

Efficacy of Breathing Control Techniques in Radiotherapy for Motion Management

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Introduction

Respiratory motion during radiotherapy poses significant challenges for accurate tumour targeting and sparing organs-at-risk. This motion can lead to suboptimal dose delivery, potentially compromising treatment efficacy and increasing toxicity. Breathing control techniques, such as breath hold, non-invasive mechanical ventilation (NIMV), and continuous positive airway pressure (CPAP), have been developed to mitigate these issues.

Aim

This study aims to provide an overview of the efficacy of various breathing control techniques in radiotherapy, focusing on their ability to reduce motion and improve treatment outcomes.

Materials and Methods

We reviewed multiple breathing control techniques, including breath hold, prolonged breath hold with supplemental oxygen, CPAP, high-frequency jet ventilation (HFJV), and NIMV. Studies are published from volunteers and clinical implementations, with motion measured using MRI and ultrasound. Techniques were evaluated based on complexity, control of anatomy, and patient comfort.

Results

Techniques can be placed in a 'breathing control landscape' (Figure 1). *Breath hold* is widely applied, yielding a significant reduction in motion for breast cancer radiotherapy. However, not all patients can maintain their breath hold for a sufficiently long duration. The use of *supplemental oxygen* roughly doubles the duration for which subjects could hold their breath. This improves the feasibility of this technique for a larger number of patients.

CPAP increases lung volume and effectively reduced breathing-induced heart motion. This technique has been successfully implemented in the treatment of over 500 patients. *HFJV* demonstrated potential for regularizing breathing patterns, but it was found to cause discomfort with frequencies exceeding 100 breaths per minute (brpm). When *NIMV* was applied at a rate of 60 brpm, the median motion of the diaphragm was reduced by 72%.

Conclusion

Breathing control techniques offer promising solutions for managing respiratory motion in radiotherapy. While breath hold and supplemental oxygen are simple and cost-effective, CPAP and – to a greater extent - mechanical ventilation provide robust motion control. Future research should focus on optimizing these techniques for patient comfort and clinical feasibility.

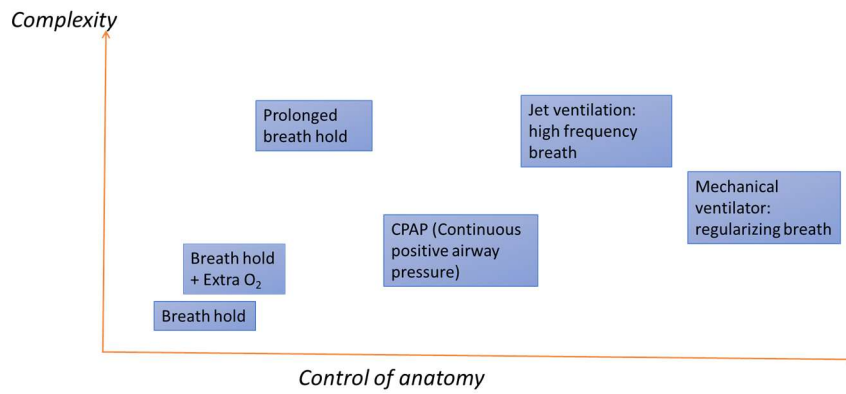


Figure 1 Qualitative indicative scheme of techniques to manage breathing. On the Y-axis the complexity of the clinical implementation as a function of the control over the anatomy on the X-axis.