdomen scan.

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	Pitch	Recon Filter	$CTDI_W$ (mGy)	z-sens. (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus*	120	160	0.5	5	6	Stnd	10	6.4	2.5	3.8	6.5

Inner ear

High contrast inner ear exam, using a narrow slice for good resolution in the *z*-axis.

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon Filter	$CTDI_W$ (mGy)	z-sens. (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus	140	120	0.8	2x 0.63	120	Bone+	45	0.9	6.6	9.4	11.7

High resolution spine

High contrast spine examination.

Scanner	kVp	mAs	Scan time (s)	Slice (mm)	FOV (mm)	Recon Filter	$CTDI_W$ (mGy)	z-sens. (mm)	Noise (%)	MTF_{50} (c/cm)	MTF_{10} (c/cm)
GE LightSpeed Plus	120	320	2	2x2.5	120	Bone+	38	2.4	13	9.7	11.8

Specification comparison

The data in the GE LightSpeed Plus column also covers the GE QX/i scanner. These two scanners have a slightly different specification, and where differences exist the QX/i data is shown within square brackets.

Scanner gantry

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Generation	3rd	3rd
Slipring	Low voltage	Low voltage
Aperture (cm)	70	72
Scan fields of view (cm)	25 and 50	18, 24, 32, 40, 50
Nominal slice widths for axial scans (mm)	0.625, 1.25, 2.5, 3.75, 5, 7.5, 10	0.5, 1, 2, 3, 4, 6, 8, 10
Tilt range (degrees)	± 30	± 30
Type of positioning lights	Laser	Laser
Accuracy of positioning lights (mm)	± 1 at any laser to patient distance	± 1

Patient couch

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Couch Top		
Material	Carbon fibre	Carbon fibre
Length and width (cm)	239 x 62 (42 just for cradle)	218.7 or 188.7 x 47 (std or short table)
Horizontal Movement		
Horizontal movement range (cm)	170 [160]	219 or 189 (std or short table)
Horizontal movement speeds (mm/sec)	up to 100	10 or 130
Accuracy/reproducibility of table positioning (mm)	± 0.25	± 0.25
Scannable horizontal range (cm):		
(i) without table top extension	160 (helical), 170 (axial & scout) [160]	180 or 150 cm (std or short table)
(ii) with table top extension(s)	160 (helical), 170 (axial & scout) [160]	218 or 183 (std or short table)
Vertical Movement		
Vertical movement range out of gantry (cm)	51 - 99	31 - 95.4
Vertical movement range in gantry (cm)	88 - 99	77.9 - 95.4
Minimum couch top height outside gantry (cm)	51	31
Weight Bearing Properties		
Maximum weight allowed on couch (kg)	205	205
Maximum weight on couch which still achieves stated performance specifications (kg)	180 (±0.25mm) 205 (±1mm)	205

X-ray generator

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Type	High frequency	High frequency
Location	Rotation assembly	Rotation assembly
Power rating (kW)	53.2 [42, 53.2 optional]	60
kV settings available	80, 100, 120, 140	80, 100, 120, 135
mA range and step size	10 - 440 (5mA steps) [10-350 / 440]	10 - 500 (10mA steps)
Max. mA allowed for each kV	80kV: 400mA [350/400] 100kV: 420mA [350/420] 120kV: 440mA [350/440] 140kV: 380mA [300/380]	80 -120kV: 500mA 135kV: 440mA

X-Ray tube

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Type and make	GE Performix	Toshiba Megacool
Focal spot size(s) (mm), quoted to IEC 336/93 standard	0.6 x 0.7 0.9 x 0.9	0.9 x 0.8 1.6 x 1.4
Total filtration (inherent + beam shaping filter) at central axis (mm Al equivalent)	4.75 (70kV, head) 5.65 (70kV, body)	> 1 (inh) + 1.5 - 10 (wedge dependent)
Anode heat capacity (MHU)	6.3	7.5
Maximum anode cooling rate (kHU/min)	840	1386
Method of cooling	Oil to air	Oil/forced air
Guaranteed tube life	One year (unlimited rotations)	300,000 rotations

