specifications

On-Board Imager  Confidence in tumor targeting
Optimized Positioning

The On-Board Imager consists of a kV X-ray source and an amorphous silicon panel that can be mounted on the Clinac® iX linear accelerator and the Trilogy® system. It is attached by robotically controlled arms that operate with three axes of motion, optimizing the position of the imaging equipment for the best possible view of a target.

Versatile Imaging

A versatile device, the On-Board Imager enables online patient repositioning by visualizing bony anatomy or radiopaque markers in pairs of radiographs – or by visualizing soft-tissue and bony anatomy in cone-beam CT images. When used in conjunction with the Varian Real-time Position Management™ (RPM) system, the On-Board Imager enables fluoroscopic pretreatment gating verification and gated radiographic anatomic image matching. And, in combination with the Varian PortalVision™ MV imaging system, the On-Board Imager allows for filmless acquisition of MV and kV radiographic pairs without gantry rotation, essentially speeding up the acquisition process.

Ideal for Dynamic Targeting IGRT

The On-Board Imager makes Dynamic Targeting® image-guided radiation therapy (IGRT) more efficient and convenient. Once a patient is set up, all subsequent imaging activities can be performed remotely, generating a smooth, convenient clinical process. The combination of robotic technology and integrated software control of all treatment parameters offers the automation, speed, and flexibility needed to make the IGRT process clinically practical. With the On-Board Imager, you can obtain kV images, adjust patient positioning as needed, and complete the treatment, all within the standard treatment time.

On-Board Imager  Confidence in tumor targeting

The On-Board Imager® (OBI) kV imaging system is a high-resolution, low-dose digital imaging system that allows users to confidently manage patient and target movement – both before and during treatments, with three modes of kilovoltage (kV) imaging: digital radiographic, cone-beam CT (CBCT), and fluoroscopic imaging.
Specifications*

1.0 Imager

The imager is a high-performance, high frame rate aSi digital imager designed for kilovoltage operation.
1.1 Model: PaxScan® 4030CB flat panel detector
1.2 Maximum pixel matrix: 2048 x 1536
1.3 Array area: 397 mm x 298 mm
1.4 X-ray detector material: CsI:Tb
1.5 Maximum frame rate: 15 fps
1.6 Dynamic range: 18,400:1
1.7 Grid: 10:1 with >70% transmission (per IEC 60627)
1.8 Operating modes
   1.8.1 Digital radiography – high quality
       2048 x 1536 (1 x 1 binning)
       Readout time: 66 ms
   1.8.2 Fluoroscopy
       1024 x 768 (2 x 2 binning)
       15 fps
   1.8.3 Dual gain
       1024 x 1536 with electronic gain
       adjustments between each readout line
       Reformatted to 1024 x 768
       11 fps (maximum 15 fps)

2.0 kV Source/X-ray Tube

The X-ray source is a general purpose rotating anode X-ray source designed for radiographic, fluoroscopic, and pulsed fluoroscopic operation.
2.1 Model: Varian G242
2.2 Anode diameter: 100 mm
2.3 Target angle: 14°
2.4 Heat capacity
   Anode: 600,000 HU (445 kJ)
   Housing: 2,000,000 HU (1480 kJ)
2.5 Cooling - Anode
   162,000 HU/min (2000 W) @ 100% anode heat storage
   81,000 HU/min (1000 W) @ 80% anode heat storage

2.6 Cooling – Housing (maximum)
   With oil cooling: 162,000 HU/min (2000 W)
   Without oil cooling: 18,000 HU/min (222 W)
2.7 Source spot
   Small: 0.4 x 0.6 mm²
   Large: 0.8 x 1.1 mm²
2.8 Focal spot superimposition
   X axis: ±0.35 mm
   Z axis: ±0.0 mm

