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Effect of administered radioactive dose level on image quality of brain perfusion imaging with 99mTc-HMPAO

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Abstract

Aim: Brain perfusion imaging by means of ^{99m}Tc-labeled hexamethyl propylene amine oxime (HMPAO) is a well-established Nuclear Medicine diagnostic procedure. The administered dose range recommended by the supplying company and reported in bibliography is rather wide (approximately 9.5-27 mCi). This fact necessitates further quantitative analysis of the technique, so as to minimise patient absorbed dose without compromising the examination diagnostic value. In this study, a quantitative evaluation of the radiopharmaceutical performance for different values of administered dose (10, 15, 20 mCi) was carried out. Subsequently, a generic image quality index was correlated with the administered dose, to produce an overall performance indicator. Through this cost-to-benefit type analysis, the necessity of administration of higher radioactive dose levels in order to perform the specific diagnostic procedure was examined.
Materials & methods: The study was based on a sample of 78 patients (56 administered with 10 mCi, 10 with 15 mCi and 12 with 20 mCi). Some patients were classified as normal, while others presented various forms of pathology. Evaluation of image quality was based on contrast, noise and contrast-to-noise ratio indicators, denoted CI, NI and CNR respectively. Calculation of all indicators was based on wavelet transform. An overall performance indicator (denoted PI), produced by the ratio of CNR by administered dose, was also calculated.
Results: Calculation of skewness parameter revealed the normality of CI, NI and non-normality of CNR, PI populations. Application of appropriate statistical tests (analysis of variance for normal and Kruskal-Wallis test for non-normal populations) showed that there is a statistically significant difference in CI ($p<0.01$), NI ($p<0.001$) and CNR ($p<0.05$), but not for PI ($p>0.05$) values. Application of Tukey test for normal populations CI, NI led to the conclusion that CI(10 mCi) = CI(20 mCi)<CI(15(mCi) and NI(10 mCi)>NI(20 mCi), while NI(15 mCi) can not be characterised. Finally, application of non-parametric multiple comparisons showed that CNR(20 mCi)>CNR(10 mCi), while CNR(15 mCi) can not be characterised.
Conclusion: Brain perfusion imaging by means of ^{99m}Tc- HMPAO utilising an administered dose of 20 mCi results in improved image quality, on the basis of the estimated indicators and for the range of radioactive dose levels examined. Additionally, this image quality improvement is sufficient to justify the increased radiation burden for the patient.

Keywords: brain perfusion imaging, ^{99m}Tc-HMPAO, wavelet transform, quantitative evaluation..

1. Introduction

Modern clinical practice is based on a plethora of diagnostic tools for the accurate diagnostic assessment of various forms of pathology. Nuclear medicine diagnostic examinations, also called scintigraphic examinations, are widely employed, due to their high diagnostic efficacy (Wolbarst [1]). In order to perform these examinations, a radioactive substance is locally concentrated in target organs under consideration. These radioactive substances are called radiopharmaceuticals and are administered either orally or intravenously (Uslu et al [2], Ha Phan et al [3]). After the elapse of a time interval, which is necessary to ensure the localisation of the radiopharmaceutical to the target region and its value is specific for each scintigraphic examination, the imaging procedure begins, by utilising gamma camera systems. Planar as well as tomographic projections are acquired, resulting in highlighting of physiology and possible pathology of the target organs.

2. Aim

Brain perfusion imaging by means of ^{99m}Tc-labeled hexamethyl propylene amine oxime (HMPAO) is a well-established Nuclear Medicine diagnostic procedure (Cavallin et al [4]). It is a method of great clinical importance for the diagnosis of Alzheimer's disease, through the differentiation of small changes in the regional cerebral blood flow (Ansar et al [5], Koulibaly et al [6]). The administered dose range recommended by the supplying company and reported in bibliography is rather wide (approximately 9.5-27 mCi). This fact necessitates further quantitative analysis of the technique, so as to minimise patient absorbed dose without compromising the examination diagnostic value. In this

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study, a quantitative evaluation of the radiopharmaceutical performance for different values of administered dose (10, 15, 20 mCi) was carried out, via application of image analysis techniques (Stefanoyiannis et al [7], Stefanoyiannis et al [8]). Typical examples of brain perfusion imaging by means of ^{99m}Tc-HMPAO and administered dose levels of 10, 15 and 20 mCi are presented in figures 1-3 respectively. Subsequently, a generic image quality index was correlated with the administered dose, to produce an overall performance indicator. Through this cost-to-benefit type analysis, the necessity of administration of higher radioactive dose levels in order to perform the specific diagnostic procedure was examined.