Detection system

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Detector type	Solid state (HiLight / Lumex)	Solid state
Number of detectors per row	888 (plus 18 reference elements)	896 (plus 1 pair ref detectors)
Number of elements along z-axis	16	34
Effective length of each element at isocentre (mm)	16 x 1.25	4 x 0.5 and 30 x 1
Total effective length of detector array at isocentre (mm)	20	32
Future option for more slices/rotation	8 slices 16 slices	--

System start-up and detector calibration

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Power-on to warm-up time (mins)	2 from fully off, 0 from standby	2 from fully off, 0 from standby
Tube warm-up time from 'cold' to operating temperature (mins)	<1	2 (0 in an emergency)
Time to perform detector calibrations at warm-up (mins)	Included in tube warm-up	1
Recommended frequency for any additional calibration by the radiographer	Once every 24 hours	1 per week
Time to perform these additional calibrations (mins)	13 (inc warm-up)	Up to 20
Total time from fully off to scanning in an emergency (mins)	< 3	2

Scan parameters

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Reconstruction fields of view (cm)	9.6 to 50	0.05 - 50
Number of simultaneous slices at each nominal axial slice width (mm)	2 x 0.625, 1 x 1.25, 4 x 1.25, 4 x 2.5, 4 x 3.75, 4 x 5	0.5, 1, 2, 3, 4, 6, 8 (4 slice mode) 10 (2 slice mode)
Scan times for axial scans (s) * = Partial scans	0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4 [0.7 ,1 ,2, 3, 4]	0.32*, 0.5, 0.75, 1, 1.5, 2, 3 (0.25* , 0.4 optional))
kV settings available	80, 100, 120, 140	80, 100, 120, 135
mA range and step size	10 - 440 (5mA steps) [10-350 / 440]	10 - 500 (10mA steps)
Max. mA allowed for each kV	80kV: 400mA [350/400] 100kV: 420mA [350/420] 120kV: 440mA [350/440] 140kV: 380mA [300/380]	80-120 kV: 500mA 135kV: 440mA

Helical scanning

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Rotation times for helical scanning (s)	0.5, 0.6, 0.7, 0.8, 0.9, 1 [0.7, 1]	0.5, 0.75, 1, 1.5
Number of simultaneous slices at each rotation time	4	4
Pitches available for routine scanning (range and increment)	2 slice : 1 4-slice : 0.75 and 1.5	0.625 -1.5 (except 1.0), increment 0.125
Recommended pitches for optimal image quality	2 slice : 1 4-slice : 0.75 and 1.5	0.625 - 1.5 (except 1.0)
Helical interpolation algorithms available	GE Proprietary algorithms (SmartHelical, MDMP and Crossbeam)	MUSCOT and TCOT
Maximum number of rotations in one helical run at standard abdomen parameters	70sec (300mA) 90sec (270mA) 110sec (250mA)	200 at 0.5s (250 at 0.4 optional)
Maximum continuous scan time (s)	120	100
Starting with a cold tube, the maximum helical scan distance using a 1 mm imaged slice thickness and a pitch of 1.5	1600 mm [1285 mm]	1750 or 1450 mm (std or short table)
Gantry tilt range for helical scanning (degrees)	± 30	± 30

Scan projection radiograph (SPR)

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Maximum SPR length (mm)	1600	1800 or 1500 (std or short table)
SPR field dimensions (mm x mm)	500x1600	width: 240, 400, 500, length: 200 - 1800 or 1500 (std or short table)
Angular positions of X-ray tube available for SPR (degrees)	any angle from 0 - 359° (1° steps)	0, 90, 180, 270 and any arbritary angle in 5º steps
Real time image	Image viewed immediately after acquisition	Yes
Accuracy of slice prescription from the scanogram (mm)	± 0.25	± 0.25
Accuracy of distance measurements from SPR's taken at isocentre (lateral and axial directions) (mm)	< 2 x image pixel size	< ± 0.5

