A comparison between the conventional manual ROI method and an automatic algorithm for semiquantitative analysis of SPECT studies

L Pagan\(^1\), C Tranfaglia\(^2\), S Galli\(^2\), G Lucchi\(^2\), B Novi\(^1\), G Fagioli\(^2\), G Guidarelli\(^1\)

\(^1\) Health Physics Unit, Maggiore Hospital of Bologna, Italy
\(^2\) Nuclear Medicine Unit, Maggiore Hospital of Bologna, Italy

E-mail: laura.pagan@ausl.bo.it

Abstract. In this study, the performance of a free software for automatic segmentation of striatal SPECT brain studies (BasGanV2 – www.aimn.it) and a standard manual Region Of Interest (ROI) method were compared. The anthropomorphic Alderson RSD phantom, filled with solutions at different concentration of \(^{123}\)I-FP-CIT with Caudate-Putamen to Background ratios between 1 and 8.7 and Caudate to Putamen ratios between 1 and 2, was imaged on a Philips-Irix triple head gamma camera. Images were reconstructed using filtered back-projection and processed with both BasGanV2, that provides normalized striatal uptake values on volumetric anatomical ROIs, and a manual method, based on average counts per voxel in ROIs drawn in a three-slice section. Caudate-Putamen/Background and Caudate/Putamen ratios obtained with the two methods were compared with true experimental ratios. Good correlation was found for each method; BasGanV2, however, has higher R index (BasGan R\(_{\text{mean}} = 0.95, p < 0.001\)) than the ROI method (R\(_{\text{mean}} = 0.89, p < 0.005\)). The results obtained suggest that this new software can be suitable in daily practice, being an accurate, simple, fully automatic and reproducible method of semiquantitative analysis of \(^{123}\)I-FP-CIT SPECT data with, moreover, the advantage of the availability of a control subject’s database.

1. Introduction

It is well known that in the last few years SPECT studies of the pre-synaptic dopaminergic system has gained a central role in the study of parkinsonian syndromes [1], and particularly in differentiating Parkinsonism from Essential Tremor and Lew Bodies Dementia from Alzheimer disease [2,3]. Qualitative, visual analysis of striatal uptake is probably the most common approach and have demonstrated to yield similar sensitivity and specificity as a non-anatomical ROI method. The semiquantitative approach however can reach a higher positive predictive value and a better likelihood ratio [4].

Furthermore, the results derived from ROIs have potential advantages because they provide a continuous variable (rather than a categorical variable), which is more likely to detect subtle changes in DAT binding in striatal subregions and allow monitoring of disease progression [3,5]. Because of this, different methods of semiquantitative analysis have been proposed to reach a better accuracy in ROI definition and activity measurement than the standard manual method.

Recently a new version of Basal Ganglia software (BasGanV2) for semiquantitative analysis of SPECT studies with \(^{123}\)I-FP-CIT (DatSCAN) is available on the website of Italian Nuclear Medicine
Association (www.aimn.it) [6]. BasGanV2 is easy to use, freely downloadable from the web and presents the advantage of automatic procedures: is user-independent and provides 3D information of the brain since it is based on a template derived from Talairach and Tournoux neuroanatomical atlas. Moreover the software tool incorporates a customisable database of controls patients.

This software tool can be used for automated and standardized processing, evaluation and documentation of DatSCAN SPECT studies, and has demonstrated its usefulness in the differential diagnosis between Parkinsonism and essential tremor [7].

The aim of this study was to evaluate the performance of both BasGanV2 and a standard method, based on manual ROI plotting, with the use of anthropomorphic striatal phantom images reconstructed by a filtered back-projection (FBP) algorithm.

2. Materials and Methods

Nine SPECT acquisitions of the Alderson phantom (designed ad hoc to reproduce the striatal morphology) were performed with the striatum and background chambers filled with solutions at different concentration of $^{123}$I-FP-CIT (GE Healthcare, Amersham, UK) in order to obtain different specific caudate to background (C/B), putamen to background (P/B) and caudate to putamen (C/P) ratios. The C-P/B and C/P ratios obtained experimentally in the nine simulations ranged from 1 to 8.7 and 1 to 2 (see table 1).

Data acquisition were carried out with a Philips-Irix triple head gamma camera equipped with low-energy, high resolution parallel hole collimators (figure 1 and 2). Total counts ranged between 2 and 3 millions, the acquisition matrix was 128 x 128 with a pixel size of 2.33 mm.

The images were reconstructed by a FBP algorithm and filtered with a Butterworth filter (order = 5; cut off = 0.26). Attenuation correction was performed according to Chang’s method ($\mu = 0.11$/cm) [8].

![Figure 1. The Alderson phantom filled with $^{123}$I-FP-CIT](image1.jpg)

![Figure 2. Images acquisition of the Alderson phantom by Philips-Irix.](image2.jpg)

Reconstructed SPECT data were processed with the “BasGanV2” software, that provides normalized striatal uptake values, and by using a conventional manual ROI method.

The BasGan algorithm performs translations and scale transformation on the bicommissural aligned input image to set the striatal templates, derived from the Talairach atlas, with standard size in an appropriate initial position. An optimization protocol automatically performs fine adjustments in the positioning of blurred templates to best match the radioactive counts, and locates an occipital ROI for background evaluation. Partial volume effect (PVE) correction is also included.

