World Academy of Science, Engineering and Technology
International Journal of Health and Medical Engineering
Vol:12, No:3, 2018

Procedure to Use Quantitative Bone-Specific SPECT/CT in North Karelia Central Hospital

L. Korpinen, P. Taskinen, P. Rautio

Abstract**—**This study aimed to describe procedures that we developed to use in the quantitative, bone-specific SPECT/CT at our hospital. Our procedures included the following questions for choosing imaging protocols, which were based on a clinical doctor's referral: (1) Is she/he a cancer patient or not? (2) Are there any indications of inflammatory rheumatoid arthritis? We performed about 1,106 skeletal scintigraphies over two years. About 394 patients were studied with quantitative bone-specific single-photon emission computed tomography/computerized tomography (SPECT/CT) (i.e., about 36% of all bone scintigraphies). Approximately 64% of the patients were studied using the conventional Anterior-Posterior/Posterior-Anterior imaging. Our procedure has improved efficiency and decreased cycle times.

Keywords**—**Skeletal scintigraphy, SPECT/CT, imaging.

I. Introduction

SKELETAL scintigraphy is one of the most frequent imaging methods in the field of nuclear medicine. With skeletal scintigraphy, it is possible to visualize bone metabolism, and it exhibits a fairly high sensitivity to detect skeletal lesions [1]. However, skeletal scintigraphy has limitations in terms of specificity and spatial resolution. Thus, quantitative bone-specific (BS) SPECT/CT was developed. In combining SPECT and CT, it is possible to overcome the limitations of skeletal scintigraphy [1]. In BS SPECT/CT, the bone-specificity is based on the classification of the tissues using low-dose CT.

According to Tuncel et al., it is possible to use the quantitative SPECT/CT in a differential diagnosis of bone metastasis from degenerative skeletal changes by skeletal SPECT/CT. Localized skeletal deterioration, and/or sclerotic changes suggest bone metastases, while sclerotic changes or skeletal deformation suggest skeletal degeneration or inflammatory diseases [2].

The European Association of Nuclear Medicine (EANM) published the practice guidelines for bone scintigraphy in 2016. The aim of the guideline is to provide an educational tool to support practitioners in appropriately recommending, performing, interpreting, and reporting the results of bone scintigraphy [3].

Through image analysis and quantification, it is possible to use a standardized uptake value (SUV), which is based on body weight (BW). It is calculated according to the equation given below; relative weight in voxels of interest (VOI) was assumed to be 1 g per 1 cm^3.

L Korpinen, P Taskinen, and P Rautio are with Clinical Physiology and Neurophysiology Unit, The North Karelia Central Hospital, Joensuu, Finland; (e-mail: leenakorpinen@gmail.com).

Kuji et al. [4] studied the topic of skeletal SUVs obtained by quantitative SPECT/CT as an osteoblastic biomarker for the discrimination of active bone metastasis in prostate cancer. They studied 170 patients with prostate cancer. They imaged the patients who underwent skeletal quantitative SPECT/CT using ^{99m}Tc-methylene-diphosphonate (MDP), through conjugate gradient reconstruction with tissue zoning, attenuation, and scatter corrections applied. They concluded that the skeletal SUVs were greater than that of the degenerative changes in patients with prostate cancer with adequate discrimination accuracy, and SUVs in quantitative SPECT/CT might be useful for the prognostication of bone osteoblastic metastatic burden in patients with prostate cancer [4].

According the Finnish Radiation and Nuclear Safety Authority (STUK) approximately 50,000 isotopic studies are performed annually in Finland. Table I shows examples of the types of isotopic studies in Finland in 2012. Most of them focused on the skeletal system. However, the lungs, kidneys, vascular system, cardiovascular system, and thyroid gland can also be studied with nuclear medicine methods [5].

TABLE I
EXAMPLES OF THE ISOTOPIC STUDIES IN FINLAND IN 2012

Isotopic study	Amount
Skeletal scintigraphy	8884
Lung scintigraphy	1821
Renal scintigraphy	1843
Gamma imaging of cardiac pump function (at equilibrium)	1016
Gamma imaging of infection site	604
Sentinel node lymphoscintigraphy	4188
Myocardial perfusion SPECT	2736
Dopamine transporter SPECT imaging	1245
Gamma imaging of thyroid metastases (after ablation)	458
Whole-body positron tomography –computed tomography (PET-CT) (F-18-FDG)	2156
The upper body PET-CT (F-18-FDG)	1322

According to STUK, one isotopic study causes about an average exposure of 4.2 mSv to the patient [5].

North Karelia Central Hospital (PKKS) offers specialized medical care and services for the inhabitants of its 14-member municipalities. Annually, about 70,000 people use these services out of about 169,000 residents.

The purpose of this work is to describe procedures that we developed to the BS SPECT/CT at PKKS Hospital.

II. Materials and Methods

Since February 2016, we have been utilizing the BS SPECT/CT and have developed related methods and protocols, with the related procedures presented here.

When selecting a scan protocol, the first step is to evaluate whether if one has an oncological patient or one not based on a clinical doctor's referral. If it is an oncologic case, we do a BS SPECT/CT imaging of the whole body and, if necessary, we also do other imaging. From possible metastases, we analyze SUV/LBM (lean body mass) values. If the referral is non-oncological, the second step is to assess whether there is a reference to inflammatory rheumatoid arthritis in the case notes. If present, we conduct conventional planar whole-body imaging in the Anterior-Posterior (AP) projection and in the Posterior-Anterior (PA) projection. Moreover, we collect additional planar images of the ankles, hands, and SI joints. Then, during the imaging phase, the physician will evaluate the images obtained from the camera. If he or she finds any evidence of malignancy or if it is unclear, either the BS SPECT/CT or SPECT imaging is made. If there is no reference to the inflammatory rheumatoid disease in step two, the physician proceeds to whole-body AP/PA imaging. Images are retaken if they are ambiguous.

Fig. 1 shows our skeletal scintigraphy procedure. The used radiopharmaceutical was ^{99m}Tc-HDP (hydroxyethylene diphosphonate). The administered activity was 10 MBq/kg, minimum-maximum activity administered was on range 400 MBq – 1000 MBq. Adult effective dose was appr. 5.7 mSv for HDP and 3-4 mSv for CT. Our SPECT/CT camera is Siemens Symbia Intevo®. We did reconstructions with Siemens xSPECT Bone -technology. We calculated SUV/LBM values with Hermes Hybrid viewer™.

