Tumor Position Stability with MANIV-DIBH: Is Repeated Intra-Fraction Imaging Necessary?

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Introduction

Mechanically assisted non-invasive ventilation (MANIV) enables stable, reproducible, and repeated deep inspiration breath-holds (DIBH) by delivering two controlled pressure levels via a mechanical ventilator. A high-pressure level provides a sustained inspiratory pressure for 20–30 seconds, while a low-pressure level allows complete exhalation, permitting CO_2 elimination and maintaining capnia within normal physiological ranges. MANIV-DIBH is used clinically, during stereotactic (SABR) and fractionated radiotherapy (RT) for thoracic and upper-abdominal tumours, enabling consistent consecutive DIBHs throughout treatment.

Aim

To evaluate tumor intra-fraction deviations during radiotherapy delivered with MANIV-DIBH and discuss their potential impact on intra-treatment imaging strategies.

Materials and Methods

This retrospective study included all patients treated with MANIV-DIBH from May 2022 for lung or upper-abdominal tumours using SABR (3–5 fractions) or fractionated RT (first five fractions analyzed). For each fraction, three cone-beam CTs (CBCTs) were acquired: before treatment (CBCT1), during treatment (CBCT2), and after treatment (CBCT3). Image-guided radiotherapy was systematically performed using CBCT1. Positional deviations in the anteroposterior, craniocaudal, and mediolateral directions were recorded (AP/CC/ML), using CBCT1 as the reference for CBCT2 and CBCT2 as the reference for CBCT3. The workflow is illustrated in Figure 1.

Results

Among 97 MANIV-DIBH treatments, 91 were eligible for analysis (81 SABR, 10 fractionated RT), targeting 14 pulmonary and 77 upper-abdominal tumours (including 46 liver lesions). A total of 771 CBCTs were acquired (441 CBCT2, 330 CBCT3), yielding 1323 intra-fraction and 988 post-fraction deviations. Breath-hold duration was 30 seconds in 82 patients, 20 seconds in 7 patients, and 40 seconds in 1 patient. The mean delivered inspiratory pressure was 17 mbar. Deviations ≥|5| mm occurred in 4.91% of all recorded deviations for CBCT2 and 3.74% for CBCT3. For lung tumours, mean population deviations were -0.3, -0.1 and 0.3 mm (AP/CC/ML) for CBCT2 and -0.1, 0.1 and -0.1 mm (AP/CC/ML) for CBCT3. Mean three-dimensional vectors (V3D) (±SD) were 2.9(±1.8) mm (CBCT2) and 3.2(±1.7) mm (CBCT3). For upper-abdominal tumours, mean population deviations were 0.0, 0.6 and -0.2 mm (AP/CC/ML) for CBCT2 and 0.3, 0.0 and 0.2 mm (AP/CC/ML) for CBCT3. Mean V3D were 3.2(±1.9) mm (CBCT2) and 3.1(±1.6) mm (CBCT3).

Conclusion

MANIV-DIBH provides stable and reproducible breath-holds, with less than 5% of intra-fraction deviations exceeding |5| mm and mean V3D all below 5 mm. These findings support the reliability of MANIV-DIBH and suggest that repeated intra-treatment imaging may not be systematically required to ensure tumor position stability for both thoracic and upper abdominal tumours.

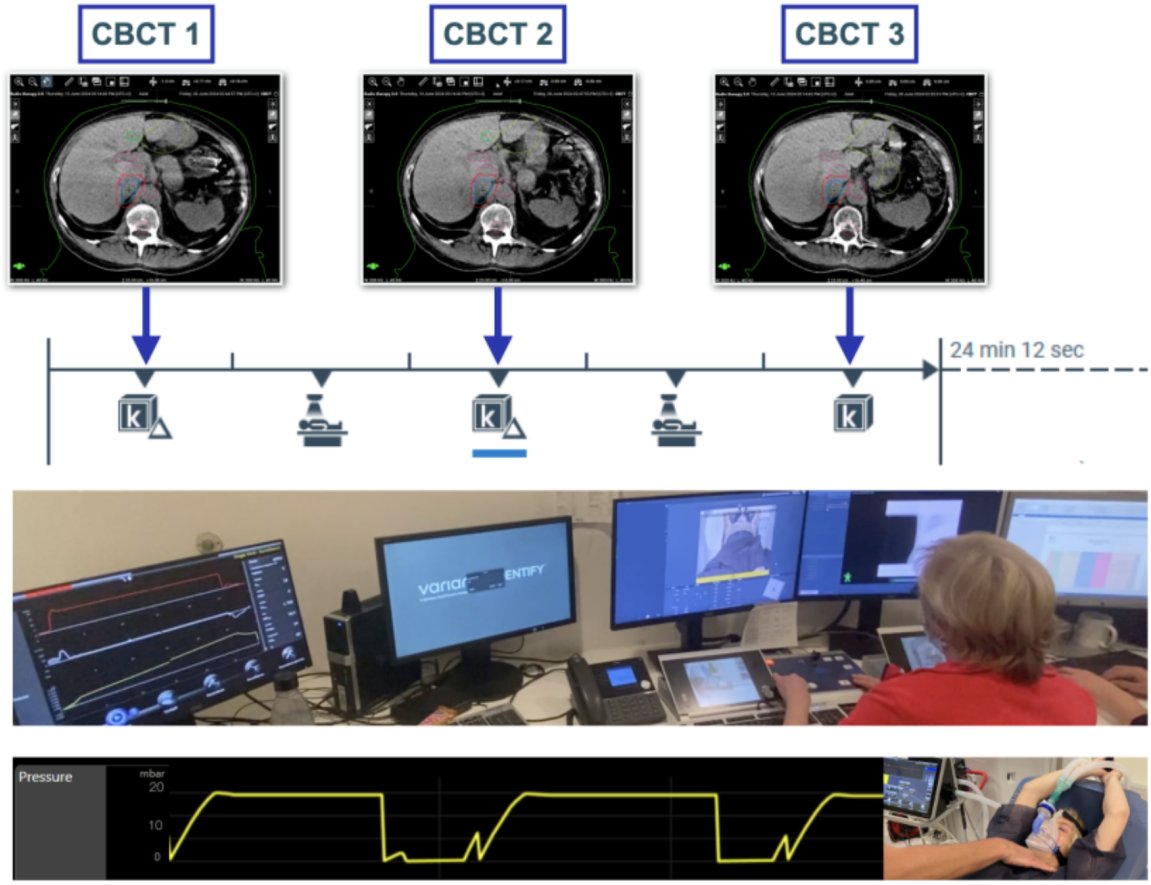

Figure 1. *Cone-beam CTs (CBCTs) acquisitions for intra-fraction motion assessment.*
All patients were treated with SABR or fractionated radiotherapy using mechanically assisted non-invasive ventilation (MANIV). MANIV delivers sustained inspiratory pressure and oxygen supplementation via a ventilator, enabling repeated and reproducible deep inspiration breath-holds (DIBH). This figure illustrates the workflow of a single SABR fraction, including the timing of the three CBCTs acquisitions: CBCT1 before treatment; CBCT2 during treatment, after the first beam delivery; and CBCT3 after treatment. Image-guided radiotherapy was systematically performed using CBCT1 to correct for inter-fraction deviations. Intra-fraction deviations were assessed and further adapted using CBCT2 and CBCT3.