3.0 X-ray Collimation

The X-ray collimation is comprised of a fixed primary beam definer and an adjustable blade collimation system. Symmetric and asymmetric field openings as well as remote adjustments are supported by the blade collimation system.
3.1 Primary beam definer
   Thickness: 20 mm Pb
   Opening: 50 x 50 cm² at 1 m
3.2 Adjustable collimator
   Blade thickness: 3 mm Pb supported by 2 mm steel
   X-ray source to top of upper blades: 91 mm
   X-ray source to top of lower blades: 107 mm
   Range of motion of each blade: -3 cm to 25 cm (defined at isocenter)
   Minimum field opening: 2.5 x 2.5 cm²
   Maximum field opening: 50 x 50 cm²
   Reproducibility: ±2 mm (Assumes stationary gantry)
3.3 Adjustable collimator features
   Symmetrical and asymmetrical field openings
   Field opening follows the detector (blade tracking)
   Remote adjustments of field opening
   Operator (manual) entry of blade settings (X1, X2, Y1, Y2) on OBI workstation

4.0 Generator

4.1 Generator power: 32 kW

* Applies to OBI Advanced Imaging; Release 1.5
4.2 Generator reproducibility

The X-ray generator output complies with the requirements set by the CDRH for reproducibility, which states that the estimated coefficient of variation for the radiation output must be $\leq 3.5\%$.

4.3 Generator linearity

For linearity, the average ratios of mR output as indicated by the exposure delivered (mAs) obtained at any two consecutive mA station settings at the same kVp shall be within the specification defined $\leq 8\%$.

5.0 Imaging Chain Overall Performance

5.1 Half value layer (HVL)

The half value layer as a function of tube potential and the total filtration for diagnostic X-ray units are published in CFR, volume 21, 1020.30, paragraph ‘M,’ table 1. For 100 kVp, the minimum HVL is equivalent to 2.7 mm of aluminum (Al). For 70 kVp, the minimum HVL is equivalent to 1.5 mm of aluminum.

5.2 Filtration

The X-ray beam path has inherent filtration of 0.7 mm plus 2.0 mm of added Al filtration.

5.3 Spatial resolution

With no obstructions in the X-ray beam, the spatial resolution of the 4030CB aSi panel is:
- 1.29 lp/mm (2 x 2 binned mode)
- 2.58 lp/mm (1 x 1 binned mode)

5.4 Grayscale linearity

The On-Board Imager is capable of displaying eleven uniform shades of gray (from black to white) using the Nuclear Associates 07-456, or a Leeds GS2 step wedge penetrometer.

5.5 Automatic brightness control (ABC)

ABC controls kVp only in pulsed digital fluoroscopy imaging mode. The ABC will maintain a constant dose rate to the imager while imaging the variable-density phantom. While in ABC mode, kVp reproducibility is within ±2 kVp, when approached from either maximum or minimum kVp using the step wedge penetrometer as a variable density phantom. The response time for kVp stabilization on an image is $\leq 3$ seconds.

5.6 Typical radiographic exposures

<table>
<thead>
<tr>
<th>µGy/mAs @ 75 kVp</th>
<th>µGy/mAs @ 100 kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>98</td>
</tr>
<tr>
<td>125</td>
<td>150</td>
</tr>
</tbody>
</table>

(Measured with the X-ray detector 100 cm from X-ray source; measurement uncertainty ±15%)

5.7 Low contrast sensitivity

Using the Leeds test object type TOR [18FG] or N3, the imager is capable of resolving a minimum of 2.33% sensitivity when using a technique of 75 kVp; 50 mA; 6 ms (2 x 2 binning; 15 fps).

Skin exposure (@ 100 cm): 213 µGy/s

Detector exposure (@ 100 cm; 1 mm Cu filtration): 4.5 µGy/s
The Exact arms are fully motorized assemblies that support and position the image detector unit and kV source used with the On-Board Imager. The Exact arms offer fully automated motion from either inside the treatment room or remotely from the control console. All arm motion is fully motorized, with a separate drive assembly for each arm part: hand, forearm, and upper arm. There is also a separate assembly for hand lateral motion on the image detector support arm. Each motorized joint has active servo feedback control to assure the arm reaches/maintains the desired position, regardless of gantry angle.

### 6.1 Arm motion velocities
- Retracted to deployed: 21 or 23 s*
- Mid to deployed: 11 or 13 s*

### 6.2 Arm position accuracy: ±2 mm

### 6.3 Arm position reproducibility: ±0.5 mm

### 6.4 Collision detection
- kV source rear cover: ±0 mm
- kV source face plate cover: ±0 mm
- kV detector cover: ±0 mm
- kV source and detector arms: ±0 mm

Collision detector paddles are located on each side of the kV source and detector arms.

