Monaco® with VMAT, Elekta Integrity™, and Elekta MLCi2 – A winning combination for faster delivery of VMAT prescriptions

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University Medical Center Mannheim
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Background
The Department of Radiotherapy and Radiation Oncology at the University Medical Center Mannheim has been active in the application and improvement of advanced treatment techniques based on multileaf collimators (MLC). Through the use of the most advanced radiation therapy technology available, the Mannheim center has become one of the most important treatment facilities for cancer patients in the Rhein-Neckar area, treating 2,300-2,400 patients per year.

The clinical team at University Medical Center Mannheim has worked closely with Elekta on the development of Integrity, the 6th generation Elekta digital control system.

The department has four Linacs on site, including two Elekta Synergy® Linacs with the Integrity digital control system and the latest Elekta MLC (MLCi2), with two additional Elekta Synergy linacs running at two separate collaborating units off site. All are connected to MOSAIQ® (version 2.0), the image-enabled Elekta oncology information system (OIS) and electronic patient record (EMR). The department has also recently implemented the Monaco® treatment planning system (TPS) for IMRT with static gantry and VMAT, incorporating the Monte Carlo dose calculation algorithm, with 4 workstations connected to one database (see Figure 1).

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Figure 1. * Integrity is Pending 510(k), not available for sale or distribution in all markets. Note: Approval of indications may vary between different countries and additional regulatory clearances in some markets may be required.
The connectivity facilitated by MOSAIQ and MOSAIQ Data Director has enabled a paperless and film-free workflow (see Figure 2).

**Challenge**

A synoptical review of available clinical data suggests that at least 50% of patients would benefit from intensity modulated radiation therapy (IMRT).\(^1\)\(^-\)\(^3\)

However, it is important that any new technique must fit into the current departmental infrastructure. Therefore, in order to provide modulated treatment for this many patients in our clinic, it is necessary to reduce treatment times of modulated therapy.

Our experience has shown that volumetric intensity modulated arc therapy (VMAT) can be used to deliver high quality modulated treatment plans in very short treatment times.

Clinical evidence suggests that most indications can be treated using VMAT, including head and neck, rectal, anal prostate and many other cancers. The impetus for increasing the use of VMAT in our department is the clinical benefit for patients using modulated treatments.
**Solution Implementation**

The combination of Integrity digital control system, Monaco with VMAT and MLCi2 has the potential to reduce treatment times in the delivery of VMAT by allowing complex plans that incorporate continuous variable dose rate (CVDR) and interdigitation. We were, therefore, very keen to evaluate this combination in order to meet our patient demands for modulated treatments - so that more patients could benefit from modulated treatments in a resource neutral way.

- CVDR allows the dose rate to be adjusted to its ideal value during delivery of VMAT prescriptions. This option makes the delivery of the prescribed dose smoother and faster, when compared to previous discrete dose rates, and can reduce delivery time by 30% (Figure 3).

![Graph showing Delivery Time vs. Dose Rate with blue and pink lines, representing discrete dose rate and CVDR respectively. The graph indicates a reduction in delivery time by 20 - 50%, on average by 30%.](image)

**Figure 3. Advantages of Continuously Variable Dose Rate (CVDR).**

Blue = discrete dose rate  
Pink = CVDR
• Interdigitation allows accurate planning and beam shaping of multiple target islands during all treatment techniques, including static, arc, IMRT, Omnip wedge, dynamic, dynamic arc and VMAT. This precise, beam-shaping capability ensures maximum conformance to target volumes, improved efficiency of dose delivery, and reduced radiation to both normal tissue and critical structures (Figure 4).

Figure 4. Interdigitation for Monaco 2.03.01 head model for MLCi2.

In order to speed up the VMAT treatment process, we created new pre-sets in MOSAIQ and XVI (X-ray volume imaging) for image guided radiation therapy (IGRT). This allowed cone beam image acquisition in a counter clockwise rotation of the gantry, prior to initiation of VMAT treatment in a clockwise rotation of the gantry, thus further minimizing total imaging and treatment time.
Results
The result of the new pre-sets in MOSAIQ, in combination with the benefits of Integrity, Monaco with VMAT and the Elekta MLCi2, meant that, in a typical one hour period during the treatment day on one linac, the total VMAT treatment time (including cone beam CT) was reduced to 27 minutes, with beam-on times of between only 2-7 minutes (Figure 5), with the remaining 33 minutes incurred by patient logistics.

<table>
<thead>
<tr>
<th>#</th>
<th>Patient</th>
<th>ID1</th>
<th>Time (beam on + imaging)</th>
<th>Crs</th>
<th>Txd-Field</th>
<th>Mode</th>
<th>MU</th>
<th>Wdg MU</th>
<th>Dose</th>
<th>Wdg Appl</th>
<th>Comp-FDA</th>
<th>Block-Other</th>
<th>V&amp;R</th>
<th>I/O</th>
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<tr>
<td>100</td>
<td>Patient A</td>
<td>AAA</td>
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<td>1</td>
<td>CT</td>
<td>X CT</td>
<td>0.0</td>
<td>0 cGy</td>
<td>vp</td>
<td>Out</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>101</td>
<td>Patient B</td>
<td>BBB</td>
<td>12:52</td>
<td>7</td>
<td>CT</td>
<td>X CT</td>
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<td></td>
<td></td>
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<tr>
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<td>4ROT1</td>
<td>6X VMAT 91C P</td>
<td>848.1</td>
<td>0.0</td>
<td>200 cGy</td>
<td>vp</td>
<td>Out</td>
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<td></td>
<td></td>
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<tr>
<td>103</td>
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<td>CCC</td>
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<td>1</td>
<td>CT</td>
<td>X CT</td>
<td>0.0</td>
<td>0 cGy</td>
<td>vp</td>
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<td></td>
<td></td>
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<tr>
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<td>13:23</td>
<td>2</td>
<td>2ROT1</td>
<td>6X VMAT 192C P</td>
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<td>200 cGy</td>
<td>vp</td>
<td>Out</td>
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<td>CT</td>
<td>X CT</td>
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<td></td>
<td></td>
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<td>Patient E</td>
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<td>13:47</td>
<td>1</td>
<td>2ROT1</td>
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</tbody>
</table>

27 min. total treatment time, including cone beam CT and imaging.