Manufacturer's performance data

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Image Quality		
Spatial resolution (lp/cm) for sharpest clinical algorithm	0% MTF: 15.4 lp/cm 10% MTF : 13.0 lp/cm (10cm DFOV, Edge alg, Small Focus)	2% MTF: 21.4 lp/cm (120 kV, 200mA, 2 mm slice width, 1s, 240 mm FOV, FC90 algorithm, small focus)
Contrast reolution: smallest rod size (mm) discernable at given parameters in 20 cm CATPHAN	5mm @ 0.3% @ 13.3 mGy: 120kVp, 100mAs, 10mm, 25cm DFOV, Std alg	5 mm @ 0.3% @ 21,8 mGy: 120kV, 190 mAs, 240 mm FOV, FC41, 8 mm slice
CT number accuracy	Water: 0 ± 3 HU	Water: 0 ± 3 HU
Dose		
$CTDI_{100}$ (mGy/100 mAs) for axial standard brain scans at given parameters:	120 kVp, 260 mAs, 2 x 10 mm	120kV, 4 x 4 mm
- centre of CTDI phantom	18.0	10.0
- periphery of CTDI phantom	18.3	11.1
$CTDI_{100}$ (mGy/100mAs) for axial standard abdomen scans	120 kVp, 260 mAs, 2 x 10 mm	120 kV, 4 x 4 mm
- centre of CTDI phantom	5.5	3.5
- periphery of CTDI phantom	11.3	7.3
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)	32 : 38 ± 9.5 (s) 24 : 28 ± 6.0 (s) 16 : 20 ± 5.0 (s) 12 : 17 ± 4.3 (s) 8 : 12 ± 3.6 (s) 4 : 8 ± 2.4 (s) 2 : 5 ± 2.0 (s)

Factors affecting image quality

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Dose		
Post-patient collimation for narrow slices	No	No
Automatic mA control (AEC / mA modulation) software	Yes (SmartmA)	Yes (Real EC (Exposure Control))
- mA adjustment for patient size	Yes	Yes
- mA adjustment along the z-axis	Yes	Yes
- mA modulation during rotation	No	No
Noise		
Adaptive filtration for noise reduction	Low signal correction	Yes (user programmable)
Resolution		
Quarter detector shift	Yes	Yes
Moving (dynamic/flying) focal spot	No	No
Number of imaging detectors per row	880	896
Sampling frequency	1640 Hz	1800 views/s (0.5s scan), 1200 views/s (>0.5s)
Artefacts		
Artefact reduction algorithms	Iterative Bone Option (IBO), Motion correction, Recon of thick slices from thinner ones	Beam hardening correction, Raster Art. Suppression Protocol (RASP), stack scanning, automatic patient motion correction
Cone beam correction	GE Proprietary algorithms (SmartHelical & MDMP Algorithm)	TCOT (modified Feldkamp method)

Operator's console

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Image Monitor		
Diagonal dimension of image screen (inches)	20	18" LCD Flatscreen or 21" CRT monitors
Number of monitors at console (functions of each if > 1)	2 (patient info and technique selection / image display)	2 (acquisition/ review and processing)
Image Display		
Image area matrix dimensions	512 x 512, 768 x 768, 1024 x 1024	512 x 512, 640 x 640, 1024 x 1024
Usual range of CT number displayed (HU)	-1024 to +3071	-1024 to +8191
Accuracy of distance measurements in x-y plane (mm)	< 2 times image pixel size	< 1 mm
Dose Information		
Weighted CTDI ($CTDI_W$) or $CTDI_{vol}$ displayed on console	Yes	Yes
Dose Length Product (DLP) displayed on console	Yes	Yes
Geometric efficiency displayed on console when <70%	Yes	Yes
Hardware Interface		
Control methods	Mouse, trackball, keyboard	Mouse, cursor, keyboard

