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Clinical Workflow Considerations for Implementation of Continuous Bed Motion PET/CT

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## Abstract

Within the last three years, a new type of technology has emerged for Positron Emission Tomography (PET) imaging that uses a continuous bed motion (CBM) acquisition. For technologists, this technology requires some modifications of the standard approach to PET protocols and imaging workflows. There are a number of key things technologists needs to learn and understand when transitioning from traditional Step and Shoot (SS) PET imaging to this new technology including the difference in acquisition types, image quality, protocol setup, and finally the impact CBM can have on workflow. This article provides key information on how CBM differs from SS and focuses on the critical items technologist may encounter when using this technology.

Keywords: CBM, PET, Gating, Continuous Bed Motion

# Introduction

Since the development of Positron Emission Tomography (PET), data has always been collected using the same type of whole-body acquisition method, known as step and shoot (SS). Another PET acquisition method, known as continuous bed motion (CBM) was described by Dahlbohm et al. in 2000 and tested on a clinical lutetium oxyorthosilicate (LSO) platform by Brasse et al. in 2002 (*1,2*). Within the last two years, this technology has become clinically available for commercial PET/CT systems. This new technology brings a few key differences in scanner operation while also having an impact on typical clinical workflows. This work provides insight into using CBM technologies and provides key comparisons between this technology and standard SS techniques. Studies at our facility were all performed under University of Tennessee Institutional Review Board Approval (#3640, #3539, #3731).

# Learning Objectives

Readers will be able to understand and be able to describe key differences between standard PET and CBM PET technologies, describe the advantages of CBM PET technologies, and assess standard PET protocols and translate them in to CBM variations.

# **Novelty of CBM**

CBM technology requires a slightly different way of thinking for technologists in order to complete a scan. The term "bed" or "beds", referring to a single field of view (FOV), is not used unless the scanner is configured for traditional acquisition methods. All that matters in designating the scan length is the desired axial range or ranges to be configured for the acquisition similar to computed tomography (CT). In the current implementation of clinical CBM technology, a technologist has the option to turn on one to four different ranges each allowing different speeds of acquisition through selected parts of the body. For example, the technologist may select a different bed speed through the head and neck axial range than what is chosen for the axial range covering the lower extremities.

## **PRIMARY DIFFERENCES**

There are several differences to consider when transitioning from traditional SS PET imaging to CBM PET imaging. These differences include acquisition execution, the quality of the images, and the protocol setup. These will be discussed in more detail in the sections below.

## **Types of Acquisitions**

The most obvious difference between the acquisition methods is the way in which the bed moves during acquisition. Traditionally with a SS type scanner the table pauses for the time selected for that bed and then moves suddenly to the next bed position, this is where the name step and shoot is derived. Then each bed is stitched together to form a whole-body image. When acquiring whole-body PET images using CBM, the table is in continuous motion from the beginning to the end of the selected axial range.

### **Image Quality and Quantification**

Although these two methods of acquisition differ most significantly in workflow, protocol design, and scanner operation, there are slight differences to image quality and quantification that are useful in determining appropriate imaging parameters. Over the past three years, several publications have been produced that have characterized performance of continuous bed motion PET/CT in relation to traditional acquisition methods. Each of these papers had different approaches but reported similar results and conclusions.

Two of the investigations of this technology reviewed clinical quantitative performance of CBM vs. SS and reported that use of CBM vs. SS resulted in no statistically significant differences between measured SUVs and visual interpretation of image data (*3,4*). A third publication comparing these technologies showed that key National Electrical Manufacturers Association (NEMA) performance and image quality parameters did not vary significantly between the acquisition methods (*5*). These studies provide evidence that imaging facilities can easily change between modes of acquisition without any need for corrections between the two techniques. Comparisons of patient preference between the two modes of acquisition indicated a strong preference for CBM where it was found to be more relaxing, quieter, and more fluid than scans performed with SS technology (*3*). When blinded to the data acquisition method, physicians also showed slight preference toward data acquired using CBM versus SS techniques (*4*). Physician preference of data could possibly be attributed to the improvement in end plane imaging using CBM techniques shown by both Osborne and Rausch in their independent studies. In both studies, end planes using CBM techniques were shown to have statistically significant improvements in image quality and quantitation.

