Hybrid Whole-body Dynamic TOF PET Imaging for Simultaneous Estimation of Compartmental and Patlak Parametric Maps from Continuous Bed Motion Data

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Abstract— **A number of studies have highlighted the clinical role of kinetic modelling following dynamic PET acquisition, since it is able to provide quantitative parameters, more closely related to the underlying pathology than semi-quantitative indices, such as SUV. However, due to the limited axial FOV of current PET scanners, temporally continuous dynamic data are only available for a single bed position. Therefore, full compartmental modelling is axially limited as opposed to whole body imaging protocols which are used in oncology, limiting its applicability in this field. Furthermore, if the blood activity concentration is derived from the images, similar dynamic data of a large blood pool are needed. Lately a new approach to clinical dynamic whole-body imaging has been proposed, consisting of an initial blood pool (cardiac) scan, followed by a number of whole body passes, to estimate whole-body Ki Patlak parametric images. While such an approach improves upon previous whole-body protocols for kinetic parameter estimation, it doesn't fully exploit the information that could be extracted, as well as the benefits of continuous bed motion (CBM) acquisition in dynamic imaging. In this work, we propose a modified CBM whole-body dynamic protocol to simultaneously perform full compartmental modelling in the FOV covering the initial blood pool scan as well as whole-body Patlak analysis. Furthermore, the new protocol does not restrict the initial blood pool scan, for which full compartmental modelling can be performed, to be limited over the heart region but to be chosen based on the localization of the disease within the body. Initial clinical whole-body dynamic scans are reported, along with the estimated micro- and macro-parameter maps. Initial results suggest that not only Ki images from full modelling provide superior tumor to background contrast and improved variance to Patlak Ki but additional micro-parameters are made available to the referring clinician, enabling multi-parametric evaluation of the disease within a clinically feasible dynamic imaging protocol.**

***Index Terms*—Whole-body PET imaging, kinetic modelling**

I. Introduction

Static PET imaging, followed by analysis using semi-quantitative indices, such as the standardised uptake values (SUVs), is used in the majority of clinical assessments in which PET has a role. However, such indices suffer from inherent variability due to a multitude of physiological and acquisition related issues, limiting the diagnostic potential that PET could deliver. During the last few years, a number of studies have highlighted the diagnostic role of pharmacokinetic modelling following dynamic PET data acquisition [1]. At the same time, kinetic analysis can assist in drug development and therapy response monitoring.

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Unlike semi-quantitative indices, full compartmental analysis requires the full time course of the activity distribution to be acquired, in order for micro-parameter maps to be estimated. Coupling this with the short initial time frames needed to capture the rapidly varying activity distribution, restricts the axial FOV that can be scanned to a single bed as opposed to whole-body protocols used in routine clinical practice in oncology. Furthermore, kinetic parameter estimation requires the availability of an arterial input function something which cannot be routinely performed in clinical practice. To circumvent these issues, a new approach to dynamic whole-body imaging has been proposed recently which makes use of Patlak graphical analysis using a non-invasive image derived input function (IDIF) [2]. The protocol involves an initial single-bed blood pool scan targeting the heart, to capture the rapidly varying activity in the blood, followed by a series of temporally non-continuous whole-body passes at equal time intervals. This allows the IDIF to be estimated from the initial continuous scan and the following non-continuous passes over the blood pool region corresponding to the initial single bed scan. Furthermore, it allows Patlak graphical analysis to be performed using the non-continuous passes to estimate whole-body macro-parameter maps of Ki. Although such a protocol improves upon previous attempts to introduce dynamic imaging in the clinic, it doesn't completely exploit the available dynamic data and the information that could potentially be extracted. In this work, we propose a modified hybrid whole-body dynamic protocol which allows not only the estimation of whole-body macro-parameter maps but also the estimation of micro-parameters in the initial bed targeting the blood pool. Furthermore, we propose extracting the IDIF from the descending or ascending aorta, thus avoiding restricting the initial blood pool in the heart region. Since the aorta covers most of the thoracic and abdominal region, selection of the initial blood pool scan can be done based on where the main pathology of interest is localized. As a result, for the FOV being covered by the initial single-bed scan and containing both the blood pool and the pathology of interest, both full kinetic modelling as well as Patlak graphical analysis can be performed. For the rest of the scanned FOV for which data are available only after the initial scan, only Patlak graphical analysis can be performed. Furthermore, the proposed protocol utilizes whole-body passes of ever increasing frame durations as opposed to passes at regular intervals to facilitate better temporal sampling for full kinetic modelling and similar to single bed protocols. Such variable temporal sampling is realized utilizing continuous bed motion data acquisition and selecting variable bed speeds amongst the whole-body passes [3]. Finally initial scans with the proposed protocol are reported along with the estimated micro- and macro-parameter images.