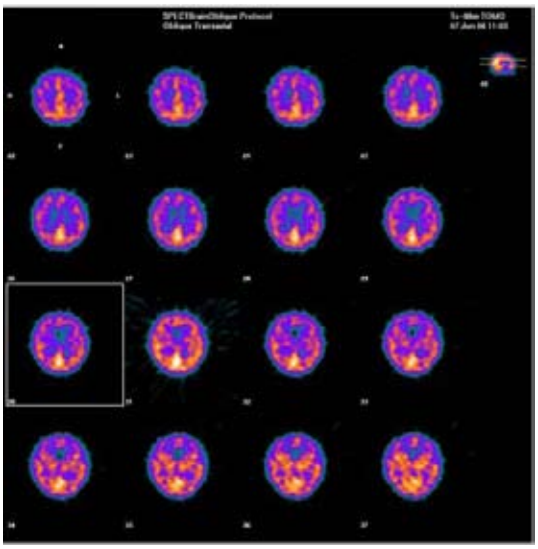

Fig 1. Brain perfusion imaging. Radiopharmaceutical: ^{99m}Tc-HMPAO, administered dose level: 10 mCi.

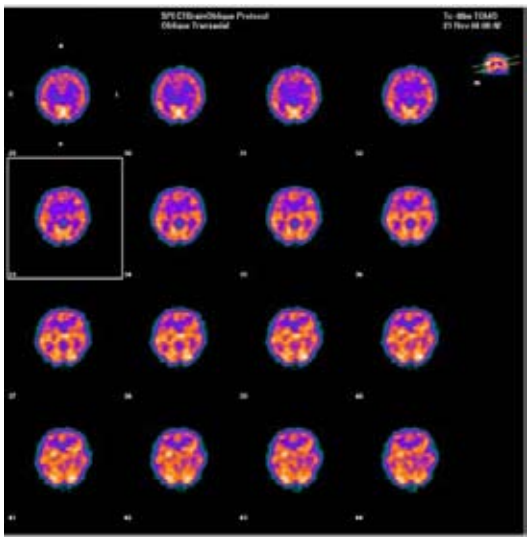

Fig 2. Brain perfusion imaging. Radiopharmaceutical: ^{99m}Tc-HMPAO, administered dose level: 15 mCi.

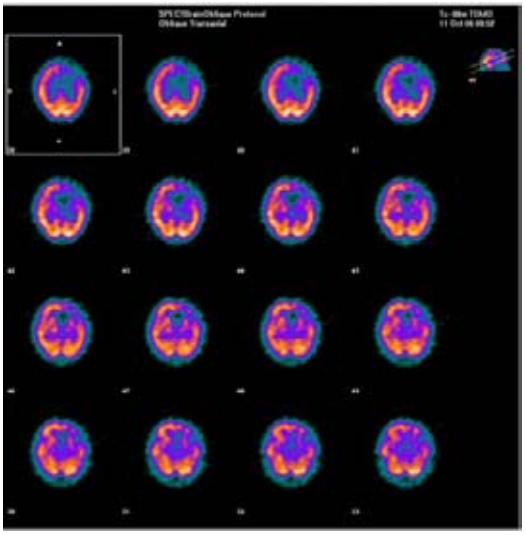

Fig 3. Brain perfusion imaging. Radiopharmaceutical: ^{99m}Tc-HMPAO, administered dose level: 20 mCi.

3. Materials & methods

A sample of 78 patients (classified as normal or presenting various forms of pathology) was utilised. The administered dose was 10 mCi for 56 patients, 15 mCi for 10 patients and 20 mCi for 12 patients. Evaluation of image quality was based on contrast, noise and contrast-to-noise ratio indicators, denoted CI, NI and CNR respectively. Calculation of all indicators was based on wavelet transform (Laine et al [9], Mallat and Hwang [10], Zong and Laine [11]). An overall performance indicator (denoted PI), produced by the ratio of CNR by administered dose, was also calculated.

