In volumetric modulated arc therapy (VMAT), treatment is delivered using a continuous arc motion of the gantry with simultaneous variation of mlc position, gantry speed and dose rate. Several manufacturers offer VMAT facilities based on conventional accelerator gantries while others offer tomographic therapy based on ring gantries. A number of centres have begun clinical VMAT treatments in recent years. The RapidArc solution for VMAT was introduced for clinical use by Varian Medical Systems, Inc in April 2008, with the first patient treated at Rigshospitalet, Copenhagen University Hospital, in May 2008.

In May 2010, RapidArc was installed retrospectively on two Clinac 21iX linear accelerators at the Beatson West of Scotland Cancer Centre (BWoSCC), Glasgow. The first head and neck VMAT patient at the BWoSCC was treated in June 2010, just four weeks after the VMAT hardware upgrade on the linear accelerators. The following article describes our experience in commissioning and introducing head and neck VMAT to BWoSCC.

Commissioning VMAT
As has become common practice in new RapidArc installations, we engaged the help of consultancy company Medical Physics Services (MPS) for commissioning. MPS was on site for one week and assisted BWoSCC physicists in the tests required to commission VMAT on the linear accelerator and to commission the Eclipse treatment planning system for VMAT planning in line with previous published commissioning schedules. MPS also advised on establishing a patient specific pre-treatment quality assurance programme.

Commissioning tests on the linear accelerator confirm the dose delivery accuracy and mlc positional accuracy with varying gantry speed and dose rate. The delivery of dose was evaluated by irradiating seven regions of equal dose using seven different combinations of dose rate, gantry position and gantry speed. The dose for each strip was within 2% of the average dose. The mlc leaf speed was confirmed by using a dynamic mlc (dmlc) test pattern that utilises four different combinations of leaf speed and dose rate to deliver four areas of equivalent dose. Again, the dose for each strip was within 2% of the average dose. The mlc positional accuracy was evaluated using a ‘picket fence’ dmlc test pattern. Positional errors can be detected visually on the film that is irradiated with the test pattern. The dose delivery and mlc position at different gantry angles was also evaluated using different mlc test patterns.

VMAT planning calculations are performed with the Varian Eclipse system using a multi-stage inverse planning optimisation algorithm, known as the Progressive Resolution Optimisation Algorithm, or PRO. The accuracy of dose calculation depends on the accuracy of key measured data such as the dosimetric leaf separation and mlc leaf transmission. Measurements had been made previously for the department’s dmlc IMRT programme but were repeated using the latest measurement technique recommended by Varian.

Moving from dmlc IMRT to VMAT for head and neck treatments
Prior to the introduction of VMAT, suitable head and neck cancers were treated using dmlc IMRT. Primarily, patients with disease in the mouth and throat region were treated, although ethmoid sinus and nasopharynx patients also received treatment with this modality. A class solution of seven equally spaced fixed gantry angles was utilised, along with template dose objectives for PTV coverage and OAR sparing.

Building on this experience, a multi-disciplinary team consisting of clinical oncologists, radiographers and physicists was established to investigate the feasibility of utilising VMAT for head and neck cancers.

Treatment planning study
A treatment planning study was performed to compare optimised dose distributions created by the PRO with those created by dmlc IMRT optimisation for head and neck cancers. Ten patients with floor of mouth disease that were previously treated using dmlc IMRT were randomly selected and replanned with a single 360° arc and double 360° arcs. Arcs were usually restricted to the transverse plane but couch rotations were allowed in exceptional cases where required to meet dose constraints. The treatment plans were evaluated by comparing various parameters, including PTV coverage, OAR dose constraints, dose bathing effect and comparison of monitor units. Use of different structures, margin creation and constraint sets was investigated.

FIGURE 1
Double arc VMAT.

Double arc VMAT was the only planning technique to achieve all the PTV dose constraints. Spinal cord and brainstem dose constraints were achieved with all planning techniques and parotid doses were comparable between the three planning techniques. Double-arc VMAT plans had superior dose conformity index and homogeneity. The dose bathing effect was assessed by measuring the volume of tissue receiving a low dose. V10Gy and V20Gy were comparable for all techniques and V3Gy and V5Gy increased for VMAT compared to dIMRT. VMAT reduces the monitor units by an average of 60% compared with dIMRT.

The optimal conditions for structure and margin drawing were investigated. It was found that the PRO algorithm performed best with a 6mm gap between PTVs and the skin.
therefore analysed to determine if the pass/fail rate could
be determined at the planning stage. An ArcCheck pass
rate above 85% was achieved when the total plan MU was
below 500MU and the leaf separation (%) <10mm was less than
20%.

To reduce unnecessarily complex and time consuming QA,
treatments are divided into two groups: 'standard' and 'com-
plex'. The grouping is determined at the treatment planning
stage. Complex plans are non-coplanar, have MU greater than
500 (based on a dose of 2Gy per fraction) or where the propor-
tion of mlc leaves with separation <10mm was greater than
20%. The dosimetry QA for this type of plan consists of dose
distribution measurements in ArcCheck only. The prediction of plan complex-
ity and the reduction of pre-treatment QA have reduced the
machine time requirement for dosimetry QA.

Patient treatment and image verification
For early patients, the imaging regime consisted of isocentre
check at simulator, weekly CBCT and kV-kV imaging for the
first five fractions. For the first cohort of patients, the CBCT
imaging confirmed the patient position but also highlighted gaps
developing between the patient and their BDS due to weight
loss.

If the patient immobilisation was compromised, their BDS
was adjusted, the isocentre position confirmed at simulator and a
verification plan was calculated on a new CT scan. If the
immobilisation was sufficient then the CBCT images were used
to modify the body outline in the planning system and a verifi-
cation plan was calculated on the original planning scan data
but with a body outline that represented any tissue changes.
The dose distribution was reviewed and particular attention
was paid to the dose to spinal cord.

Data from the first ten patients was analysed to compare
tissue changes, ie weight loss or weight gain, with spinal cord
dose over the course of the treatment. Weight loss occurred from
week 3 of treatment and could contribute to an increased spinal
cord dose but because dose is delivered from 360° round the
patient, this was rarely significant. On the other hand, due to the
highly conformal dose distribution, accurate and repro-
ducible immobilisation and patient positioning is crucial. With
this in mind, radiography and oncologist colleagues performed a
study comparing kV-kV and CBCT imaging for patient setup. It
was concluded that kV-kV imaging could replace weekly CBCT
for patient setup verification.

As a result of these studies, our imaging protocol for head
and neck VMAT treatments now consists of a CBCT scan at
#1 with a repeat CT planning scan during week 4 of treatment,
kV-kV imaging at #2 -5 and weekly thereafter. This has allowed
the treatment slot length to be reduced from 20 minutes to 10
minutes.

Current and future developments
The reduction in treatment slot length and reduction in pre-
treatment dosimetry QA has allowed us to increase our head
and neck VMAT patient numbers from four a month to eight a
month. Since June 2010, more than 70 head and neck patients
have received treatment with VMAT. In October 2011, BWoSCC
commenced stereotactic ablative radiotherapy (SABR) treat-
ments utilising RapidArc to achieve highly conformal dose deliv-
ery within the standard 10 minute treatment slot. VMAT has
also been used to treat CNS and thyroid cancers at the
BWoSCC. Other services planned for clinical starts in 2011/12
that will utilise VMAT at the BWoSCC include whole CNS and
prostate. It is anticipated that the installation of three new
Varian TrueBeam linear accelerators at the BWoSCC com-
encing in early 2012 will allow a significant further expan-
sion in the type and number of treatments able to be performed
with the VMAT technique.

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References