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Fuzja SPECT-CT: nowe narzędzie diagnostyczne w endokrynologii

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Streszczenie

Wstęp: Wprowadzenie standardu DICOM do wszystkich urządzeń diagnostyki obrazowej umożliwiło fuzję obrazów tomografii emisyjnej pojedynczego fotonu (SPECT, *single photon emission computed tomography)*, tomografii komputerowej (CT, *computed tomography*), magnetycznego rezonansu jądrowego (MRI, *magnetic resonanse imaging*) i innych typów danych obrazowania biomedycznego. Fuzję można wykonywanywać w dwojaki sposób, za pomocą dedykowanych skanerów hybrydowych lub przez oprogramowanie niezwiązane z konkretnym urządzeniem.

Technologia fuzji posiada niezmierny potencjał w diagnostyce obrazowej do wykrywania licznych stanów, takich jak choroby nowotworowe, choroba Alzheimera oraz inne zaburzenia nerwowe.

W ośrodku autorów ponad 2 lata temu stopniowo wprowadzono fuzję SPECT-CT w diagnostyce klinicznej wielu schorzeń endokrynologicznych oraz onkologicznych. Użyto danych obrazowych SPECT oraz CT wykonanych na oddzielnych i niezależnych urządzeniach (dwugłowicowej gamma-kamerze E.Cam-Duet firmy Siemens i szesnastorzędowym tomografie komputerowym *Somatom Sensation* firmy Siemens).

Materiał i metody: Prosty i szybki algorytm o niskiej złożoności obliczeniowej zastosowano do wykonania fuzji kolejnych 81 przypadków. Trzydziestu dwóch pacjentów zakwalifikowano do fuzji SPECT-CT po terapeutycznym leczeniu ^{131}I u chorych po amputacji tarczycy z powodu raka, 12 — po podaniu radioaktywnych analogów somatostatyny, 7 — po terapeutycznym podaniu ^{131}I MIBG, 6 — po diagnostycznym podaniu MIBG z ^{131}I lub ^{123}I, 3 — po scyntygrafii przytarczyc oraz 2 — po scyntygrafii kości.

Najbardziej powszechnym wskazaniem do fuzji była potrzeba scharakteryzowania podejrzanych zmian wykrytych na skanach CT poprzez zachodzące w nich zmiany metaboliczne. Lokalizacja anatomiczna ognisk gromadzenia widzianych na obrazach SPECT oraz ocena efektów terapii radioizotopowej były kolejnymi najczęstszymi przyczynami wskazań.

Wyniki: Obserwowane błędy nałożenia wynikały z tak zwanych czynników ludzkich: nieprecyzyjnego wyboru położenia markerów, ruchów oddechowych oraz przemieszczenia markerów między kolejnymi badaniami. Fuzję ponad 74% chorych określono jako „bardzo dobrą" lub „dobrą".

Wnioski: Wybór chorych, wyszkolenie personelu (zwłaszcza techników i fizyków) oraz współpraca z radiologiem to najbardziej istotne czynniki, które umożliwiają właściwe zastosowanie oraz interpretację fuzji obrazów SPECT-CT.

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***Słowa kluczowe**: fuzja obrazów, SPECT-CT*

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SPECT-CT fusion: a new diagnostic tool for endocrinology

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Abstract

Introduction: The introduction of the DICOM format in all diagnostic imaging devices allowed coregistering SPECT, CT, MR and other types of biomedical imaging. Fusion can be performed by dedicated hybrid devices or by means of software. The fusion algorithm consists of two steps: coregistration and simultaneous visualization. Our center gradually implemented SPECT-CT fusion in clinical diagnostic work-up of several endocrinologic and oncologic diseases more than 2 years ago.