### 6.5 Arm controls

#### 6.5.1 Hand pendant
When in the treatment room, the arms are controlled by an infrared hand pendant, powered by a rechargeable battery. There are five preset target positions and the arms can be controlled individually, as a pair (OBI) or all arms at once (OBI plus PortalVision arm).

#### 6.5.2 On-Board Imager console
When at the treatment control room, the OBI console provides the following remote motion capabilities:
- Motion enable button
- Retract MV arm
- Retract kV arms
- Auto go MV arm
- Auto go kV arms
- Out kV arms

### 6.6 Emergency features
There is a backup motion control in case the Exact arm or its controller becomes defective or when communication with the hand pendant cannot be established. There is no backup power supply if there is a power failure. The couch can be moved longitudinally — using emergency power — to clear the arms.

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Table 2: Exact Arm Motion Ranges

<table>
<thead>
<tr>
<th>Motion</th>
<th>kVD Arm</th>
<th>kVS Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical* @ Beam Axis</td>
<td>-2 / +80</td>
<td>-80 / -100</td>
</tr>
<tr>
<td>Lateral**</td>
<td>-18 / +16</td>
<td>N/A</td>
</tr>
<tr>
<td>Longitudinal*** @ Isocenter</td>
<td>-4 / +5</td>
<td>-7 / +45</td>
</tr>
<tr>
<td>Longitudinal 30-50 cm Below Isocenter</td>
<td>-20.5 / +24</td>
<td>N/A</td>
</tr>
<tr>
<td>Longitudinal 77 cm Below Isocenter</td>
<td>-19 / +24</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* "Vertical” motion: Motion toward or away from the MV beam path
** "Lateral” motion: Motion parallel to the path of the MV beam
*** "Longitudinal” motion: Motion away from or towards the gantry

* With the B503104 elbow motor.
7.0 Mechanical Specifications - Accelerator

7.1 Accelerator isocenter

Addition of the On-Board Imager hardware does not degrade the accelerator isocenter specification for all three rotational axes: gantry, couch, and collimator.

7.1.1 The rotational excursions of the gantry shall be confined within a sphere of ≤1.0 mm radius throughout the entire 360° of rotation.

7.1.2 The rotational excursions of the collimator shall be confined within a sphere of ≤1.0 mm radius.

7.2 kV detector (kVD) and kV source (kVS) axis coincident with gantry rotation axis

The kVD and kVS arms’ axis is coincident (isocentric) to the gantry rotational axis and is confined within a sphere of ≤1.5 mm radius throughout the entire 360° of gantry rotation.

7.3 Remote couch motion

7.3.1 Small, corrective automatic motion x, y, z corrections with 36” base frame x, y, z, and rotation corrections with 52” base frame

7.3.2 Large, planned automatic motion

8.0 Geometric Accuracy

8.1 Alignment of digital graticule with MV (radiation) isocenter ±3/4 mm (Requires IsoCal option)

9.0 Application Software

9.1 User interface

The On-Board Imager application has separate workspaces for different tasks: a 2D/2D acquisition workspace, a 2D/2D match workspace, a 3D/3D match workspace. Cone-beam CT images are acquired using a separate application. Each of these OBI workspaces have several screen layouts that are operator selectable (e.g., 3-panel and 4-panel layouts for 3D/3D Match). The application toolbar at the top of the screen shows the functions available for image acquisition and anatomy matching. A dynamic window displaying a tree view of the plan becomes visible when the mouse pointer is moved to the left border of the main application window.

Many user-adjustable parameters are persistent and saved for reuse in subsequent sessions.

9.2 Clinical modes

9.2.1 kV, kV pair

9.2.2 MV, kV pair (requires PortalVision)

No gantry rotation needed

9.2.3 Gated kV, kV pairs (requires RPM respiratory gating system)

kV radiographs acquired at specific times in the respiratory cycle

9.2.4 MarkerMatch™ marker localization software

Automatically identify radiopaque markers in reference CT and each kV radiograph

9.2.5 Pretreatment fluoroscopic verification of RPM respiratory gating system

9.2.6 Cone-beam CT

9.3 Matching tools

The automatch capability is not a single algorithm but a framework containing a number of pre-defined parameters sets to control the automatch behavior for both 2D/2D and 3D/3D matching. There is also an automatch editing environment where new parameter sets can be created, with each parameter set containing between 1-10 stages. For each stage in the parameter set, one can select the optimizer (e.g., direction set, downhill simplex), the similarity measure (e.g., mutual information, pattern intensity), the search step size, the resolution of the input images, and image pre-filters (to increase accuracy or reduce the probability of falling into local minima). MarkerMatch marker localization software is a separate proprietary radiopaque marker detection algorithm.
9.4 Image match verification tools
- Blend images
- Split window
- Moving window (spy glass)
- Complementary color blending

