cardiac death. Two noninvasive imaging techniques, echocardiography (2D and 3D) and gated myocardial perfusion SPECT are accepted methods to estimate left ventricular end-diastolic and end-systolic volumes, therefore left ventricular function, which correlates with the prognosis and left ventricular remodeling. Functional measurement and biomarker (which supposed to be harmful for the myocardium resulting myocardial damage and remodeling) tests have not been simultaneously correlated with the degree of cardiac remodeling (in human).
The main aim for the study is to find a correlation between serum biomarker levels and left ventricular remodeling assessed by noninvasive cardiologic methods, such as 2D-, 3D-echocardiography and gated myocardial perfusion SPECT.
Material and methods: 30 patients with acute ST-segment elevation MI are planed to be enrolled in the project based on inclusion [patient with ST-segment elevation MI for the first time; total proximal coronary occlusion verified by coronary angiography (more than 5–7/17 segments involved); adequate patient compliance] and exclusion criteria [diabetes mellitus; former myocardial infarction (based on patient history); inadequate patient compliance]. Blood samples are collected within 24 hours after primer PCI, 5 days and 6 months later for specific biochemical analysis. In the subacute phase (5–7th day) Technecium-99m SestaMIBI rest gated myocardial perfusion SPECT is performed using standard protocol to measure the different left ventricular parameters such as ejection fraction and left ventricular diameters. Similarly, in the chronic phase (6th month) stress/rest perfusion scan is repeated. Simultaneously with the SPECT, 3D-echocardiography is assessed in the subacute and chronic phase and the same left ventricular parameters are determined.
Preliminary results: Until this time 10 patient's data have been collected. Left ventricular parameters such as left ventricular end-systolic and end-diastolic diameters have shown systematical changes after 6 month. Most of the patients have improvement in ejection fraction and left ventricular diameters as well. Despite the similar medical conditions and the same treatment 3 patients shows reduction in the left ventricular function and increase in diameter. Testing the correlation between the two noninvasive methods there were no significant differences in the measurements of values. Determinations of blood biomarker levels are in progress.
Conclusion: Despite the fact that patients in our study had similar medical condition and the same treatment, different changes have developed in the left ventricular parameters after myocardial infarction. These facts suggest the role of biomarkers in the development of left ventricular remodeling.

037

SURFACES, ATLASES, AND OTHER ADVANCED IMAGING TECHNIQUES IN THE SERVICE OF NUCLEAR MEDICINE

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Background: Novel imaging techniques like structural and functional MRI, DTI fiber tracking, low resolution EEG tomography etc. require more and more complex processing methods and visualization techniques. Under the scope of the Central Nervous Imaging project (CSI, www.eniac-csi.com) of the ENIAC consortium, the multimodal workgroup of the Department of Nuclear Medicine, Debrecen, performed intensive developments regarding such state-of-the-art multimodal medical imaging methods. Our purpose was to investigate possible applications of these methods in the case of PET/CT based virtual bronchoscopy, computer aided diagnosis of irritated bowel syndrome (IBS), decision support system for the classification of pulmonary accumulations, and brain atlas based statistical analysis of FDG and metionin PET examinations.
Material and methods: Institutional developments related to the CSI project have been performed in the framework of the MultiModal Medical Imaging (M3i, www.minipetct.hu/m3i) software library system, and extended by 3rd party software tools, involving techniques like manual and automatic image segmentation, 3D mesh reconstruction, multiparametric surface visualization, VOI and mash based parcellation and statistical analysis, co-registration, spatial standardization and digital brain atlas techniques.
Our region growing algorithm was adapted for low-dose CT-based bronchus, lung and colon segmentation. 3D meshes were reconstructed and parametrized to perform an effective visualization of PET data on the surface of the organs. Our adaptive region growing algorithm was also extended to obtain the skeleton of bronchus and bowel models, thus allowing interactive navigation in the 3D virtual space, and provide the opportunity to perform statistical analysis based on VOIs following the trajectory of the bowel.
Marker based semi-automatic and automatic segmentation algorithms were developed for segmenting other objects, like FDG-PET accumulations in the human lung. An image co-registration pipeline dedicated for the spatial standardization of PET brain images was developed, which, with the aid of our multi-atlas database and atlas framework, allows digital brain atlas based quantitative statistical analysis.
Results: As a result, Virtuous, (www.minipetct.com/virtuous) a user-friendly software application for PET/CT based virtual bronchoscopy was developed. Software components developed for computer-aided diagnosis of IBS and decision support system for the classification of FDG-PET accumulations were implemented as plug-ins for our multimodal medical image analysis program called BrainMOD (www.minipetct.com/brainmod). Atlas space PET analysis toolkit was integrated into our brain atlas assisted image analysis software called BrainLOC (www.minipetct.com/brainloc).
Conclusion: The investigated advanced medical imaging techniques originally developed for other modalities can be effectively adapted to CT and PET data; however, more efforts are required to improve the applicability of these methods in nuclear medicine projects.

