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# Extended localization and adaptive dose calculation using HU corrected cone beam CT: Phantom study

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ABSTRACT

*Background and aim:* The practicability of computing dose calculation on cone beam CT (CBCT) has been widely investigated. In most clinical scenarios, the craniocaudal scanning length of CBCT is found to be inadequate for localization. This study aims to explore extended tomographic localization and adaptive dose calculation strategies using Hounsfield unit (HU) corrected CBCT image sets.

*Materials and methods:* Planning CT (pCT) images of the Rando phantom ($T_{12}$-to-midthigh) were acquired with pelvic-protocol using Biograph CT-scanner. Similarly, half-fan CBCT were acquired with fixed parameters using Clinac2100C/D linear accelerator integrated with an on-board imager with 2-longitudinal positions of the table. For extended localization and dose calculation, two stitching strategies viz., one with "penumbral-overlap" ($S_1$) and the other with "no-overlap" ($S_2$) and a local HU-correction technique were performed using custom-developed MATLAB scripts. Fluence modulated treatment plans computed on pCT were mapped with stitched CBCT and the dosimetric analyses such as dose-profile comparison, 3D-gamma ($\gamma$) evaluation and dose-volume histogram (DVH) comparison were performed.

*Results:* Localizing scanning length of CBCT was extended by up to 15 cm and 16 cm in $S_1$ and $S_2$ strategies, respectively. Treatment plan mapping resulted in minor variations in the volumes of delineated structures and the beam centre co-ordinates. While the former showed maximum variations of −1.4% and −1.6%, the latter showed maximum of 1.4 mm and 2.7 mm differences in anteroposterior direction in $S_1$ and $S_2$ protocols, respectively. Dosimetric evaluations viz., dose profile and DVH comparisons were found to be in agreement with one another. In addition, $\gamma$-evaluation results showed superior pass-rates (≥98.5%) for both 3%/3 mm dose-difference (DD) and distance-to-agreement (DTA) and 2%/2 mm DD/DTA criteria with desirable dosimetric accuracy.

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*Conclusion:* Cone beam tomographic stitching and local HU-correction strategies developed to facilitate extended localization and dose calculation enables routine adaptive re-planning while circumventing the need for repeated pCT.



## 1. Background and aim

Linear accelerators integrated with kilovoltage (kV) on board imaging (OBI) system (sharing the same frame of reference) are widely used to facilitate online setup verification and correction during the course of radiotherapy.[1,2] The OBI system provides cone beam CT (CBCT) images of high spatial resolution with clinically appropriate field of view (FOV) for precise localization of bone and soft tissue boundaries.[3–5] Several authors have reported the practicability of computing dose calculation on CBCT images while addressing HU inaccuracies with appropriate scatter rejection and HU correction strategies.[6–16] The off-centred detector panel arrangement in half-fan (HF) acquisition geometry of the OBI system limits the longitudinal coverage to a mere 16 cm with a maximum reconstruction diameter of 45 cm.[17] However, in most clinical scenarios, the craniocaudal scanning length of CBCT is found to be inadequate for localizing the planning target volumes (PTV) with extended nodal coverage.[18] In the present study, we propose to explore extended localization (EL) and a novel strategy for HU correction that is required for using CBCT in routine adaptive dose calculation (ADC) and evaluation.

## 2. Materials and methods

### 2.1. Image acquisition

In our study, CBCT images of the Rando phantom (The Phantom Laboratory, NY) were acquired using OBI v1.6 system (Varian Medical Systems, Palo Alto, CA), with HF acquisition mode (body scan) with a half bow-tie filter (hBTF). In the HF acquisition geometry, the OBI system acquires 600–700 partially-covered projection images over a gantry rotation of 360° while the detector panel is off-centred to permit maximum FOV. To aid optimum baseline comparison with planning CT (pCT), CBCT images were acquired with fixed acquisition parameters viz., 125 kVp, 80 mA, 45 cm reconstruction diameter (*d*), 16 cm scanning length (*l*) and 2 mm slice thickness with 512 × 512 pixels resolution. Similarly, pCT images ($T_{12}$ vertebrae to mid-thigh) were acquired with 120 kVp and 200 mA using Biograph True Point HD CT (Siemens Medical Systems, Germany). In our study, we developed two different stitching protocols to extend the longitudinal scanning length of CBCT, one with "penumbral overlap" and the other with "no overlap" (as illustrated in Fig. 1).

### 2.2. Stitching protocols

In order to overcome the HU difference at penumbral regions of CBCT, two consecutive HF-CBCT images were acquired with penumbral overlap (*n*) in the first strategy ($S_1$), one

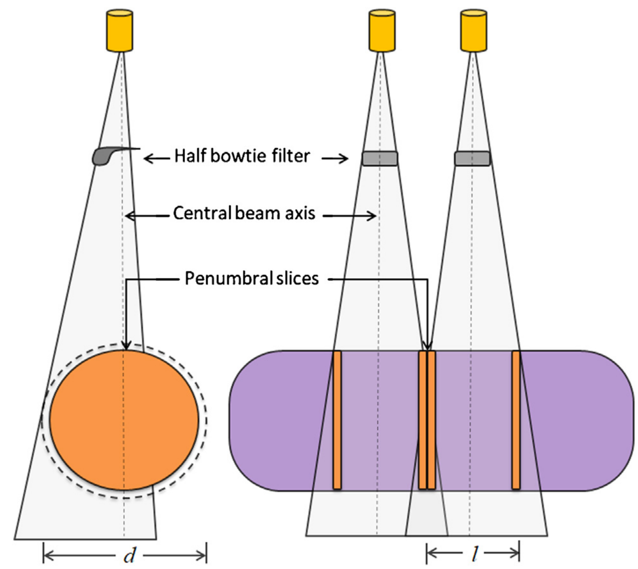


**Fig. 1 – Schematic of HF-CBCT acquisition geometry without overlap ($S_2$-protocol, $n = 0$) at penumbral region.**

at the isocentre, (i.e. at the first cone beam centre) where the couch longitudinal 'Z' is considered as 'zero' and the other with a couch shift "$Z \pm \Delta$" (where $\Delta = l - n$). In the second strategy ($S_2$), straightforward image stitching was performed without penumbral overlap ($n = 0$) in which $\Delta = l$. In both cases, acquisition led to two distinct sets of DICOM images with unique identifiers (UIDs) viz., StudyInstanceUID, SeriesInstanceUID and FrameOfReferenceUID and respective TableTopLongitudinalPosition (TTLP), InstanceNumber (IN) and ImagePositionPatient (IPP), which uniquely identify every entity in the DICOM image. In our study, we developed a DICOM handling software using MATLAB scripts (MathWorks Inc., Natick, MA) for tomographic image stitching. The custom-developed stitching software can read the DICOM header of each series and identify the overlapping slices using corresponding TTLP and IN at the time of acquisition. Further, it performs HU averaging at the overlapping slices and rewrites the resultant series with the same UIDs.

### 2.3. Local HU correction

Accumulation of increased photon scatter in the flat-panel detector due to large cone angles in CBCT acquisition geometry leads to an increase in the HU values in reconstructed images. In this study, it was proposed to explore a new approach for local HU ($HU_L$) correction in regions of high densities[16,19] using custom-developed MATLAB scripts. The purpose of this $HU_L$ technique was to perform accurate dose calculation on stitched CBCT (sCBCT) for use in routine