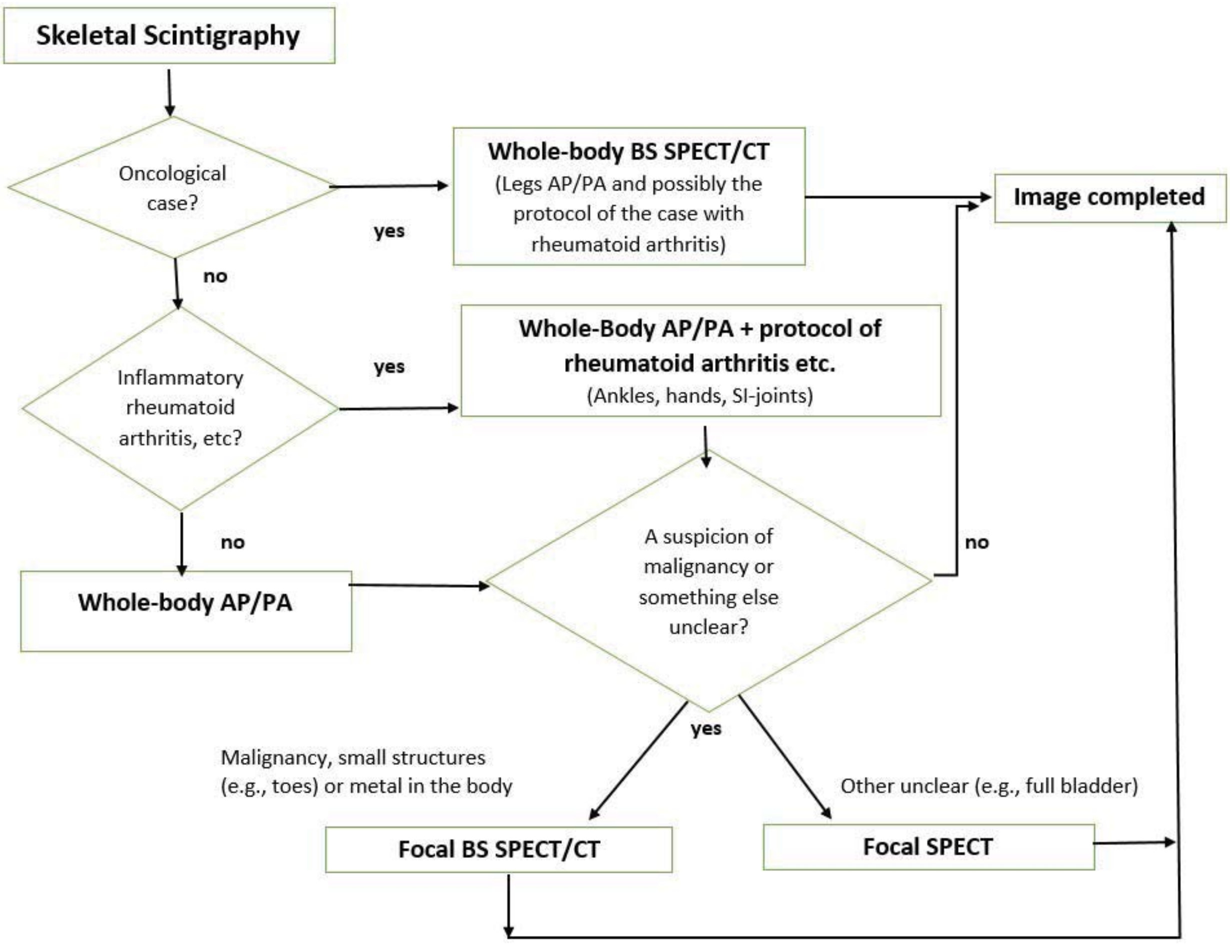

Fig. 1 Developed procedure of skeletal scintigraphy

III. Examples of Patients' Images of SPECT/CT

According to the above-described procedure (Fig. 1), we have performed about 1,106 skeletal scintigraphies over two years. We have imaged 394 patients with BS SPECT/CT (i.e., about 36% of all bone metastases). Approximately 64% of the patients have been imagined with the conventional AP/PA imaging.

A. Case 1—Breast Cancer Patient

Breast cancer was diagnosed 5 years ago and treated (no metastases). For over a year, the patient had low back pain. In the early part of the year while undergoing private magnetic imaging, possible sacroiliitis was suspected. Skeletal scintigraphy was performed with traditional AP/PA (in May 2016) with suspected metastases (Fig. 2.). In the summer, a new magnetic resonance imaging revealed again possible sacroliitis, but malignancy was also possible. Mid-September (2016): abdominal whole-body AP/PA images (Fig. 3) and Figs. 4-7 show images with SPECT/CT.