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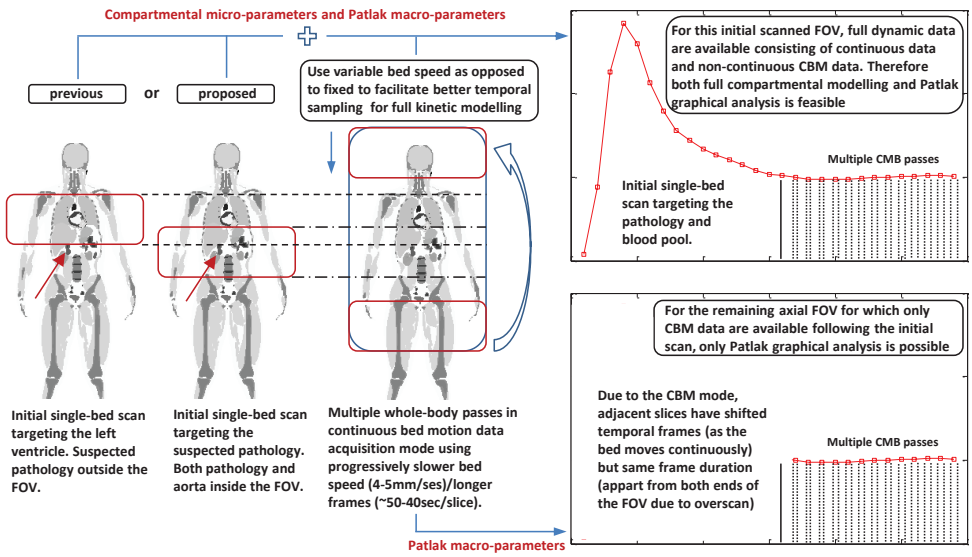
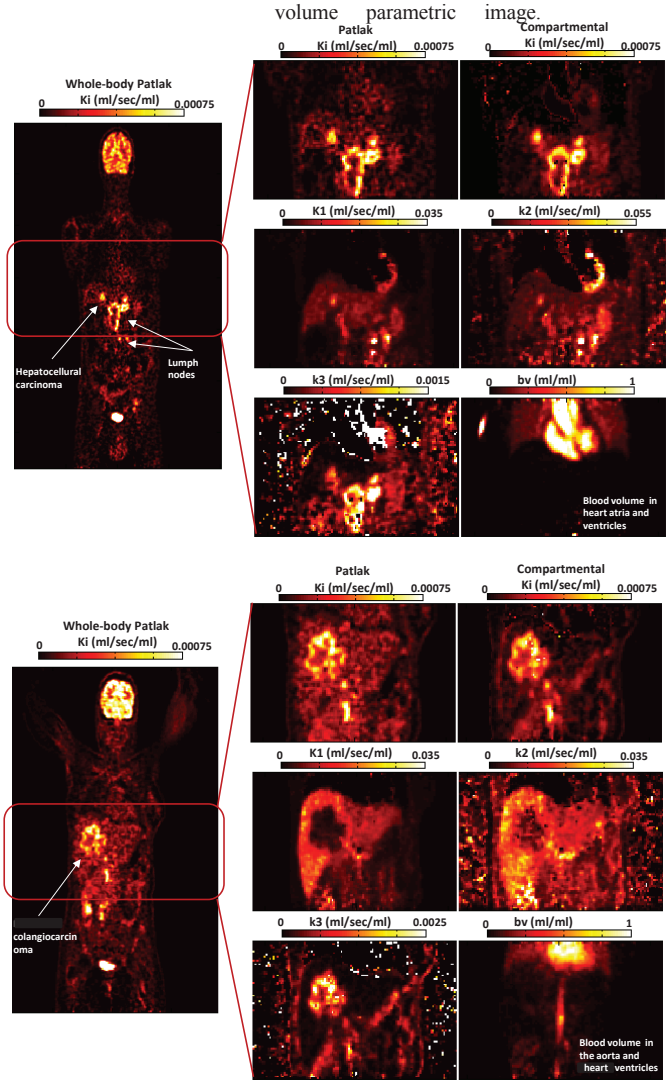