## **Protocol Setup**

The acquisition protocol set up for the technologist has a few changes when going from SS to CBM that require slight differences in the way the technologist must think about imaging the patient. In traditional SS imaging, the number of minutes per bed and the total number of beds required to cover the desired axial range are used to determine the total scan time. With CBM, the bed speed (mm/sec) and the axial range are all that used to determine scan time. If more counts are needed, we would increase the minutes per bed, but with CBM, the inverse is true and bed speed is decreased to increase the number of counts in the acquisition. This concept is very similar to setting up a nuclear medicine bone scan. There is also the potential for time savings when

setting up protocols using CBM techniques. Being able to use ranges instead of individual beds saves the technologist time by decreasing the number of mouse clicks involved and enables optimization of the exact ranges required to cover a given anatomical region (6).

The most important improvement for a technologist is being able to set the FOV with CT like ranges, obviating the need for individual PET beds. Many times a technologist is faced with needing slightly more coverage for the PET FOV and is forced to add a complete bed to the acquisition protocol. This additional bed adds scan time and results in additional radiation exposure from having to extend the CT range to match the PET FOV. When setting up a CBM PET-CT the technologist is now able to select exact ranges that are desired for both CT and PET FOVs resulting in optimized scan time and an average of five percent CT dose reduction for the patient (*4*).

## IMPACT ON WORKFLOW

CBM technology impacts several key aspects of the imaging workflow including: length of scan time, the protocol setup time, capabilities of complex protocols, and improve gating. Almost everything CBM is capable of is possible with SS, but with more scan and setup time needed (4).

### **CBM Enables Exact Range Selection**

#### Standard Whole-body PET Protocols

For standard whole-body PET imaging protocols, selecting the exact axial PET range has the largest impact on workflow. This has the potential to lower the CT dose for the patient and reduce the amount of time on the scanner. A shorter scan may have some advantages, including a faster workflow and a decrease in overall patient motion. Faster workflows result in schedule optimization that can lead to improved imaging efficiency and potentially improved patient experience by minimizing their required time on the scanner.

#### Melanoma

The biggest influence CBM has on a melanoma protocol is the capability to select multiple ranges with independent bed speed settings. The setup time for a melanoma protocol using SS can take longer than other protocols because of the large number of beds needed to complete the scan. It is common in melanoma PET imaging that the imaging time in the lower extremities is reduced resulting in decreased time per bed in traditional SS imaging and increased bed speed for CBM imaging (7). Current clinical implementations of CBM have multiple selectable ranges that enable selection of a single range to cover the patient's body (head through pelvis) set at normal institutional bed speed settings, and another range to cover the legs with increased bed speed over the extremities (Table 1). To setup this protocol, the technologist would only have to set the speed for two ranges, instead of clicking on each bed of a traditional SS protocol, which may require manual setup of 4-5 beds depending upon the height of the patient. The result is a faster setup time and the potential for an optimized scan time (Figure 1).

#### Gating

At our institution, the use of CBM range selection has influenced the efficiency of gating protocols. For example, most patients' lungs will not fit into a single bed, but the range covered by having to select two full beds is excessive as shown in Figure 2 (8). The amount of time it takes to gate two beds over the lungs during the whole-body scan can almost triple the time it takes to do a normal whole-body scan (4,9). Most institutions with SS do not gate lung scans because of the time required for these studies (8,9).

CBM permits an exact range to be selected over the lungs, which optimizes time and makes these protocols feasible for routine clinical use. When using CBM gating compared to SS gating there is an average of a 23% reduction in total acquisition time (9). At our institution, prior to the implementation of CBM, gating was previously performed on studies by referring physician request only. Since using CBM to optimize our workflows, we now are able to offer gated PET imaging on all studies where respiratory motion could negatively impact the diagnostic quality of images. This includes routine use on all clinical indications of lung, pancreas, liver, and gastric disease. Our institutions protocol setting for gating can be seen in Table 1.