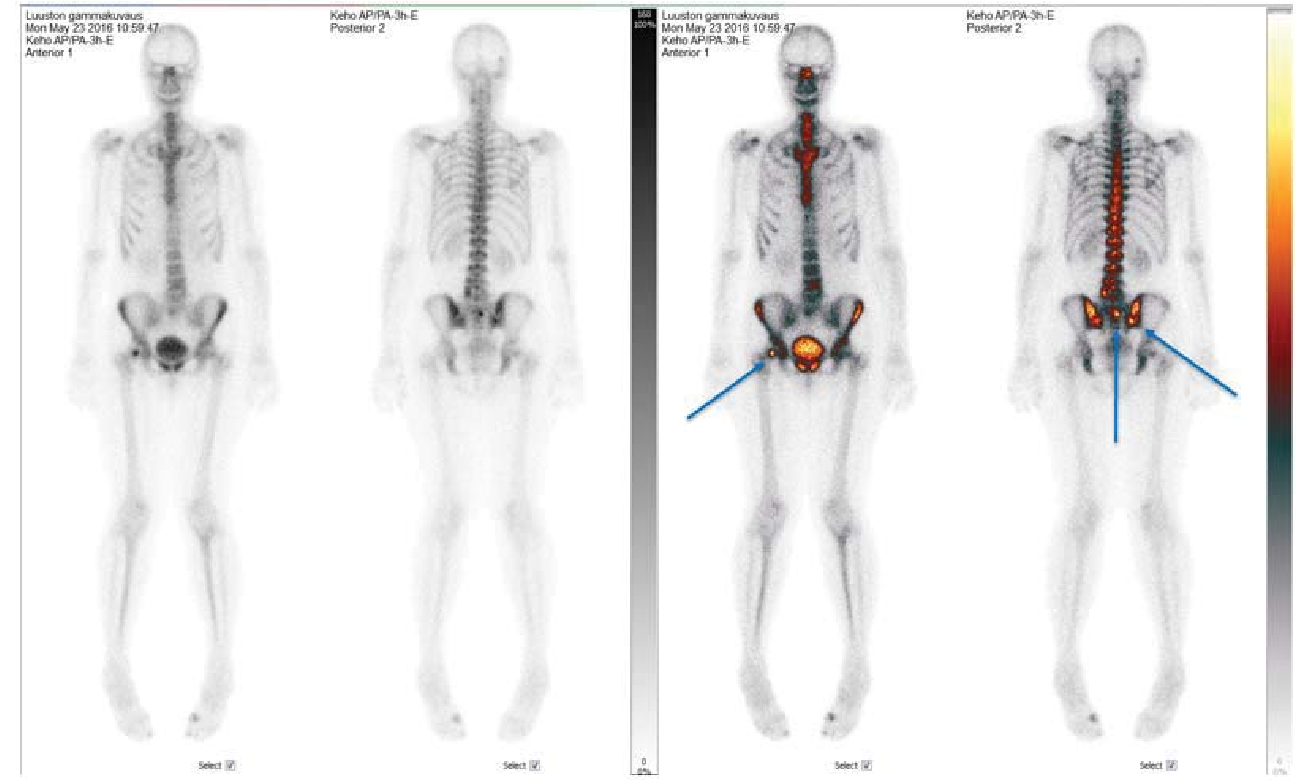

Fig. 2 Case 1: first planar whole-body images (arrows = suspensions of metastases)

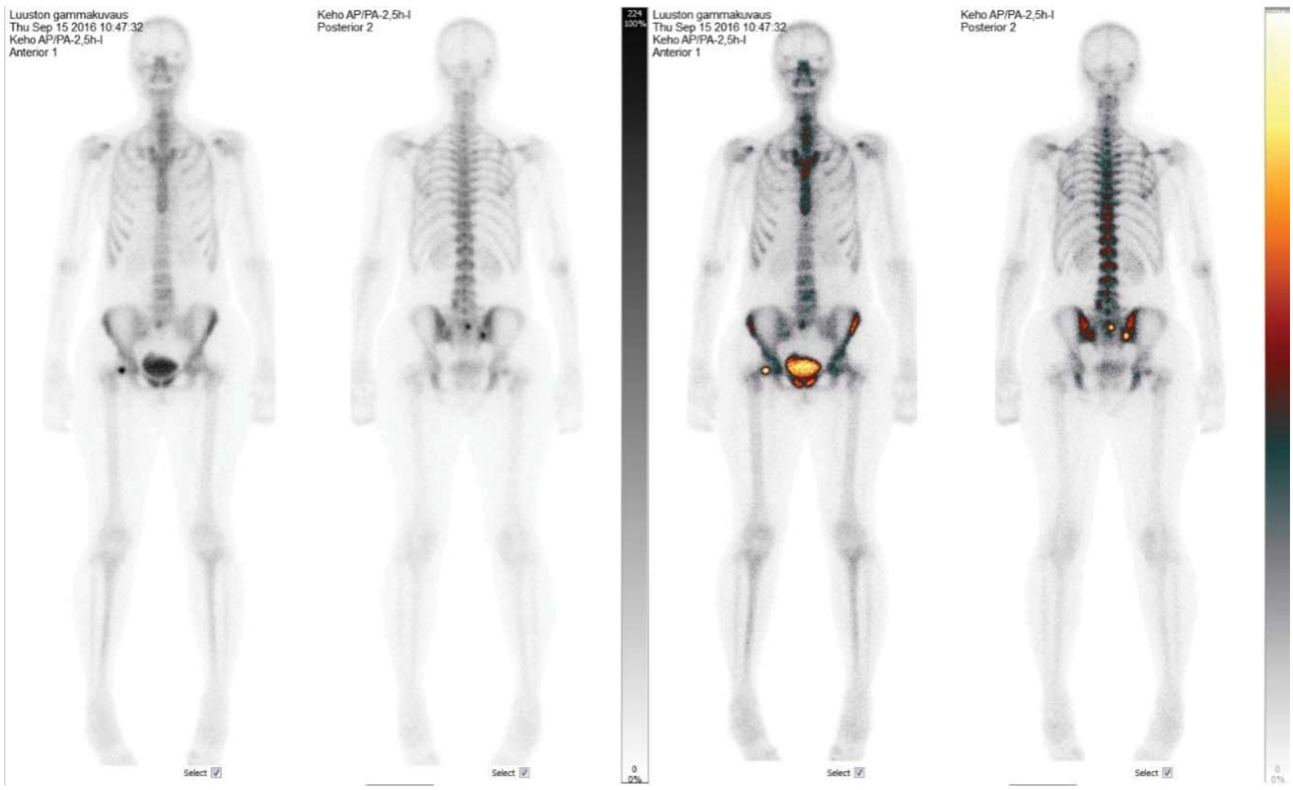

Fig. 3 Case 1: second planar whole-body images (possible metastases at arrows in Fig. 2)