Main computer

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Make and model	HP XW8000	2 x Dual Processor
Operating system	Linux RedHat 7.3	Windows
Type and speed of CPU	2 x 3 GHz	3.06Ghz (scan console and display console)
Amount of computer RAM (Mbytes):		
(i) supplied as standard	2048	1.5 GB (scan console) 3.0 GB (display console)
(ii) maximum	12 GB	1.5 GB (scan console) 3.0 GB (display console)

Image storage

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Hard disk storage		
Total standard hard disk capacity (Gbytes)	254	152
Maximum hard disk capacity (Gbytes)	254	152
Hard disk capacity for image storage (Gbytes and no. of uncompressed 512x512 images)	146 (250,000 images)	60,000 (2 x 18 GB)
Hard disk capacity for storage of raw data files (Gbytes and no. of data files)	72 (9000 4 slice axial data files)	3600 rotations (36 GB)
Archive Options		
Archive options	MOD [images] & DVD [scan data, protocols] (standard)	MOD
Capacity of a single archive disk (Gbytes and no. of images)	4.6 (9400 losslessly compressed 512x512 images or 700 raw data files)	4.8 GB 16,000 images 140 rotations raw data
Time to mount an archive disk or tape (s)	5-6 in background operation	less than 20s
Archive data transfer rate (images/s)	1 (read) 0.7 (write)	background task

Image reconstruction

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Reconstruction matrix	512 x 512	256, 512
Minimum reconstruction interval in helical scanning (mm)	0.1	0.1
Reconstruction Times		
Time (s) from the start of data acquisition to the appearance of the 30th image of a series:		
(i) standard axial brain scan	27	20 s
(ii) axial spine scan	14	20 s
(iii) helical abdomen scan	10	2.5 s (real time) 15 s (after scan completion)
Parallel Processing Details		
Simultaneous scanning and reconstruction	Yes	Yes
Any delay in either scanning or reconstruction when performed concurrently	No	No
Simultaneous scanning and routine analysis	Yes	Yes
Simultaneous scanning and archiving and/or hard copying	Yes	Yes
Simultaneous scanning and transfer to second console/workstation	Yes	Yes

3D reconstruction

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
3D reconstruction on main console (MC) and workstation (WS)		
MIPs and MinIPs (maximum and minimum intensity projections)	MC-standard WS-standard (MIP & MinIP)	MC-standard WS-standard
SSD (3D Shaded Surface Display)	MC-optional WS-standard (3D)	MC-standard WS-standard
3D volume rendering software	MC-N/A WS-standard (Volume Rendering)	MC-standard WS-standard
3D virtual endoscopy	MC-optional WS-standard (Navigator)	MC-optional WS-standard
MPR (Multi-planar reconstruction)	MC-standard WS-standard (MPR & MPVR)	MC-standard WS-standard
Planes available in MPR	Axial, para-axial, sagittal, coronal, oblique, curvilinear	Axial, sagittal, coronal, oblique, curved with cross cut through the curved reformat

Optional features

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Contrast injector	Optional	Optional
Contrast media bolus tracking	Standard (SmartPrep)	Standard
CT fluoroscopy software and hardware	Optional (SmartStep)	Optional
Hard-copy imaging device	Optional	Optional
Radiotherapy planning accessories		
Radiotherapy planning table top	Optional (RT flat pad and 'Exact' couch top)	Optional
Carbon fibre breast board	Optional	N/A
Means for attaching patient immobilisation devices and a stereotactic frame to the end of the couch	Optional (Exact couch)	Optional
Software Packages on main console (MC) and workstation (WS)		
Bone mineral densitometry	MC-N/A WS-optional (BMD)	MC-optional WS-N/A
CT angiography	MC-standard WS-standard, AVA (Vessel Assessment) option on WS	MC-standard WS-standard
Dental	MC-optional WS-optional (Dentascan)	MC-optional WS-optional
Radiotherapy CT simulation software	MC-N/A WS-optional (CT sim)	MC-N/A WS-optional
Prospective ECG-triggered cardiac software	MC-optional WS-optional (SmartScore)	MC-optional WS-optional
Retrospective ECG-gated cardiac software	MC-optional (Cardiac Snapshot); MC & WS-optional (Cardiac Imaging)	MC-optional WS-optional (Prospective Gating)
Perfusion software	MC-optional WS-optional CT Perfusion	MC- optional WS-N/A