9.5 Other tools
- Measure distance
- Measure angle

10.0 Cone-beam CT

10.1 Image performance specifications
See Table 3.

10.2 CBCT modes and CBCT dose
CBCT acquisition uses pre-defined modes which define the acquisition and reconstruction parameters. The parameters can be customized for particular clinical situations. Once calibrated, new CBCT modes are available for use.

Pre-defined CBCT modes and the corresponding doses are shown in Table 4.

Table 3: Image Performance Specifications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CBCT Performance Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Number Range</td>
<td>-1024 to +3072 or greater</td>
</tr>
<tr>
<td>CT Number Accuracy</td>
<td>±40 HU for 20 cm diameter (water equivalent) phantom</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>4-7 lp/mm Using a full-fan acquisition and a Catphan 504 phantom; depends upon image matrix and reconstruction filter</td>
</tr>
<tr>
<td>Low Contrast Resolution</td>
<td>1.0%; 15 mm diameter object visible Using a full-fan acquisition with a Catphan 504 phantom; 5 mm slice thickness; dose of 19 mGy (CTDIw body dose)</td>
</tr>
<tr>
<td>CT Number Uniformity (cupping)</td>
<td>±40 HU from center to edge Using a full-fan acquisition and the Image Uniformity insert of a Catphan 504 phantom</td>
</tr>
<tr>
<td>CT Number Linearity</td>
<td>CT number versus measured attenuation (mu) has a regression coefficient of 0.95 for a four-point calibration Using a full-fan acquisition with the Sensitometry insert of a Catphan 504 phantom</td>
</tr>
<tr>
<td>Reconstruction Field of View</td>
<td>24 cm or 25.5 cm diameter x 17 cm axial length (head scan) 45 cm diameter x 15 cm axial length (pelvis scan)</td>
</tr>
<tr>
<td>Reconstruction Matrices</td>
<td>128 x 128, 256 x 256; 384 x 384; 512 x 512</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>1 – 5 mm in 0.5 mm steps; plus 10 mm</td>
</tr>
<tr>
<td>Acquisition and Reconstruction Time</td>
<td>200° scan: 40 s* or 48 s** 360° scan: 70 s* or 88 s** * Dell 690/490 workstations ** Dell 670 workstations Time measured from start of gantry rotation to end of CBCT reconstruction when using 384 x 384 matrix and 2.5 mm slice thickness; measurement uncertainty 10%</td>
</tr>
<tr>
<td>CBCT Workload (X-ray tube thermal limits)</td>
<td>5 pelvis scans/hour or 25 standard-dose head scans/hour* 40 pelvis scans/hour or unlimited acquisition of standard-dose head scans** *Without oil-cooled housing **With oil-cooled housing</td>
</tr>
</tbody>
</table>
Table 4: CBCT Modes