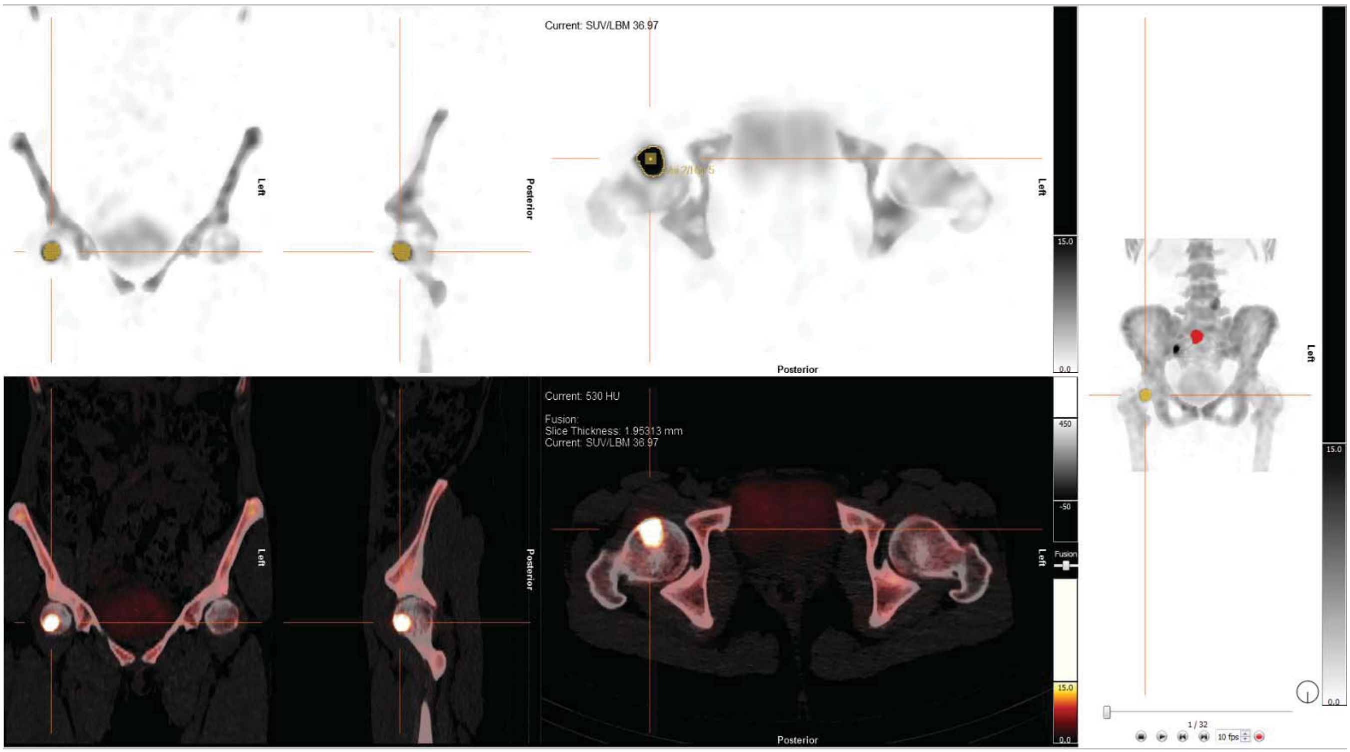

Fig. 4 Case 1: SPECT images and SPECT/CT images (metastases, SUV/LBM max 36.97)

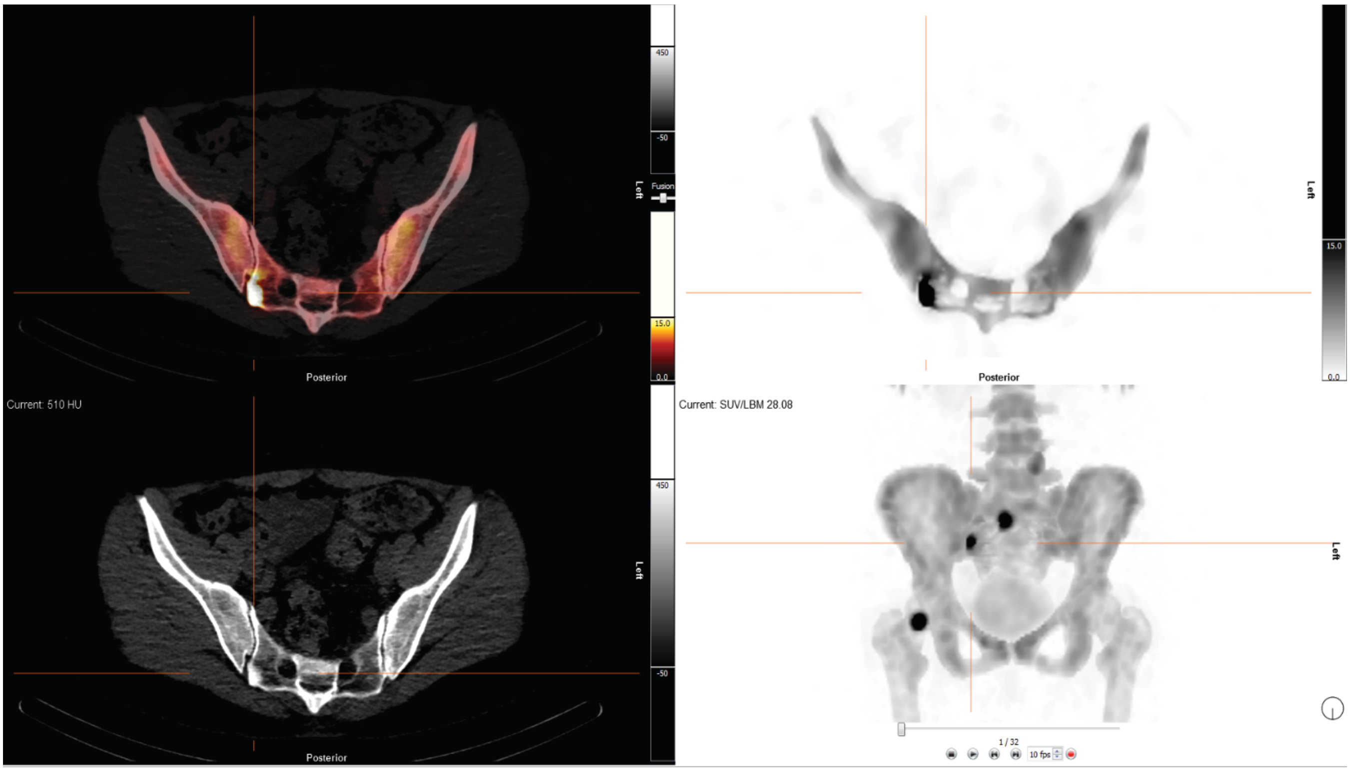

Fig. 5 Case 1: SPECT images, CT images and SPECT/CT image (metastases, SUV/LBM max 28.08)