Fig.1 The protocol consists of an initial single-bed scan targeting the main pathology of interest followed by a number of whole-body passes in CBM mode. The initial scan can target the pathology as opposed to targeting the LV since the IDIF can be extracted from the aorta if the heart is not in the FOV. The whole-body passes are acquired using varying bed speed to provide a temporal sampling more suited to full kinetic modelling. Due to the motion of the bed each slice has different absolute framing, though the frame duration is the same.

Fig.2 Parametric Ki images estimated with Patlak and full compartmental modelling, as well as K_1, k_2, k_3 and blood volume images. On the 1st patient (top) the pathology was localized close to the heart therefore IDIF extraction was done from the LV. On the 2nd patient (bottom) the pathology was localized in the abdomen therefore the descending aorta was used. The blood pools can also be seen in the blood volume parametric image.



II. Methods - Results

The proposed protocol is depicted in Fig. 1. Data from 3 patients were acquired on the mCT PET/CT (Siemens Healthcare,Erlangen)in order to evaluate the clinical feasibility and test the impact of CBM mode on full kinetic modelling. Following bolus injection of [^{18}F]FDG (210-310MBq), the protocol involved an initial single-bed continuous 6-min scan over the suspected disease, including either the aorta or heart ventricles (or both). Following the initial scan, 13 temporally non-continuous whole-body frames were acquired (axial FOV ~1m) in CBM mode. Three progressively slower bed speeds were selected (5.0-4.0mm/sec) in order to generate time frames of progressively longer durations similar to conventional single bed dynamic imaging. Additionally, late venous sampling was performed to measure the plasma-to-whole blood ratio and to cross correlate the measurements with the IDIF. List-mode data from the single-bed scan were split into 20 time frames (8×5sec, 4×10sec, 4×25sec, 4×45sec), while CBM data framing was fixed and dictated by the pass bed speed (3×44sec, 5×50sec, 5×56sec). Following image reconstruction (TOF PSF OP-OSEM [5iter, 16sub]) Patlak analysis was performed in the entire whole-body scanned image. Furthermore, full compartmental modelling using a 2-tissue model (4 parameters) and the GLLS method, was performed in the region covering the initial single-bed scan. Input function extraction was performed either from the LV ventricle or the descending aorta, while for the single bed where full compartmental modelling was performed, a basis function approach was used to fit the delay. Kinetic analysis from two dynamic scans can be seen in Fig.2

III. Discussion - Conclusion

Initial results suggest that the proposed protocol is able to provide not only improved Ki images, but a multitude of parameters regarding the pathology of interest, potentially enabling an improved diagnosis upon existing static and dynamic whole-body protocols. Further data acquisition, and analysis is currently under way to assess and optimize the proposed methodology both with clinical and simulated data.

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