038

DETERMINATION OF THE CONTRAST RECOVERY OF SMALL ANIMAL PET SCANNERS

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Background: The NEMA-NU4 standard is a practical tool to analyze and compare the different scanners. The standard provides an image quality phantom (NU4IQ) to determine some "basic" image capability parameter of the system [Uniformity, Spill-over ratio, activity recovery coefficient (ARC)]. The ARC parameters are determined using the five-rods region of the phantom, which are located in zero background. In the case of small animal PET scanners it also would be advantageous to measure the contrast recovery coefficient (CRC) parameters, utilizing a similar type of measurement that is defined for the human PET systems. The CRC parameters are to be measured with a phantom witch have six fillable spheres embedded in a large background chamber. The first goal of this study was to determine the CRC parameters of some small animal PET scanners using a Micro Hollow Sphere (MHS) phantom. Furthermore, we tried to work out a measurement protocol to

generate images including the activity filled rods in background activity using NU4IQ phantom.

Material and methods: The determination of CRC was measured on the MiniPET-II and a Siemens Inveon PET scanner utilizing the MHS. This phantom contain four fillable spheres with different radius (1.95 mm, 2.47 mm, 3.1 mm and 3.9 mm) embedded in a cylindrical chamber (diameter: 40 mm, height: 82 mm). The measurements were performed at three different object contrast (OC) ratio (2, 4 and 8). The determination of CRC was performed using the BrainMOD software.

The NU4IQ is inappropriate for the determination of CRC. However, we defined a "t" length list-mode acquisition using the filled NU4IQ, setting two phantom positions. During the first phantom position scan the uniform region of NU4IQ is centered in the FOV and scanned for "t0", after the rods contained phantom region is moved to the scanner center with "tr" scan time (t0 + tr = t). Thus, this acquisition method "manually" sums up the uniform and the rod parts of the NU4IQ phantom. After the measurement the CRC can be easily calculated in same way as in the human image quality calculation. This measurement was performed on MiniPET-II, Siemens Inveon, GE Explore Vista and Genesis4 small animal PET systems.

Results: We found that the contrast recovery depends on the OC and the size of the spheres. Increasing the size of the spheres the CRC improves. In the case of MiniPET-II the minimum and maximum value of CRC (at OC = 8) are 0.3 and 0.6, respectively. These parameters at Siemens Inveon were 0.34 and 0.65, respectively. The CRC parameters were determined width the NU4IQ and the following sequence was found between the scanners: Siemens Inveon, GE Explore Vista, MiniPET-II and Genesis4.

Conclusion: It can be concluded that the MHS phantom is a practical tool to determine the CRC parameters of small animal PET systems. Furthermore, we found that our special measurement protocol with the NU4IQ is a useful method for CRC determination.

039

AUTOMATED REFERENCE REGION DELINEATION FOR QUANTITATIVE FDG-PET RAT BRAIN STUDIES

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Background: The possibility of the quantitative small animal PET study applications is restricted by the arterial blood-sampling since special tools, reproducible measuring protocol and validated software are needed. In the absence of these means, methods based on reference region can be applied, which require more complex data processing and the uncertainty of reference region delineation can influence the calculations. Dynamic rat brain 18F-FDG studies were carried out by the MiniPET-II PET scanner for quantitative analysis in our department. The "whiskers" areas were used as reference regions.

Our goal was to develop a model-independent automated VOI delineating algorithm, which allows to select reference areas based on dynamic image series.

Material and methods: From six rat 18F-FDG studies 60 × 1 min dynamic images and two integrated static images (first 10 and last 20 minutes) were used for the development of automated VOI delineation. The left and right reference region and 3 cerebral regions (left and right hemisphere and cerebellum) were delineated on static images by 3 mm diameter spherical VOIs.

We constructed a model curve from the average of the 12 tissue curves belonging to the reference regions for generating wavelet-correlation maps from the dynamic images. Cluster analysis was used to emphasize the highly correlated connected areas on the frontal part of the skull from the correlation map.

Since the identification of the objects in PET images is difficult, the goodness of the automated method was characterized by the changing of noise characteristics, and the trends of the curves in the reference regions. The noise was characterized by the sum of squared differences between the curve and trend curve, the latter was calculated by the wavelet-based multi resolution analysis. The changing in trend curve was defined by the ratio of the average from the first 5 minutes and the average from the last 30 minutes.