#### **CBM Enables Complex Protocols**

Numerous times in PET/CT imaging there is a need for high resolution imaging through a specific area of the body depending on the diagnosis. There are times as well when a high resolution area is needed along with a gating scan. SS imaging is able to complete this type of acquisition but at the cost of a significant increase in scan time. Depending on the area, the time of 2-3 beds would have to be tripled to achieve the desired image quality. The outcome is a lengthy scan that may not be clinically possible for every patient without a significant impact on departmental scheduling. CBM offers the ability to create complex protocols using exact range selection over multiple areas to optimize a single study to acquire high resolution, standard whole-body, gated acquisitions, and fast extremity imaging all within the same scan protocol. An example of clinical use of such a protocol for our institutions would be a melanoma patient with lung disease accompanied by brain metastases in the brain. A complex protocol for this patient would include the following ranges and settings and is shown in FIGURE 3: First range from top of head to the apices of the lungs scanned at a speed of 0.5 mm/sec, Second range is from apices of the lungs to the base of the lungs scanned at a speed of 0.4 mm/sec, Third range from base of the lungs through the abdomen and pelvis scanned at a speed of 1.5 mm/sec, Forth range from bottom of pelvis through the lower extremities scanned at 2 mm/sec.

The result is that in a single pass, the physician now has a high resolution head, motion corrected lungs, and whole-body melanoma scan in an optimized scan time. The key is

being able to select the exact axial ranges for the desired areas, instead of being limited to individual bed sizes when using SS. The impact of single bed sizes becomes more pronounced with systems that have small axial FOVs (3-ring vs. 4-ring).

## **CBM Limitation: Single-bed Acquisitions**

Single-bed acquisitions do not see the general time savings and workflow setup benefits of CBM PET imaging. For example when imaging brains, liver, or any limited imaging that would fit in one bed size there is not a specific need to set exact axial ranges. The smallest range that can be set using CBM protocols is determined by the maximum axial FOV of the PET scanner plus a slight additional overscan amount.

## CONCLUSION

There are key differences between SS and CBM imaging that technologists should learn when transitioning from SS to CBM PET/CT. These key differences include: how the acquisition is acquired, image quality, protocol setup, and the impact on their daily workflow. With these differences come some advantages to using CBM vs SS such as efficient protocol setup, more efficient gated acquisitions, and the ability to complete complex protocols in one pass and within a scan time that makes it possible for everyday clinical use.

# DISCLOSURE

Dustin Osborne and Shelley Acuff occasionally provide expert testimonial to Siemens Medical Solutions USA, Inc.

The University of Tennessee has ongoing collaborative relationships with Siemens Medical Solutions USA, Inc.

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FIGURE 1: PET/CT Melanoma Protocol setup using 2 CBM ranges

## FIGURE 2

Comparing Respirtaory Gating using SS vs CBM

- A. Multibed Step& Shoot shows number of beds required to cover lungs
- B. Three Range CBM Gating image shows how exact ranges can be set around the lung field and the advantage of not being limited by bed size



# FIGURE 3

Example of a complex workflow and the ranges set on a Topogram.



## TABLE 1

| Protocol    | Range 1         | Range 2         | Range 3     | Range 4       |
|-------------|-----------------|-----------------|-------------|---------------|
| Standard    | 1.5mm/sec       |                 |             |               |
| Whole-body  | (eyes- thighs)  |                 |             |               |
| Melanoma    | 1.5mm/sec       | 2mm/sec         |             |               |
|             | (eyes- thighs)  | (thighs- toes)  |             |               |
| Respiratory | 1.5mm/sec       | 0.4mm/sec       | 1.5mm/sec   |               |
| Gating      | (Eyes- lung     | (lung apex-lung | (lung base- |               |
|             | apex)           | base)           | thighs)     |               |
| High Res    | 0.5 mm/sec      | 1.5 mm/sec      | 0.4 mm/sec  | 1.5 mm/sec    |
| Combination | (top of skull – | (skull base –   | (lung apex- | (base of lung |
| Scan (High  | base of skull)  | lung apex)      | lung base)  | – thighs)     |
| Res Head,   |                 |                 |             |               |
| Gated Lung) |                 |                 |             |               |