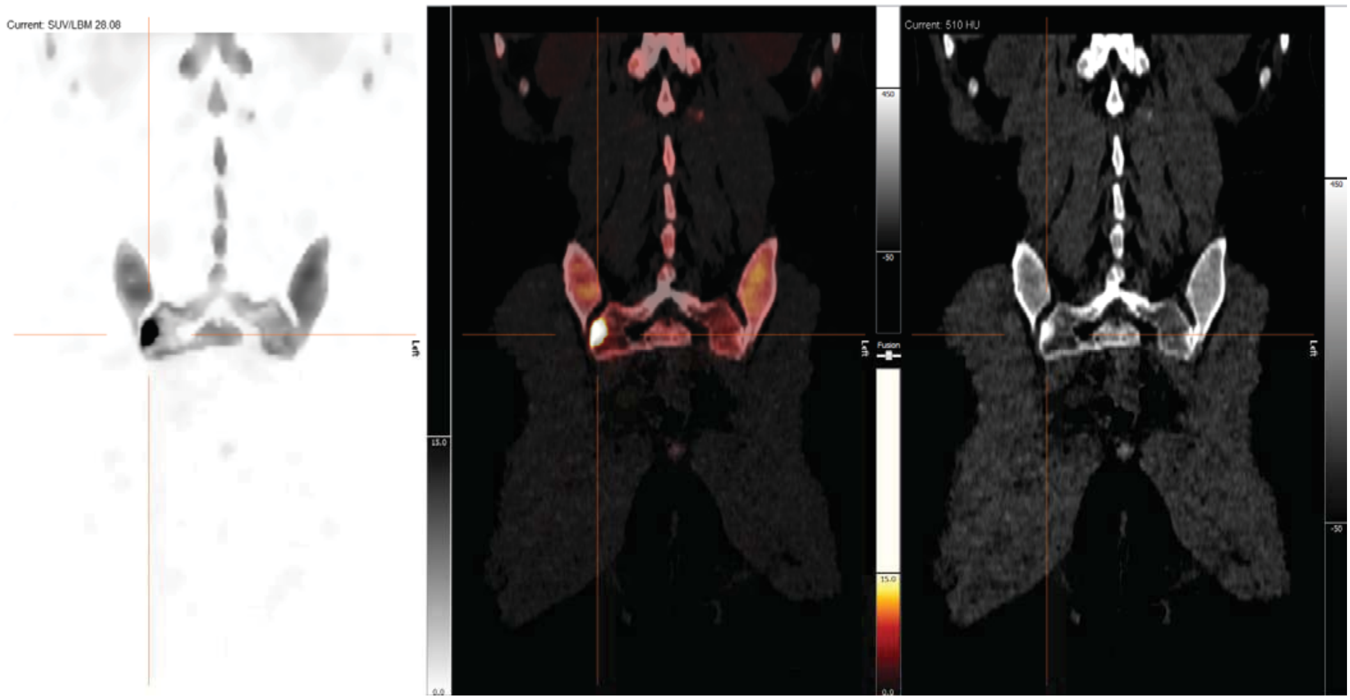

Fig. 6 Case 1: SPECT image, SPECT/CT image and CT images (metastasis, SUV/LBM max 28.08)

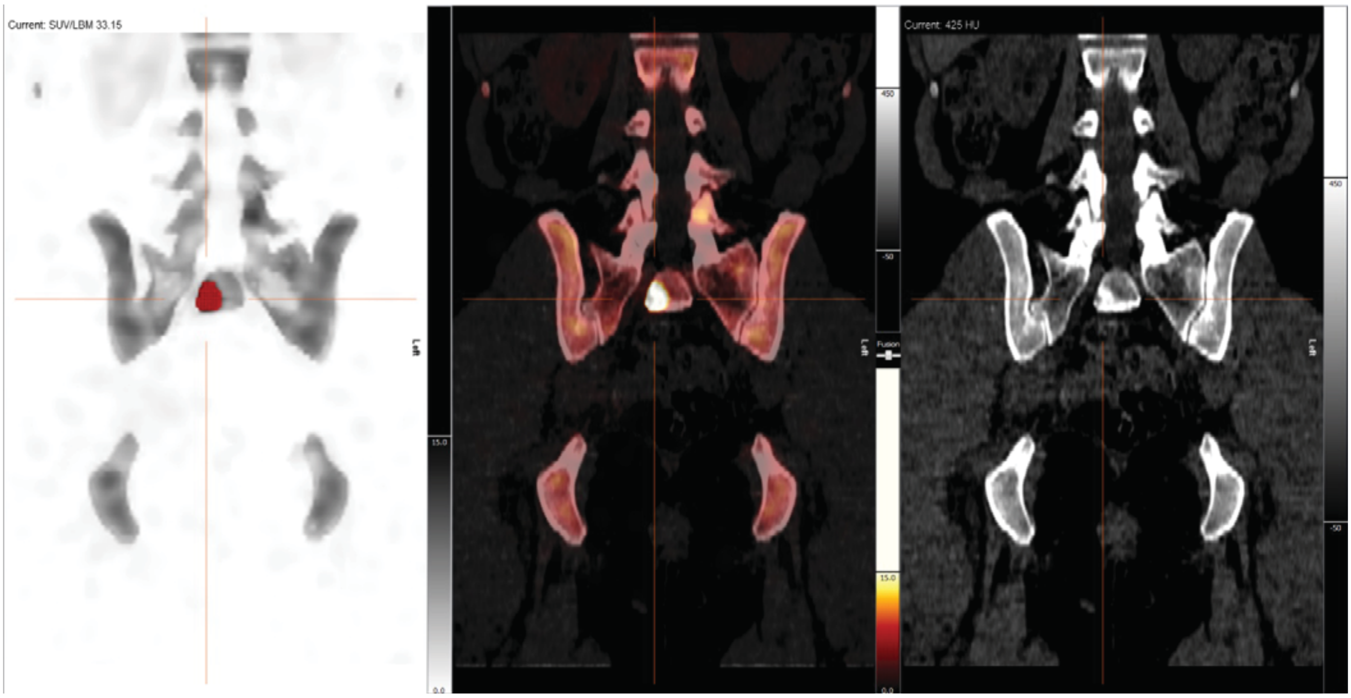

Fig. 7 Case 1: SPECT image, SPECT/CT image and CT image (metastasis, SUV/LBM max 33.15)

B. Case 2—Prostate Cancer Patient

Fig. 8 shows a Case 2 with many metastases.

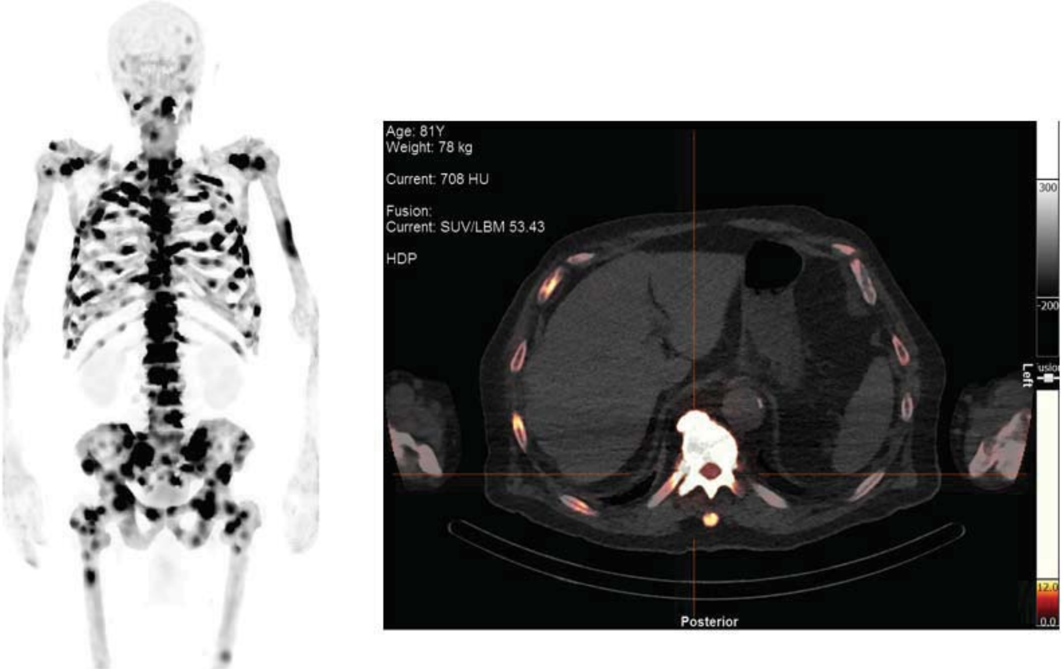

Fig. 8 Case 2: SPECT images and SPECT/CT image (metastasis around the spinal canal, the risk of the spinal compression)