Results and conclusion: The automatically delineated reference regions were close to the manually selected regions in each case, as checked by image fusion technique. The noise characteristics of the tissue curves in these regions were better in 5 cases compared to manually selected curves, the relative error was 0.85, the deviation 0.19, and was worse only in one case. There were no relevant differences in the changing of trend curves (average: 1.04). The results prove that the automated method can produce similar curves with better noise characteristics compared to manually delineated curves. One of the possible directions of the development is the combination of the introduced curve characteristics and region growing technique, which can be used in effective "blood curve"-like voxel-set delineation. Additional result is the delineation of the presumably arterial areas, which were basically different from the original reference regions. The application of these areas in kinetic modeling must be investigated in the future.

040

NOISE ANALYSIS OF WHOLE BODY FDG PET IMAGES

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Background: Instead of using continous bed motion during CT examinations, Whole Body PET scans are typically acquired in discrete axial positions. For each bed position the length of the acquisition time conventionally remains the same, however the total acquisition of the scan is usually adjusted to the patients weight or Body-mass-index. Because of the varying amount of attenuation in different sections of the body and the heterogenous activity distributions it is expected that the signal-to-noise values will vary accordingly in each bed position. However, for medical reports it would be more convenient to have relatively constant signal-to-noise through the axial slices, therefore, it would be important to know how could the clinical PET images be described with only one signal-to-noise parameter. The main challange is to estimate the noise (pixel variance), since for this purpose a PET scan should be repeated several times and that is hardly possible to carry out in the clinical routine.

Material and methods: To resolve the problem, we defined a new algorithm that assigns a Standard Deviation/Mean value to every voxel of the reconstructed PET image. These values were obtained from the list mode file of three-minute whole body PET acquisitions, while 12 × 15 second, 6 × 30 second and 3 × 60 second segments of the list mode file were reconstructed into identical image series. This resulted in three separate possible estimation of the image noise. From the identical image series we computed pixel-wise the Mean and Standard Deviation values, resulting in a Mean and a Standard Deviation image volume. As a pixel-by-pixel ratio of these two a Standard Deviation/Mean (SD/Mean) image was created and for each slice a mean value was calculated (as the Noise Parameter) from the pixels inside the body contour.

From the 60 second images 4 subreconstructions were performed with shorter times (10, 12, 15, 20 seconds) from which estimated 60 second noise image was created pixel-by-pixel via linear regression.
Results: The average of the SD/Mean image pixels varied between 0.1–0.25, moreover, it was visible on the PET image volume that this parameters correlates with the more noisy sections. The SD/Mean values calculated from the three series reconstructed with different times were consistently decresing with the acquisition time, and this tendency was correlating with the estimation from Poisson statistics. We examined the correlation of the Attenuation Correction Factors and the SD/Mean parameters for 12 patients, and the results slightly but clearly differed from those experienced via former phantom measurements. The image noise measured from the three 60 seconds image sets proposes correlation with the estimated noise image created via linear regression from the sub60 second image noise series. Therefore, the estimation of image noise from subrecostructions could be a possible method to resolve the problem.
Conclusions: This new method could be easily used for the determination of pixel noise for PET scans, therefore, we propose to use it for the optimization of PET acquisition protocols.