Installation requirements

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Environmental requirements (max/min temperature, humidity) in scanner room	15-26 ºC, 30-60% non-cond. rel. humidity	18-28 ºC, rel. humidity 40-80%
Environmental requirements (max/min temperature, humidity) in scanner control room	15-26 ºC, 30-60% non-cond. rel. humidity	18-28 ºC, humidity 40-80%
Peak heat output from system during scanning (kW)	7.1 (75 rot/patient, 4 patient/hour)	11.7 max
System cooling method	Output to air	Output to air
Air conditioning requirements for scanner room of minimum floor area	Recommended	Not necessary but recommended
Minimum floor area required for the system (m^2)	28	27 or 25 (std or short table)
Dimensions of:		
(i) Gantry (H x W x D (mm)) and weight (kg)	1887 x 2230 x 1007 1269kg [1415 kg]	1950 x 2330 x 960, 1750kg
(ii) Couch (H x W x L (mm)) and weight (kg)	1120 x 610 x 2387 340kg [334 kg]	450 x 630 x 2690, 450kg (std version) 450 x 630 x 2390, 420kg (short table)
(iii) Supplementary units (H(mm)xW(mm)xD(mm)) and weight (kg)	Power Unit: 1270 x 762 x 585, 408kg [336 kg]	Transformer: 980 x 800 x 770, 550kg
Power supply requirements	3 phase 380-480V, 90kVA	3 phase 380-440V, 100kVA

Independent workstation

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Is a workstation provided?	Yes	Yes
Computer make and model	HP XW8000	Dual processor
Operating system	Linux Red Hat 7.3	Windows
Type and speed of CPU	2 x 3 GHz	X86 3.06 GHz
Amount of computer RAM (Mbytes):		
(i) supplied as standard	2048	3 GB
(ii) maximum	4096	3 GB
Total hard disk storage capacity (Gbytes):		
(i) supplied as standard	2 x 72	58
(ii) maximum	2 x 72	58
Archive options	CD standard, MOD optional	MOD optional
Capacity of a single archive disk (Gbytes)	4.6 (9400 losslessly compressed 512x512 images or 700 raw data files)	4.8 GB
Environmental requirements (max/min temperature, humidity) for workstation	10-40 ºC, 20-80 % rel. non-cond. humidity at 40 ºC	18-28 ºC, rel. humidity 40-80%

Image transfer and connectivity

	GE LightSpeed Plus [QX/i]	Toshiba Aquilion 4
Speed of scanner/workstation connections to local area networks (Mbits/s)	100	100
Remote PC access to images on workstation	Optional	Optional
DICOM services on Main Console		
Storage	SCU, SCP	SCU, SCP
Print	SCU	SCU
Query / retrieve	SCU, SCP	SCU, SCP
Modality worklist	Optional	SCU
Performed procedure step	Optional	SCP
Sorage commitment	SCU	SCP
DICOM services on Workstation		
Storage	SCU, SCP	SCU, SCP
Print	SCU	SCU
Query / retrieve	SCU	SCU, SCP
Modality worklist management	--	SCU
Performed procedure step	--	SCP
Sorage commitment	--	SCP

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:

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

σ = image noise, given as the standard deviation of pixel values, expressed as a percentage of the attenuation of water. The standard deviation is obtained from a 500 mm^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 algorithms with standard spatial resolution values are chosen to minimise the dependency of Q_2 upon reconstruction algorithms. The reconstruction algorithm with $MTF_{50\%}$ and $MTF_{10\%}$ values as close as possible to 3.4 c/cm and 6.0 c/m is used.