<table>
<thead>
<tr>
<th></th>
<th>Standard-Dose Head</th>
<th>Low-Dose Head</th>
<th>High-Quality Head</th>
<th>Pelvis</th>
<th>Pelvis Spot Light</th>
<th>Low-Dose Thorax</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray Voltage (kV)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>125</td>
<td>125</td>
<td>110</td>
</tr>
<tr>
<td>X-Ray Current (mA)</td>
<td>20</td>
<td>10</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Pulse Length (ms)</td>
<td>20</td>
<td>20</td>
<td>25</td>
<td>13</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Gantry Rotation Range (degrees)</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>360</td>
<td>200</td>
<td>360</td>
</tr>
<tr>
<td>mAs</td>
<td>145</td>
<td>72</td>
<td>720</td>
<td>700</td>
<td>720</td>
<td>262</td>
</tr>
<tr>
<td>CTDI\text{w}, norm (mGy/100 mAs)*</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.6</td>
<td>3.4**</td>
<td>1.8</td>
</tr>
<tr>
<td>CTDI\text{w} (mGy)</td>
<td>3.9</td>
<td>2.0</td>
<td>19.4</td>
<td>17.7</td>
<td>24.5**</td>
<td>4.7</td>
</tr>
<tr>
<td>Fan Type</td>
<td>Full fan</td>
<td>Full fan</td>
<td>Full fan</td>
<td>Half fan</td>
<td>Full fan</td>
<td>Half fan</td>
</tr>
<tr>
<td>Default Pixel Matrix</td>
<td>384 x 384</td>
<td>384 x 384</td>
<td>384 x 384</td>
<td>384 x 384</td>
<td>384 x 384</td>
<td>384 x 384</td>
</tr>
<tr>
<td>Slice Thickness (mm)</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Reconstruction Filter</td>
<td>Sharp</td>
<td>Standard</td>
<td>Sharp</td>
<td>Sharp</td>
<td>Sharp</td>
<td>Standard</td>
</tr>
</tbody>
</table>

* Measurement uncertainty ±15%; gantry rotational velocity must be exactly 6.0°/s
** When using half-fan bow-tie

11.0 Supplied Q/A and Calibration Phantoms

- Isocenter cube phantom
- Marker phantom
- Leeds TORR-18FG phantom
- kV blade calibration plate
- CBCT body normalization phantom: 45 cm diameter (Polyurethane foam)
- CBCT head normalization phantom: 24 cm or 25.5 cm diameter (High-density polyethylene)
- CBCT geometry calibration phantom
- Catphan 504 (or equivalent): CT image quality phantom

12.0 Information Systems

12.1 All functionality is supported in a Varian Inspiration™ environment: the Eclipse™ treatment planning system with ARIA® or VARiS Vision™ (Vision client applications 7.3.10 SP3 or newer, and VARiS Vision database 7.1.67.1 SP11 or newer) oncology information system environments.

12.2 Typical uncompressed (compressed) file sizes

12.2.1 Radiographs
- Standard resolution: 1.5 MB (450 kB)
- High resolution: 6.0 MB (2 MB)

12.2.2 CBCT
- 512 x 512 matrix: 0.5 MB/slice (0.18 MB/slice)
- 384 x 384 matrix: 0.3 MB/slice (0.1 MB/slice)
- Typical scan: 64-72 slices
- Range: 30-180 slices
13.0 Third-Party Treatment Planning and Information Systems

13.1 Third-party treatment planning systems with VARiS Vision or ARIA oncology information system environments

13.1.1 The radiographic and fluoroscopic modes are supported, if the treatment planning system supports export of reference images such as digitally reconstructed radiographs (DRRs) in any of the following formats: DICOM RT image, DICOM secondary capture image, or bitmap (e.g., BMP, TIF). Image alignment and scaling may be required after image import.

13.1.2 MarkerMatch and CBCT imaging and patient positioning modes are supported, if the treatment planning system supports export of CT image, RT structures (contours), and RT plan (with dose prescription, reference point doses, and 3D isocenter position) in DICOM RT format. The DICOM RT data needs to be imported into VARiS Vision using the Eclipse treatment planning system (SV or VX package), which is capable of importing the 3D data required by the MarkerMatch and CBCT applications. The ARIA oncology information system can import the DICOM RT data directly using DICOM RT, without the need for Eclipse SV/VX.

13.2 Third-party information systems

Support for the OBI radiographic mode requires that the information system is able to send DICOM CT images, DICOM RT structures, and RT plans into 4DITC/OBI when requested. Therefore, information systems that support the OBI radiographic mode may not support the OBI CBCT mode.

Much of the DICOM information originates from the treatment planning system. Since the On-Board Imager does not interact directly with the treatment planning system, it is the responsibility of the information system vendor to identify supported treatment planning systems.

For those information systems that cannot handle volumetric information, the OBI application supports the selection of reference CT and isocenter information from DICOM media file format files exported from the planning system. The DICOM RT plan, the RT structure sets, and the DICOM CT images for each patient must be located in one directory accessible by the file system of the OBI workstation.

Please contact your Varian District Sales Manager or your Varian representative to get more details about third-party information and treatment planning systems that support the On-Board Imager.

Specifications subject to change without notice.