041

ACCREDITATION QUALITY CONTROL PERFORMANCES OF DIFFERENT PET SCANNERS

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Background: It is a critical point to assure similar image qualities for PET scanners in multicenter diagnostical studies including several PET-CT centers. For this purpose, the multicenter studies usually define the minimal criteria in terms of image quality for the PET-CT systems that can be included in the study. In the last few years accreditation protocols of two major international associations are also available. However, these two associations, the European Association of Nuclear Medicine (EANM) and the American College of Radiology (ACR) propose to use different phantom scans and image capability criteria for the PET scanners. The ACR recommends a specially designed ACR phantom, and the specific parameters for the quantitative measurement are the SUV Mean, SUV maximum and standard deviation for the region of interests. The EANM accreditation uses the NEMA 2007 IQ phantom, and the protocol includes the calculation of the Activity Recovery Coefficients (ARC) obtained from the intensities in the six spheres of the phantom. Both of the two accreditations limits for the calculated parameters and delivers the PET scanner acceptable or not. The aim of this work was to investigate different PET scanners from several vendors, and their acceptance by the two accreditation protocols mentioned above.
Material and methods: Our investigation included the following PET-CT scanners: Siemens TruePoint HD (Budapest), Siemens Biograph 16 (Nagyvárad), Philips Gemini 64 TF (Debrecen) and Siemens mCT (Doha/Qatar). The EANM protocol was performed on all of the four scanners and the ACR protocol was performed on the Philips Gemini and the Siemens mCT scanners. The EANM PET accreditation protocol gives minimum and maximum criteria for the Activity Recovery Coefficients, while the ACR protocol gives them to the calculated SUV max values. These parameters have been investigated by the "eanm_qc_tools_v15082011" program and with algorithms implemented in Matlab. It has been also investigated in this work, how the different acquisition and reconstruction parameters affect the calculated values of interest mentioned above.
Results: Only the Siemens Biograph 16 system fulfils the EANM PET accreditation requirement using the default clinical acquisition and reconstruction protocol. The other three PET cameras "overfulfil", that is, most of ARC values were higher than the prescribed maximums. In the case of the Siemens TruePoint HD and Philips 64 TF systems the ARC values shifted into the required interval if we changed the reconstruction or acquisition settings from the clinical defaults. For example at the Siemens system we had to turn off the point spread function modelling (TrueX) option during the reconstruction and to apply a Gaussian postfilter (with 4 mm window) on the images. Nevertheless, these modifications could be large impact on the resulted image quality. The all ARC data of the mCT PET camera were definitely higher that the required maximal values independently on the acquisition and reconstruction settings. Considering the ACR phantom measurement, the calculated SUV maximum values were in the required range for the Philips 64 TF camera but could not be fulfilled the ACR accreditation criteria in the case of the mCT system beside any reconstruction and/or acquisition settings.
Conclusions: Though the EANM or ACR accreditation based phantom measurements can be carry out with easily and clearly, the predefined criterions and the related ARC and SUV parameter intervals can be only satisfied if the users impair the default reconstruction and/or acquisition protocol settings used in the clinical routine. The latest (the state of the art) system was the Siemens mCT scanner in this study, nevertheless the results obtained with this camera could not fulfil at all the requirements of the accreditations.

042

OPTIMAL PARAMETER SETTINGS OF 3D PARALLEL PROJECTION BASED SPECT RECONSTRUCTION PROCEDURE FOR CLINICAL APPLICATIONS

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Background: Parallel projection based Single Photon Emission Computer Tomography (SPECT) imaging is the most widely used procedure till nowadays, having several limitations in image quality. The following components have important rules in image quality such as: the contradiction between the resolution and sensitivity, the non-linear distant dependent spatial resolution (DDSR) and most of the case the non-uniform attenuation media around the imaged objects. Essentially, we have worked out multi-modality (SPECT/CT) based 3D iterative (MLEM method) reconstruction procedure for parallel projection based human and small animal imaging. Main goal of our current research/developing work is to find out those parameterization ways (including acquisition parameterization too) for the clinical/biological applications and various imaging systems (general purpose and/or dedicated systems) where the acquisition time/processing time/obtained image quality jointly will be significantly better than the traditional 2D method depending on the clinical conditions.
Material and methods: DDSR describing by point spread function (PSF) has determinant effect on the model of parallel projection. PSF is determined by a dedicated calibration procedure. It is necessary to acquire point spread functions at predefined distances from the detector surfaces for all the collimators and isotopes combinations to be used in the imagings. Then will be derived the inherent forward projection operator describing the distant dependent compensation

by 3 parameters modeling. The non-uniform photon attenuation map is determined by co-registered and resampled CT imaging. Signal/noise ratio of SPECT studies are determined by count rate of the projections (acquisition time) and the sufficient overlapping of the imaged object (angular sampling rate), which has significant influence to the number of iteration convergence. The following parameters have effect on image quality to be obtained by the 3D iterative reconstruction way:

1. Pre-filtering of the 2D projection data (parameterization of 2D pre-filtering)
2. Parameter setting for sub-set
3. Determination of the number of iteration (based on convergence curve)
4. Stabilization of the convergence by regularization [Total Variation Norm (TV norm)]

Effect of a particular parameter set to the reconstruction is tested by physical/anatomical (Jaszczak phantom, Hoffman phantom...) phantom measurements, where the evaluation is carried out by multi-modality, semi-quantitative and qualitative way. The results obtained from both humans and small animals were always compared with the traditional 2D reconstruction methods in order to exclude the accidental artifacts.

Results and conclusions: Currently brain, bone, heart and liver SPECT/CT cases are parameterized for the possible daily clinical applications mainly for 128^3 volume discretization (voxel size range is 2.3 mm–4 mm). The reconstruction time under the current GPU technology is 5–7 min. with sub-set = 8, number of iteration = 20 parameters. In case of small animal acqusition 256 × 256 × 64 volume discretization (1 mm voxel size) had been applied and the reconstruction time became 40 min. We may make the following conclusion from the parameterization method regarding to the individual biological objects, that the parameter settings for the 3D recontsruction is suitable to optimise either by organs or by acqusition methods. We continue our optimal parametrization work systhematically for other organs and acqusition methods.

