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A Method for Quantitative Characterisation of Artefacts Caused by Urinary Excretion of 18F-FDG

Authors

Bach-Gansmo T1, **Seierstad** T2, **Bogsrud** TV1, **Aas** M1, **Skretting** A2

Departments of nuclear medicine¹ and medical physics and technology ². The Norwegian Radium Hospital, Oslo, Norway

Introduction

The presence of large quantities of 18F-FDG in the urinary bladder as well as changes in activity and volume over time may hamper the detection by PET of pathological accumulation of FDG in, or adjacent to, the bladder (1). The reason for this is that part of the reconstructed image close to the bladder contour contains artefacts that are perceived as noise. Bladder emptying has been proposed to circumvent such problems (1-3). This paper describes a method of providing objective measurements of these artifactual variations of image intensity (artefacts). The method was applied to a retrospective comparison of the artefacts in gamma-camera PET obtained by using a number of different strategies to empty the bladder. This method may also be applied to compare, for example, the effects of different filters or reconstruction algorithms on such artefacts.

Materials and Methods

Description and Quantifications of Artefacts

Data processing was completed using IDL (Interactive Data Language, Research systems Inc, Colorado, USA). The physicist processing the data was 'blind' in respect of the catheterisation status of the patient.

A 3-dimensional representation was used to create a coronal projection (Fig. 1a), which, in turn, was used to determine the cranio-caudal extent of the region that was affected by bladder activity. The line indices nupp and nlow in this coronal projection correspond to the upper and lower transverse slices which show bladder activity. These indices gave the number of slices affected, nlines = (nupp – nlow +1), as well as the index of the central bladder slice, ncentral= (nupp + nlow)/2. Next, the transverse images corresponding to the selected lines in the coronal projection were added to form a transverse projection of the bladder region. In this image, a region of interest (ROI) was interactively drawn along the contour of the bladder, keeping the drawn curve separate from the bladder (Fig. 1b). From this ROI total reconstructed bladder counts were determined. The program then created a 6 pixels-wide rim ROI adjacent to, and surrounding the bladder ROI. Using the rim ROI, mean values and standard deviations (SD) were calculated for the central slice (slice ncentral) and for a slice situated 4 slices (16.6 mm) above the upper limit, i.e. for slice number nab = nupp+4 (Fig. 1). In this latter slice there was no interference from bladder activity and the SD was considered as a measure of the variation in normal signal intensity.

The artefacts due to activity in the bladder were finally characterised by an artefact induction factor (AIF) which was defined as 'the ratio between the SD of the reconstructed counts in the rim ROI of the central slice and the corresponding quantity calculated for an identical rim ROI in slice nab situated above the bladder region'.

Study Categories & Associated Procedures

Gamma-camera PET examinations performed over the last 3 years were retrospectively grouped in three categories depending on bladder emptying strategy. From these groups a total of 17 patients were arbitrarily selected for inclusion in this analysis. Since the aim was to characterise artefacts caused by urinary FDG, patients with focal activity adjacent to the bladder region were not included. The categories were as follows:

Category 1 (n=6): No catheter. This group consisted of patients who refused catheterisation or patients for whom catheterisation was not considered necessary because of the expected location of the tumour. Furosemide could not be administered to these patients as the urge to void might interrupt the examination.

Category 2 (n=7): Ordinary 2-way catheter. These patients presented with indwelling catheters and did not have their catheter changed for the purpose of the PET examination. Category 3 (n=4): 3-way Foley catheter no. 16 or 18 (BARD Ltd, UK). In these patients bladder irrigation was performed during data acquisition in the pelvic region. A 3-way catheter contains an additional third channel for infusion through which 1-1 litres of saline was injected into the bladder during the 40 minute data acquisition of the pelvic region.

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The two last categories of patients required bladder catheterisation to ensure an accurate diagnostic examination of the pelvic region.

Image Acquisition

The patients were administered 150-175 MBq ¹⁸F-FDG i.v. In catheterised patients 1 litre of saline and 20 mg of furosemide i.v. was also administered in order to flush the bladder and clear the intrarenal collecting systems and

ureters (4). After 1-1.5 hours of rest in a quiet, dark room, gamma-camera PET was performed using an ADAC Vertex MCD AC dual-head gamma camera (ADAC/Philips, California, USA) with 5/8 inch sodium iodide crystals. Two 20% energy windows were centred at 230 and 511 keV photon energies and coincidence events between scattered and totally absorbed photons were accepted. The coincidence events obtained at 32 equally spaced angles were Fourier rebinned and images were reconstructed in the ADAC system by an OSEM method using 8 subsets, 2 iterations, and axial smoothing. Attenuation correction was based on transmission data measured with ¹³⁷Cs sources.

For the patients included in this study, three bed positions were acquired. The axial field overlap was 30% and subsequent processing resulted in a knitted image set of up to 128x128x320 voxels. Each voxel measured 4.15x4.15x4.15 mm³. The imaging always started with the pelvic region, thus avoiding caudal bladder overlap.

The knitted image sets were converted to an INTERFILE format and transferred to a PC for artefact characterisation and quantification.

Results

The variation in AIF among patients was recorded and the SD of this AIF was used to compare the artefacts drawn from different categories.

The AIF was reduced from 1.6 in patients without a catheter to 1.2 in patients with an ordinary catheter. This was further reduced to 0.9 in examinations performed with a 3-way catheter (Table 1). In the latter case the random artefacts seen in the bladder region were smaller than those seen in the region above the bladder.

The amount of ¹⁸F-FDG in the bladder and the associated artefacts were significantly reduced by the urine dilution and evacuation of the bladder with a 2-way catheter. This was further reduced by the 3-way technique as represented in the AIF (Table 1).

The cranio-caudal extent of the bladder-artefact region was also closely correlated with the urine dilution/irrigation technique (Table 1, Fig. 2).

In patients who did not have a catheter, the mean vertical bladder extension was 33 mm (range 29-46 mm) and the rendering of the pelvis was on all occasions disturbed by artefacts. The corresponding extension was 19 mm (range 0-29 mm) in the patients who had 2-way catheters. In patients with a 3-way catheter and bladder irrigation the bladder was observed as a hypo-intense region, partly due to the infused saline and partly induced by the inflated balloon.

Discussion

The AIF gave consistent results in accordance with the visual impression of the artefacts and considerable variations were observed across the three categories.

In the examinations performed without indwelling catheters, large volumes of the pelvic region were rendered incapable of diagnosis by reconstruction artefacts, resulting in a mean AIF of 1.6. An ordinary catheter was sufficient to completely empty the bladder in some patients, leaving no artefacts in the adjacent image regions. However, as demonstrated by the mean vertical bladder extent (Table 1), the artefacts varied considerably and in some examinations had the same appearance as in patients who did not have a catheter. This was further confirmed by the AIF, which varied from 0.97 to 1.87.

No artefacts were seen in the images of the patients where a 3-way catheter was combined with bladder irrigation. In these patients the bladder was perceived as an area of lower intensity than the surroundings, resulting in a mean AIF of 0.91. The low intensity of the bladder region explains the AIF 1 in this category. In dedicated PET-scanning with ¹⁸F-FDG the duration of imaging in each bed position is of the order of 3-5 minutes, and artefacts due to bladder activity is less problematic. However, in studies where the urine excretion is rapid (together with or alongside compounds other than FDG) and imaging is started immediately after injection, then artefacts may have clinical significance. The analytical method described in this paper may also provide a quantitative measure of these disturbances.

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