C. Case 3—Breast Cancer Patient with Back Pain

Figs. 9-11 show Case 3 with possible metastases.

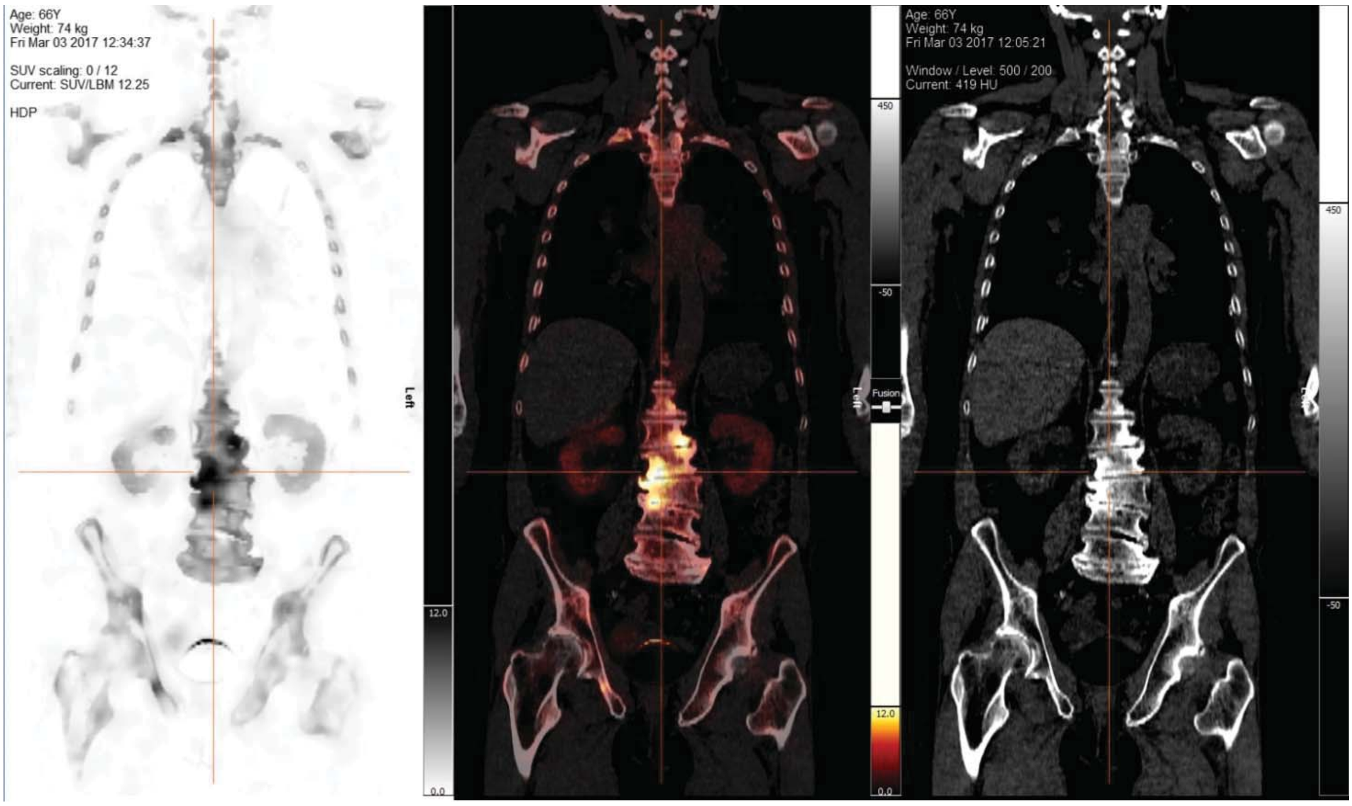

Fig. 9 Case 3: SPECT image, SPECT/CT image and CT image (degenerative changes on the lumbar spine)

Fig. 10 Case 3: SPECT/CT images (arrow = metastasis, SUV/LBM max 12.25)