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

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

Appendix 2: Manufacturers' comments

Responses are included from the following manufacturers:

GE Medical Systems

Where appropriate ImPACT have included a short reply.

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

December 11, 2003

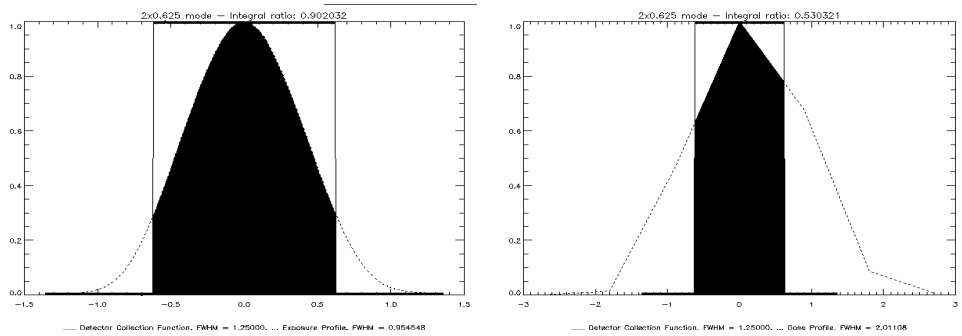
Dear Sir or Madam:

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 is in discussion with GE on this matter, but the issue has not been resolved at the time of publication.

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

The inner ear protocol listed in point 4 relates to the 16 slice CT comparison report.

Appendix 3: ImPACT and the MHRA

Background

One of the roles of the Medicines and Healthcare products Regulatory Agency (MHRA) is to fund evaluation programmes for medical devices and equipment. The programme includes evaluation of x-ray Computed Tomography Equipment currently available on the UK market.

MHRA aims to ensure that evaluation techniques keep abreast of improvements in CT imaging performance and that MHRA reports present evaluation information that is timely, useful and readily understood.

ImPACT

ImPACT (Imaging Performance Assessment of Computed Tomography) is the MHRA'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.

Members of ImPACT contributing to and writing this report: N. Keat, D. J. Platten, M. A. Lewis, J. F. Barrett and S. Edyvean (ImPACT Group Leader).

ImPACT and MHRA 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

Tel: 020 8725 3366

Fax: 020 8725 3969

email: impact@impactscan.org

web site: http://www.impactscan.org

MHRA contact point for general information on the CT evaluation programme:

Programme Manager
Room 1207, Hannibal House
Elephant and Castle
London SE1 6TQ

Tel: 020 7972 8156

Fax: 020 7972 8105

MEDICINES AND HEALTCARE PRODUCTS REGULATORY AGENCY

MHRA Evaluation Reports

MHRA evaluation reports are published by the Medicines and Healthcare products Regulatory Agency, an Executive Agency of the Department of Health. They are available free of charge to the UK National Health Service (NHS), and are for sale to commercial organisations and other interested parties. A free catalogue of available reports can be obtained from the Orders Department, or downloaded from the MHRA web site:

http://www.mhra.gov.uk

The Medicines and Healthcare products Regulatory Agency was created on 1 April 2003 from the merger of the Medical Devices Agency and the Medicines Control Agency. Further details are available at www.mhra.gov.uk. The MHRA is an executive agency of the Department of Health.

Ordering

Send your order to the address given below, stating the number, title and quantity of each report required. Your reports will be despatched by second class post the following working day. If you are not a representative of the NHS, you will be invoiced separately. Non-NHS customers are reminded that it is not possible to offer refunds for reports ordered in error.

Orders Department
Room 1207
MHRA
Hannibal House
Elephant and Castle
London
SE1 6TQ

Tel: 020-7972 8181
Fax: 020-7972 8105
E-mail: des@mhra.gsi.gov.uk

Enquiries

General publication enquiries should be directed to the Orders Department:

Tel: 020-7972 8181
Fax: 020-7972 8105
E-mail: des@mhra.gsi.gov.uk

ISBN 1 84182 789 4

Smart number 36 33857 1