In order to derive the contrast indicator, the non-subsampled biorthogonal discrete wavelet transform (NB DWT) has been used. The magnitudes of wavelet coefficients in the 2nd scale, corresponding to a certain ROI sampling the brain region, are used for contrast estimation. Specifically, the wavelet coefficient magnitudes are averaged to determine the contrast indicator (Costaridou et al [12]).

The NB DWT has also been exploited for noise indicator estimation. Particularly, the 1st scale of the NB DWT has been utilised, as it is the scale mostly contaminated by noise. Noise indicator in brain region is estimated as the mean power of the magnitude wavelet coefficients, ranging from zero up to a threshold, called reference noise power. The reference noise power is estimated as the mean power of the 1st scale magnitude wavelet coefficients in the signal-free background of the image (Stefanoyiannis et al [13]).

4. Results

Figure 4 shows the results of the estimation of image quality indicators CI, NI and CNR and the overall performance indicator PI for the subsamples of 10, 15 and 20 mCi..

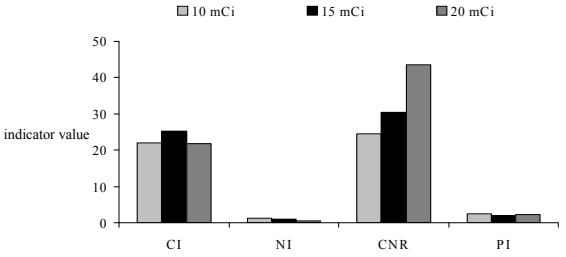

Fig 4. Results of indicators' estimation.

The results of quantitative evaluation are presented in table 1, where the % differences of estimated indicators for 15 mCi and 20 mCi subsamples versus the control subsample of 10 mCi are reported.

Table 1.
Results of quantitative evaluation

	CI	NI	CNR	PI
% diff. (15 mCi vs. 10 mCi)	14.58	-25.13	24.41	-17.06
% diff. (20 mCi vs. 10 mCi)	-1.18	-52.09	78.01	-11.00

In Table 2, the results of further statistical analysis are presented.

Table 2.
Statistical analysis

PARAMETER	POPULATION	STATISTICAL TEST	RESULT
CI	normal	ANOVA	SS ($p<0.01$)
NI	normal	ANOVA	SS ($p<0.001$)
CNR	non-Gaussian	Kruskal-Wallis	SS ($p<0.05$)
PI	non-Gaussian	Kruskal-Wallis	SNS ($p>0.05$)

Abbreviations: CI: contrast indicator, NI: noise indicator, CNR : contrast-to-noise ratio, PI : performance indicator, ANOVA : analysis of variance, SS : statistically significant, SNS : statistically non-significant.

Calculation of skewness parameter revealed the normality of CI, NI and non-normality of CNR, PI populations. Application of appropriate statistical tests (analysis of variance for normal and Kruskal-Wallis test for non-normal populations) showed that there is a statistically significant difference in CI ($p<0.01$), NI ($p<0.001$) and CNR ($p<0.05$), but not for PI ($p>0.05$) values. Application of Tukey test for normal populations CI, NI led to the conclusion that CI(10 mCi) = CI(20 mCi)<CI(15(mCi) and NI(10 mCi)>NI(20 mCi), while NI(15 mCi) can not be characterised. Finally, application of non-parametric multiple comparisons showed that CNR(20 mCi)>CNR(10 mCi), while CNR(15 mCi) can not be characterised.

5. Conclusions

Brain perfusion imaging by means of ^{99m}Tc-HMPAO is a well-established Nuclear Medicine diagnostic procedure for the detection of Alzheimer's disease. Recent studies performing patient-by-patient comparison between this technique and DSC-MRI (a technique based on nuclear magnetic resonance) proved the superiority of the former in the diagnosis of Alzheimer's disease, as well as the other forms of dementia (Cavallin et al [4], Kubota et al [14]). Therefore, optimisation of the administered dose to carry out the specific examination is rather crucial. According to the results of the present study, brain perfusion imaging by means of ^{99m}Tc- HMPAO utilising an administered dose of 20 mCi results in improved image quality, on the basis of the estimated indicators (for the range of administered dose values examined). Additionally, this image quality improvement is sufficient to justify the increased patient absorbed dose. As an open issue, the future study of image quality for higher values of administered dose is mentioned, always in the framework of internationally acceptable clinical practice.

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