Figure 5. One hour routine treatment. Patient logistics vs. treatment time (IGRT + VMAT): 50% / 50%. Beam-on times between 2 and 7 minutes.
**Discussion**

The combination of Elekta Integrity, Monaco with VMAT and Elekta MLCi2 resulted in 20-30% faster treatment times consistently. This was achieved, primarily, through CVDR (allowing 50% higher dose rates than before) and interdigitation. This meant that, in a one hour time slot, a high degree of modulation could be achieved with significantly faster treatment times (Figure 6).

<table>
<thead>
<tr>
<th></th>
<th>MIMIC (Corvus)</th>
<th>IMRT 7F (Hyperion)</th>
<th>IMRT 9F (Hyperion)</th>
<th>VMAT (Monaco)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{\text{meanPTV1}}$ [Gy]</td>
<td>59.9 ± 0.1</td>
<td>60 ± 0.4</td>
<td>60.1 ± 0.5</td>
<td>60.6 ± 0.3</td>
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<tr>
<td>$D_{\text{meanPTV2}}$ [Gy]</td>
<td>55.7 ± 0.7</td>
<td>56.4 ± 0.4</td>
<td>56.5 ± 0.4</td>
<td>56.7 ± 0.7</td>
</tr>
<tr>
<td>$D_{99%PTV1}$ [Gy]</td>
<td>56.0 ± 0.4</td>
<td>51.7 ± 1.5</td>
<td>52.0 ± 1.6</td>
<td>53.3 ± 0.6</td>
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<tr>
<td>$D_{99%PTV2}$ [Gy]</td>
<td>53.0 ± 0.7</td>
<td>50.3 ± 0.8</td>
<td>50.6 ± 0.8</td>
<td>51.6 ± 1.7</td>
</tr>
<tr>
<td>$D_{\text{meanParotis}}$ [Gy]</td>
<td>19.5 ± 0.9</td>
<td>14.1 ± 1.1</td>
<td>13.9 ± 1.5</td>
<td>14.9 ± 0.6</td>
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<tr>
<td>CI</td>
<td>1.98 ± 0.13</td>
<td>2.23 ± 0.13</td>
<td>2.23 ± 0.12</td>
<td>1.82 ± 0.12</td>
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<tr>
<td>HI$_{\text{PTV1}}$</td>
<td>1.12 ± 0.02</td>
<td>1.20 ± 0.06</td>
<td>1.20 ± 0.07</td>
<td>1.11 ± 0.01</td>
</tr>
<tr>
<td>HI$_{\text{PTV2}}$</td>
<td>1.11 ± 0.02</td>
<td>1.15 ± 0.02</td>
<td>1.13 ± 0.02</td>
<td>1.12 ± 0.02</td>
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<tr>
<td>MU</td>
<td>2551 ± 349</td>
<td>945.2 ± 201</td>
<td>925 ± 234</td>
<td>521.5 ± 53</td>
</tr>
<tr>
<td>Treatment Time [min]</td>
<td>12.8 ± 1.7</td>
<td>7.6 ± 0.3</td>
<td>8.5 ± 0.4</td>
<td><strong>6.2 ± 1.0$^a$$^b$</strong></td>
</tr>
</tbody>
</table>

*Figure 6. DVH-parameters and treatment efficiency for different treatment modalities (mean ± SD). The two values for the treatment time of VMAT display the old (a) and the most recent (b) linac control system.*

Since imaging (for IGRT) and VMAT treatment times were reduced significantly, more patients could receive modulated treatments per day.

Currently, the two Elekta Synergy Linacs in the department are used exclusively for modulated treatments, allowing the clinic to treat around 70 patients with modulated radiation therapy every day.

Not only do these efficiencies enable more patients to receive the clinical benefits of modulated therapy, but the shorter treatment time is easier and more comfortable for patients, particularly if they have painful lesions or severe discomfort. In addition, position insecurities are reduced to ensure more accurate treatment delivery.

The center will soon be able to treat around 1000 patients per year with modulated radiation therapy, approaching 50% of the total treatments performed. Already, 60% of the modulated treatments are VMAT and it is anticipated that this will increase to 80% VMAT in mid-2011, with the remainder receiving static gantry IMRT with dynamic MLC sequencing.

Significantly, the use of Monaco with VMAT for treatment planning has been beneficial in a number of ways:

- The Monte Carlo dose calculation algorithm gives extremely precise dose calculation.
- It is very easy to commission additional machines, especially if they have the same set up, which saves time.
- Both static and VMAT treatment plans can be planned on the same interface.
- The system is very robust, intuitive and easy to use, delivering good quality plans consistently, thus, the high number of modulated plans can be handled efficiently.

Leaf speed is currently the rate limiting factor. The next generation Elekta MLC$^*$ will have double the leaf speed compared to the current MLC, which will allow the beam-on time to be reduced by a further 50%. This will take the delivery of normofractionated modulated treatments consistently to <3 minutes and therefore to an extremely low percentage of total slot time.

$^*$ The next generation Elekta MLC is a works in progress and is not available for sale or distribution in all markets. Note: Specifications are provisional.
References