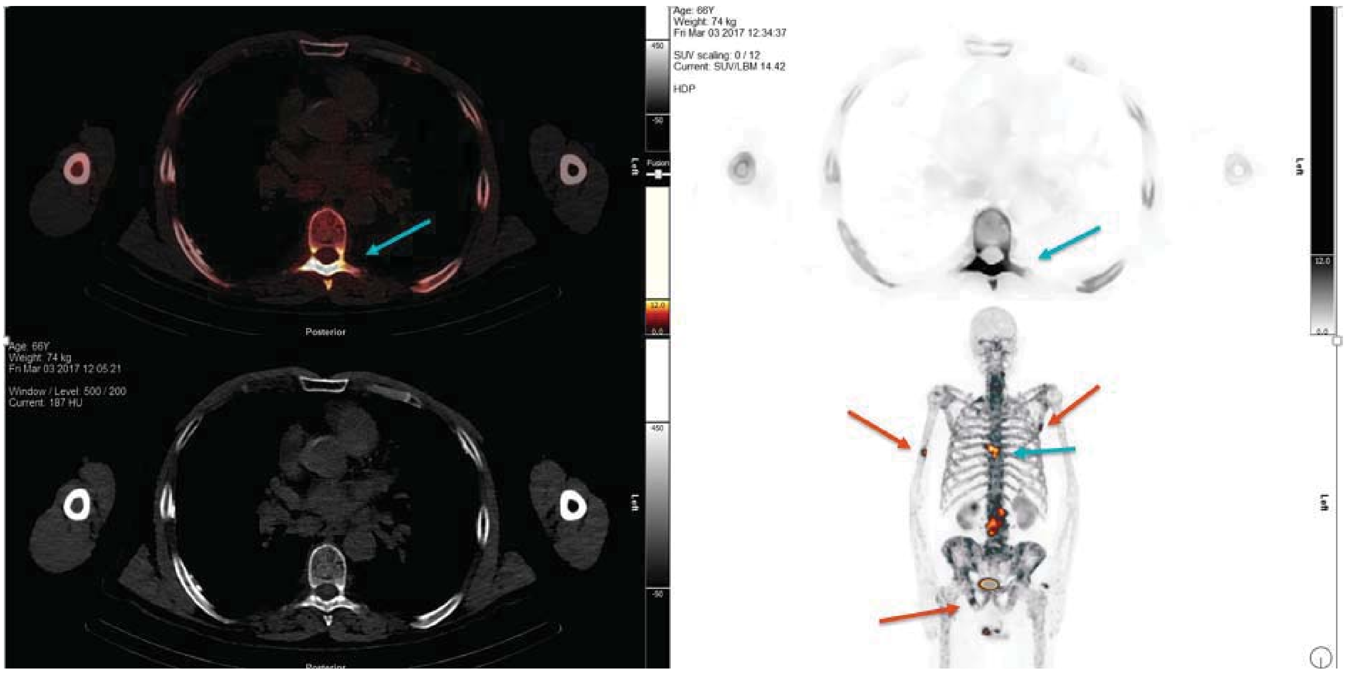

Fig. 11 Case 3: SPECT images, SPECT/CT image and CT image (arrows = metastases, SUV/LBM max 14.42)

D. Case 4—Breast Cancer Patient

Figs. 12–13 show Case 4 with initial metastasis.

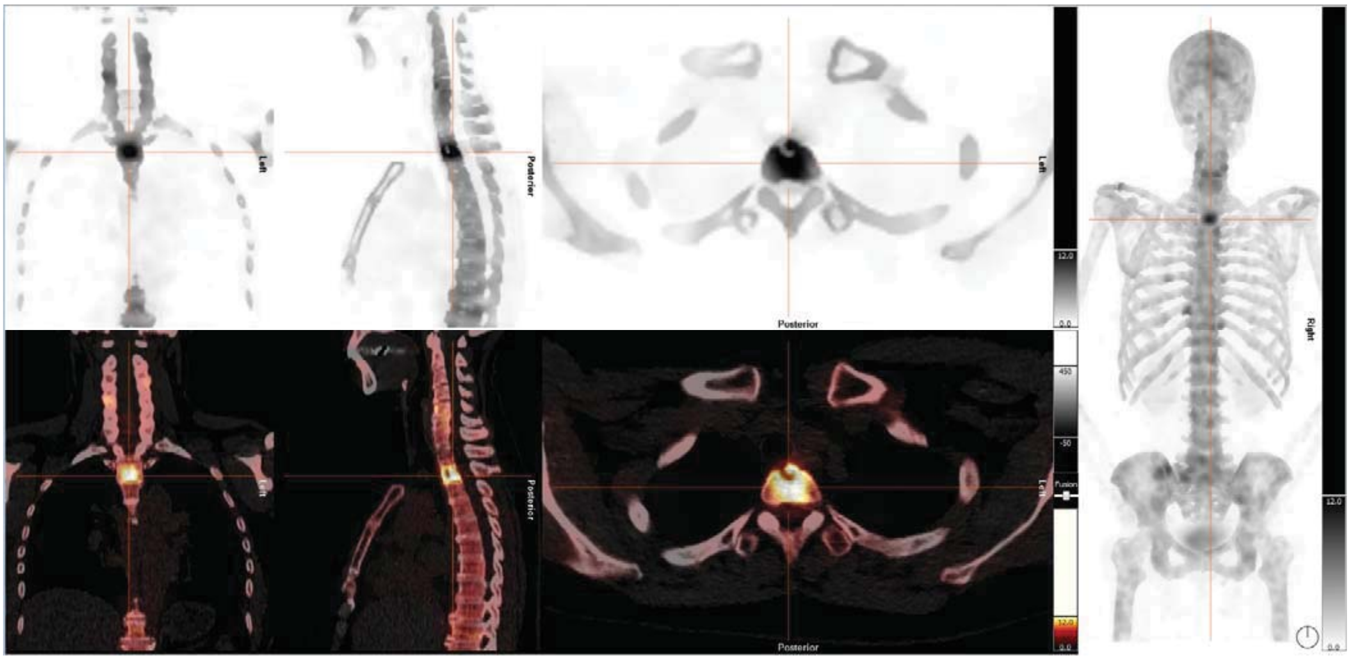

Fig. 12 Case 4: SPECT images and SPECT/CT images (an example of a metastasis)

