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# Volumetric Modulated Arc Therapy (VMAT): The gold standard for the present and future of radiotherapy?

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**Introduction:**
External beam radiotherapy has advanced from two-dimensional planning to intensity modulated and arc therapies. Clinical use of advanced photon therapy is increasing significantly with intensity modulated radiotherapy (IMRT) use rates constant over three decades.

An Australian and New Zealand survey recorded 46% facilities utilize both IMRT and VMAT and 27% facilities use IMRT only. Additional publications record a decline in 3DCRT usage (67.5 % to 4.3%) and increased VMAT usage (0% to 54.8%) between 2009 and 2017 for non-small cell lung cancer (NSCLC). This trend has been observed in several other treatment sites.

Previously two review papers were published on the clinical use of VMAT and its outcomes, assessing VMAT at the start of its implementation (2000-2010) and looking at the clinical outcomes of its implementation (2009-2016). Both found that although the use of VMAT was increasing, based on planning and feasibility studies, clinical outcome studies were scarce and report only acute toxicities. Little data on long term clinical outcomes of VMAT were cited.

We review the current treatment techniques of six clinical sites (2017-2020), the dosimetric and clinical studies and the future role of VMAT.

**Methodology:** Searches were performed through google scholar and the National Library of Medicine - PubMed using the terms "VMAT""clinical outcomes"and "dosimetric outcomes"for the period January 2017 to present.

**Results:**
Forty-one papers were assessed involving 5,841 patients; 20 clinical outcome studies, 21 dosimetric studies; 36 analysed doses to patients; 5 assessed doses to phantoms or CT scans; 31 retrospective studies; 10 prospective studies.

Carcinoma of prostate and cervix widely use VMAT, reporting few late toxicities and comparable acute toxicities to IMRT. VMAT utilizing hypofractionated radiotherapy schemes and simultaneous integrated boost produce reduced toxicity rates and improved tumour control for patients with prostate cancer and are beneficial for patients where brachytherapy is not feasible.

Anorectal case studies advocate VMAT to become the gold standard, owing to anal sphincter sparing, hot spot dose reduction, better conformity and homogeneity indices, toxicity reduction and successful treatment results. Dosimetric studies have reported comparable tumour coverage between 5F-IMRT, 7F-IMRT and VMAT. However, conformity indices are better with VMAT. IMRT is only preferred for those who require intestinal protection. Significant sparing of OARs is reported for intensity modulated proton therapy (IMPT) compared to VMAT.

3DCRT has been the gold standard for breast cancer radiotherapy. However, many centres have adopted VMAT from the outcomes of dosimetric investigations, which found superior tumour coverage with one main drawback, low-dose baths to OARs which exceed that of 3DCRT. There are several scenarios where 3DCRT is still preferred. However, new techniques like tangential VMAT meet lower OAR constraints with improved target coverage.

Treatment of the lung has widely used VMAT techniques and flattening filter free (FFF) beams and jaw-tracking technology to reduce low-dose spillage to OARs. Wide retrospective studies revealed longer overall survival rates with IMRT and VMAT compared with 3DCRT and as such VMAT and IMRT are recommended for the management of patients with stage III NSCLC.

Many studies for nasopharyngeal cancer (NPC) reveal IMRT and VMAT plans do not differ vastly and both techniques can meet the clinical requirements. Additionally, tumour control, survival and changes in quality of life are comparative for NPC with IMRT or VMAT.

Although VMAT has been widely applied in clinical practice to oesophageal cases, 3DCRT remains the standard technique. Numerous planning studies demonstrated the superiority of IMRT over 3DCRT however,

due to lack of clinical trials it is difficult to say if these dosimetric benefits translate into favourable clinical outcomes. One study suggests modern techniques were effective with toxicities less than grade IV however, local-regional failure was still the most common failure pattern. Dosimetric studies point to proton therapy for clinical improvement linked to dosimetric metrics.

Prospective proton therapy studies also show clinical benefits for oropharyngeal cancer with reduced rates of PEG-tube replacement, acute hospitalization and narcotic requirements compared to VMAT. Although longer follow up is needed to determine long-term effects, initial findings show a reduction in acute toxicity and hence improved quality of life.

Treatment of brain metastases can employ VMAT, CyberKnife (CK) or GammaKnife platforms. 6MV FFF beams can significantly improve target prescription dose conformity compared to CK. VMAT SRS has been used forsingle and multiple metastatic lesions however statistically significant low-dose spillage occur. VMAT for brain metastases reveal lower mean OARs doses, better conformities and hippocampal avoidance while maintaining target conformity and homogeneity.

**Conclusion:**
Current publications for different clinical sites suggest though 3DCRT, IMRT, VMAT and IMPT are implemented, VMAT and IMRT are most used with greater advantages of VMAT usage in most cases. Few clinical outcome studies are published with the majority reporting only acute toxicities. The need is evident for long-term, multi-centre, prospective clinical trials to fully access and accept best practices distinct to sites.

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