Results are displayed in a report which includes graphical visualization of ratio uptake calculations compared with a reference built-in database (population of 96 subjects with essential tremor from a multicenter study by the AIMN Neurology Study Group).

In the conventional manual method, ROIs were drawn on the head of the caudate, the putamen and the parieto-occipital region choosing the slice where the striatum could be best identified and adding the adjacent upper and lower slices to build a three-slice section. Ratios were calculated, according to
the same formula which is automatically applied by BasGAN (striatum-background/background), based on average counts per voxel. PVE correction was not applied to the manual ROI analysis.

Correlation analysis was performed between true and measured ratios for each method, after checking for normal distribution of the data by using Kolmogorov-Smirnov test.

3. Results
Table 1 presents the true and measured uptake ratios obtained in this study. Good agreement has been found for both methods.

Both methods underestimated almost all the binding values. This could be due to the attenuation correction method based on a mathematic standard algorithm, which maybe is less accurate than the one based on transmission data (i.e. low-energy TC scan). This hypothesis is under investigation. The manual method, however, underestimates values more than BasGANv2, probably due to the absence both of PVE correction and the lack of 3D striatal structure information.

Both considered methods have demonstrated good correlation for $^{123}$I-FP-CIT SPECT study measurements, as shown in table 2. In fact all the $R$ striata values are high. The lower index value obtained with both methods for the right caudate can be explained by a slightly less accurate filling of this chamber that presents a different and less advantageous morphology with respect to the contralateral, making it difficult to avoid the presence of air bubbles in it.

The BasGANv2 algorithm, however, performed better in determining all considered uptake ratios compared to the manual ROI method evidenced by the higher $R$ index and a better linear trend, as shown in figure 3.

Table 1. True and measured uptake data of phantom studies normalized to the occipital reference ROI.

| Experimental session | Left Caudate True values | BasGAN values | ROI method values | Left Putamen True values | BasGAN values | ROI method values | Right Caudate True values | BasGAN values | ROI method values | Right Putamen True values | BasGAN values | ROI method values |
|----------------------|-------------------------|--------------|------------------|-------------------------|--------------|------------------|--------------------------|--------------|------------------|--------------------------|--------------|------------------|
| 1                    | 2.7                     | 2.7          | 1.4              | 1.0                     | 1.3          | 0.7              | 7.8                      | 4.6          | 2.9              | 5.0                      | 3.6          | 2.4              |
| 2                    | 3.5                     | 2.7          | 1.5              | 3.5                     | 2.3          | 1.5              | 5.0                      | 3.4          | 2.3              | 5.0                      | 3.0          | 2.2              |
| 3                    | 4.7                     | 4.3          | 2.6              | 4.8                     | 4.3          | 3.0              | 8.0                      | 6.3          | 4.2              | 8.0                      | 6.2          | 4.6              |
| 4                    | 5.7                     | 4.8          | 3.1              | 5.7                     | 4.1          | 2.9              | 7.8                      | 5.6          | 3.3              | 7.8                      | 4.9          | 3.0              |
| 5                    | 6.5                     | 6.6          | 4.3              | 6.6                     | 5.7          | 4.1              | 8.0                      | 7.0          | 4.7              | 8.0                      | 6.5          | 4.6              |
| 6                    | 8.0                     | 7.7          | 4.9              | 8.0                     | 7.0          | 4.6              | 8.0                      | 7.3          | 4.4              | 8.0                      | 6.7          | 4.7              |
| 7                    | 8.7                     | 7.0          | 5.0              | 8.7                     | 6.7          | 4.8              | 8.7                      | 6.9          | 4.2              | 8.7                      | 6.0          | 3.9              |
| 8                    | 8.7                     | 6.2          | 3.5              | 4.0                     | 3.5          | 1.6              | 8.7                      | 5.8          | 3.7              | 4.0                      | 3.1          | 1.6              |
| 9                    | 8.7                     | 6.8          | 3.7              | 7.2                     | 5.8          | 3.3              | 8.7                      | 6.7          | 4.3              | 7.2                      | 5.4          | 3.7              |

Table 2. $R$ values obtained in BasGAN ($p < 0.001$, except for right C/B where $p < 0.01$) and manual ROI methods ($p < 0.005$, except for right C/B where $p < 0.05$).

| Method       | Left C/B | Left P/B | Right C/B | Right P/B | Right C/P | Left C/P |
|--------------|----------|----------|-----------|-----------|-----------|----------|
| BasGANv2     | 0.93     | 0.97     | 0.78      | 0.93      | 0.95      | 0.94     |
| Manual ROI   | 0.87     | 0.96     | 0.72      | 0.89      | 0.95      | 0.93     |

4. Conclusions
In this study BasGANv2 performed better than the standard ROI method considered, confirming to be an accurate automatic algorithm for 3D semi-quantification of SPECT uptake. The ROI positioning is based on a template derived from Talairach and Tournoux neuroanatomical atlas being user-independent, and, furthermore, the software includes PVE correction and the possibility to utilise a control subjects database.
Therefore, this new software is suitable for the daily practice, being a simple and accurate method of semiquantitative analysis with the advantage to give reproducible results, simplifying the follow-up of patients and allowing multicenter comparison studies.

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