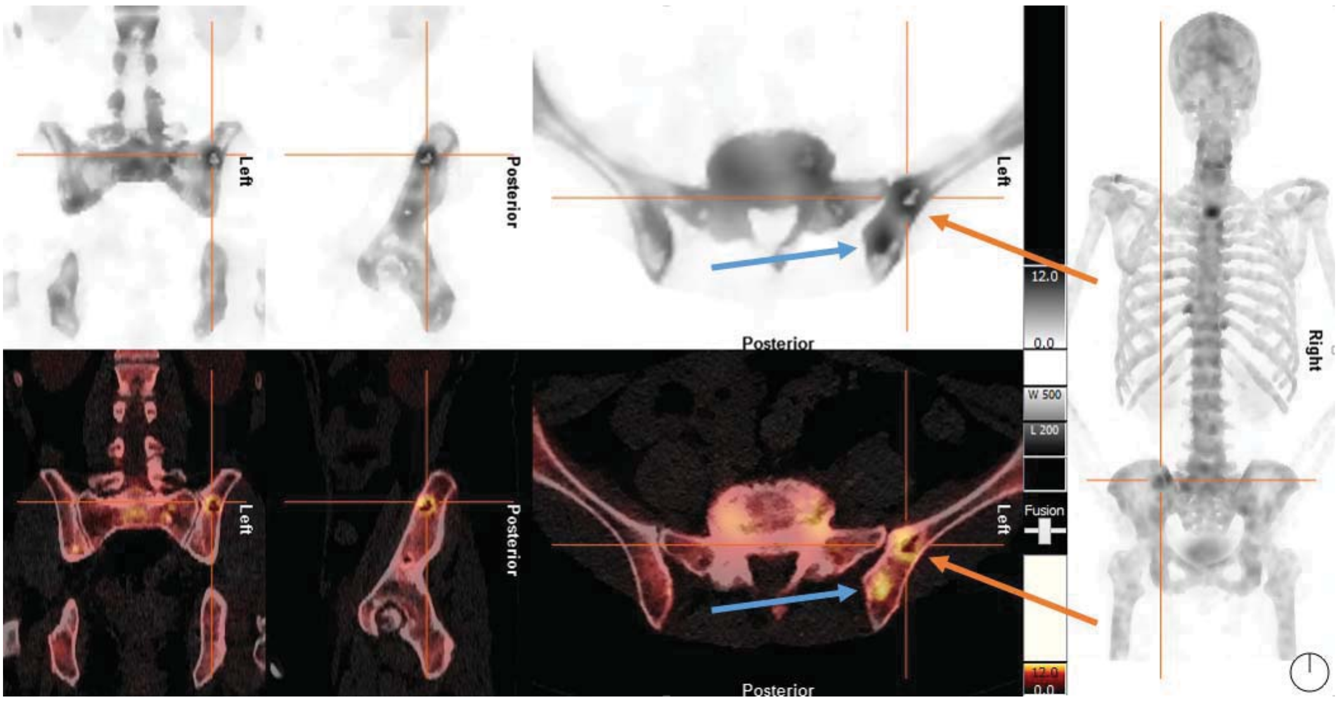

Fig. 13 Case 4: SPECT images and SPECT/CT (Blue arrows = osteoblastic metastasis and orange arrows = osteoclastic metastasis)

IV. Discussion

Skeletal nuclear medicine imaging is a fast-developing technology. Earlier it was only possible to use planar whole-body images and focal planar images. Typically, the colors of those images were only different grey scales. However, we have used a more informative combined grey and customized color scale (see Figs. 2 and 3). Nowadays it is possible to use three-dimensional SPECT and SPECT/CT. For example, we can do the animations of the interesting findings. In addition, we can calculate the SUV/LBM values, e.g., from metastases or possible metastases. SUV/LBM values are useful, e.g., when we compare the changes before and after the treatments of metastases or cancer.

It is also possible to obtain high SUV values without evidence of metastasis or cancer; therefore, the location is also important. For example, we can find degenerative changes with quite high SUV values.

Rager et al. compared the diagnostic accuracy of the two approaches using 212 consecutive patients with a history of cancer who were referred for bone scans to detect bone metastases. They concluded that whole-body SPECT/CT had a higher sensitivity than targeted SPECT/CT for detecting bone metastasis and, as a result, changed the diagnosis in 12 patients out of 212 (5.7%) [6]. In our procedure, we used whole-body SPECT/CT when we had an oncological patient.

Based on our experiments, SPECT/CT increases the sensitive and specificity of skeletal gamma scintigraphy. It is possible to find small tumor colonies early. Challenges are the level of detail, time and, effort required to gain CT knowledge.

V. Conclusion

The developed procedure has been well-practiced. A clear classification will enhance the efficiency and speed up the work phases. In addition, the use of our new procedure has increased the quantitative and accurate positioning of the imaging results, which has significantly improved the diagnostics and the level of observation monitoring. In the future, we can also transfer some ideas from this procedure to other areas nuclear medicine imaging.

Acknowledgment

The staff of the Clinical Physiology and Neurophysiology Unit (at PKKS) is gratefully acknowledged.

References

[1] K. Torsten, “Skeletal SPECT/CT: a review,” *Clin Transl Imaging*, vol. 2, pp. 505–517, December. 2014.

[2] M. Tuncel E. Lay Ergun, and T. M. Caglar, “Clinical impact of SPECT-CT on bone scintigraphy in oncology: pattern approach,” *J BUON*, vol. 21, pp. 1296–1306, September-October 2016.

[3] T. Van den Wyngaert, K. Strobel, W. U. Kampen, T. Kuwert, W. van der Bruggen, H. K. Mohan, G. Gnanasegaran, R. Delgado-Bolton, W. A. Weber, M. Beheshti, W. Langsteger, F. Giammarile, F. M. Mottaghy, F. Paycha, corresponding author and on behalf of the EANM Bone & Joint Committee and the Oncology Committee, The EANM practice guidelines for bone scintigraphy, *Eur J Nucl Med Mol Imaging*, 43, pp. 1723–1738, June. 2016.

[4] I. Kuji, T. Yamane, A. Seto, Y. Yasumizu, S. Shirotake and M. Oyama,“Skeletal standardized uptake values obtained by quantitative SPECT/CT as an osteoblastic biomarker for the discrimination of active bone metastasis in prostate cancer,” *European Journal of Hybrid Imaging*, vol. 1, p. 2, October2017.

[5] STUK, Use of radiation in health care http://www.stuk.fi/web/en/topics/use-of-radiation-in-health-care/nuclear-medicine

[6] O. Rager, R. Nkoulou, N. Exquis, V. Garibotto, C. Tabouret-Viaud, H. Zaidi, G. Amzalag, S. Anne Lee-Felker, T. Zilli, and O. Ratib, “Whole-Body SPECT/CT versus Planar Bone Scan with Targeted SPECT/CT for Metastatic Workup,” *BioMed Research International*, vol. Article ID 7039406, 8 pages, July 2017.

Leena Korpinen, professor, MD, and tech. PhD., is a specializing physician at North Karelia Central Hospital, in the Clinical Physiology and Neurophysiology Unit, and an adjunct professor (Medical Technology) at the University of Tampere (Faculty of Medicine and Life Sciences) in Finland. Her interest areas are environmental health, health effects of electric and magnetic fields, clinical physiology, and nuclear medicine. She does interdisciplinary research, applying the research traditions of both medical and technical sciences. Dr. Korpinen’s main expertise lies in public and occupational exposure to electromagnetic fields (ELF), assessment of health effects caused by such exposure, and reducing them. She is also a member of the Bioelectromagnetics Society (BEMS), European BioElectromagnetics Association (EBEA), Conseil International des Grands Réseaux Electriques (CIGRE), and is the secretary of the Scientific Committee on Radiation and Work of the International Commission on Occupational Health (ICOH).

Pentti Taskinen is a physicist at North Karelia Central Hospital, in the Clinical Physiology and Neurophysiology Unit at Joensuu. He has innovatively followed the development of the physical issues of nuclear medicine at PKKS throughout his career and brought new, evidence-based methods to the PKKS. In 2016, PKKS introduced a new camera (SPECT/CT), for which he developed new imaging protocols for physicians. He works actively with other specializations and develops co-operation so that clinicians get the best possible service in practice.

Pentti Rautio, chief physician of Medical Imaging at North Karelia Central Hospital (PKKS) at Joensuu. He has brought new, evidence-based methods to the PKKS and has actively trained new specializing physicians for several years. He collaborates actively with other specializations to enhance clinical outcomes.