043

RELEVANCE OF TUMOR HETEROGENEITY IN HUMAN PET EXAMINATIONS HETEROGENIC PHANTOM AS MODEL TUMOR

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PET technique has bigger and bigger part in the shadowing of oncologic therapy, which mainly characterizes the accumulation of radiopharmacon of each tumor with a SUV mean and SUV maximum value. The numbers of articles in scientific journals which also deal with tumor heterogeneity are highly increased in the past years. There are several index-numbers for inhomogeneity of accumulation of radiopharmacon (heterogeneity, entropy, correlation, contrast, size and intensity-variance). The central question of the articles is whether the measureable inhomogeneity parameters do have predictive value or not. Principally these are statistical examinations, which correlate tumor heterogeneity parameters to answers of patients to the treatment. However, it is still unclear, what kind of real tissue inhomogeneity exists in each tumor and what do these calculated data and correlation reflect. The usage and trustworthiness of applied various heterogeneity parameters could be tested on inhomogeneity phantoms, but this construction is not found in the literature yet. Presumably, it is not randomly, because it seems to be difficult to construct a phantom contains inhomogeneous activity distribution constantly in time, furthermore which is easily constructed and adaptable at any examination place. In this study we aimed to construct and test our heterogeneous phantom.

The expectation in connection with any phantom to be possible to make reproducible measurement, and the place-activity relationship has to be known inside of it. It is so complicate in the case of the heterogeneous phantom, because the size scale of the heterogeneity has to comparable or must be smaller than the spatial resolution of human camera (~4 mm). After trying several geometries, we prepared a phantom which is able to model heterogeneous tumor. It consists of a syringe and a silicone tube system rolled around of it, means more layers which can be filled separately.

The referred and above mentioned heterogeneity parameters were tested by different known contrast values. Phantom filled with F18 activity mixed with diluted CT contrast material, thus CT image identified (mask) the inhomogeneous areas, independently the worse spatial resolution of PET images. It allows the determination of activity recovery coefficient (RC) to each of the partial region as well, with which each camera can be characterized. In the case of a tumor, the RC is strongly distorted by partial volume or spillover effect.

044

INVESTIGATION OF APICAL LESION IN PARALLEL MYOCARDIAL PERFUSION SPECT IMAGING

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Background: One of the largest application fields of the Single Photon Emission Computed Tomography (SPECT) technology is the parallel imaging based myocardial perfusion scintigraphy. Any image improvements resulting from the evaluation of the distortions and noise phenomena have significant effect in the diagnostic value of this field. Several distortion effects had been compensated by inherent way — non-uniform photon abortion and non-liner distant dependent spatial resolution (DDSR) effects of the imaging — by our developed novel 3D iterative reconstruction method. But, equivocal hypo-perfusion segment had been detected around the apical region of the myocardium systematically both on mathematical, physical phantoms and human studies. We concluded during discovering of the problem the Partial Volume Effect (PVE) phenomenon may result the distortion. Aim of the current research is to discover the impact of the 3D parallel projection based reconstruction parameters exclusively on the apical lesion effect.

Material and methods: A mathematical phantom similar to the myocardium structure (bullet phantom) as well as the NCAT phantom that is a real mathematical representation of the human thorax was used in the investigation. Projection images were generated by the forward projection operator of our MLEM based reconstruction algorithm with attenuation correction and compensation for the DDSR effect. The apical lesion phenomenon has been tested by the function of various spatial resolutions and imaging blurring. Two different discretization of the volume have been applied: 256^3 discretization by voxel sizes of 2 mm and 128^3 discretization by voxel sizes of 4 mm. The extent of the detector blurring effect was set according to the Mediso Ltd. AnyScan SC (multi-modality SPECT/CT) system with LEHR collimator. The apical lesion effect has been tested in the function of detector blurring extent.

Results and conclusion: The degree of apical lesion has been decreased if 256^3 volume with voxel sizes of 2 mm were applied instead of the 128^3 volume with voxel sizes of 4 mm. Finer volume discretization caused reduced Partial Volume Effect. Smaller extent of detector blurring (smaller blurring means better resolution imaging application) resulted less apical lesion, as well. Further investigations are planned to analyze the influences of the distortion effects of gamma photon Compton scattering, more intensively around the apical segment of the myocardium.