Material and methods: An easy and fast algorithm in terms of computational complexity of image fusion was presented and applied to 81 consecutive cases. Thirty-two patients were scheduled to SPECT-CT fusion after thyroidectomy and ^{131}I treatment for thyroid cancer, twelve after somatostatine receptor scintigraphy, seven after ^{131}I MIBG therapy, six after diagnostic MIBG scintigraphy with ^{123}I or ^{131}I, three after parathyroid scintigraphy and two after bone scan.
The most common indication to the fusion was the need of metabolic characterization of suspected lesions detected on CT scan. The anatomic localization of a focal uptake seen on SPECT and the evaluation of the radiometabolic therapy effect folloved.

Results: A variance of error level observed was a result of human factor, decision on marker's placement, respiratory movements and marker's displacement between acquisitions. However, 74% of patients in our series have fusion results classified as "very good" or "good".

Conclusions: The selection of patients, the training of the personel and the cooperation with radiologists are the most important factors for a correct application and interpretation of the SPECT-CT image fusion.

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Key words*: image fusion, SPECT-CT, multimodality co-registration*

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Introduction

Because of lack of anatomic information nuclear medicine studies are sometimes insufficient for full diagnosis. On the other hand, information carried by the CT scans, especially in endocrinology, are not always satisfying while functional changes are often not evident in anatomical imaging.

The introduction of a unique standard format for encoding biomedical imaging (DICOM format) allowed co-registering multimodality examinations, as CT, MR as well as such nuclear medicine techniques as positron emission tomography (PET) and single photon emission tomography (SPECT) [1–4]. The cut-edge of this technology is represented by the hybrid devices of PET with computed tomography (PET-CT) or SPECT with computed tomography SPECT-CT); on the other hand, it is possible with minimal cost to accomplish a clinically valuable fusion between CT and SPECT scans by using self-made or commercial dedicated software [5–7].

Multimodality image co registration can be achieved by several techniques. The use of external markers is indicated for SPECT studies with a low anatomic information [8] (e.g. SPECT performed with 131-I after radiometabolic treatment of differentiated thyroid cancer).

Combination of the functional information from nuclear medicine imaging and the anatomic information from CT and magnetic resonance imaging (MRI) can improve diagnostic capability and facilitate image interpretation.

Materials and methods

CT studies were acquired using 16-row tomograph Siemens Somatom Sensation 16. Routine acquisition protocol was used. In cases of lungs and abdomen studies CT series for image fusion was acquired with mid-breath.

SPECT studies were acquired using Siemens E.CAM DUET dual-head gamma camera (matrix 128 × 128, zoom: 1.00–2.00, 64 frames/35 up to 60 s each, energetic window contained standard lines of the diagnostic isotope and the line 122 keV of ^{57}Co-Cobalt markers, autocontour).

CT and SPECT scans were performed usually on the same day.

In the present work, eighty-one consecutive fusion procedures performed from October 2003 to April 2006 were evaluated. Thirty-two patients were scheduled to SPECT-CT fusion after ablative ^{131}I treatment and after thyroidectomy for thyroid cancer, twelve after somatostatine receptor scintigraphy, seven after ^{131}I MIBG therapy, six after diagnostic MIBG scintigraphy with ^{123}I or ^{131}I, three after parathyroid scintigraphy and two after bone scan.

The clinical indication to fusion were:

- detection and localization of a clinically suspected tumor recurrence,
- anatomical localization of a focal uptake evident on the SPECT study, or
- metabolical characterization of a lesion detected on CT study.

In the first group the order of execution of CT and SPECT was not important; in the second group CT was always scheduled after SPECT scan, and vice-versa for the last group.

The point-based method was used to perform image fusion. Four ^{57}Co-Cobalt markers were used for calculating the transformation matrix and quality control. Markers were made of plexiglas with ^{57}Co point source inside (marker diameter: 2 cm, thickness: 2 mm). The markers were placed on patient's body before the studies and not removed between the SPECT and the CT acquisitions.

The correctness of the algorithm was checked with cylinder phantom made of plexiglas with two orthogonal triangles of the glass capillaries filled with technetium — 99 m isotope. Cobalt markers were placed outside the cylinder with respect to the algorithm assumptions. Mathematical basis of the algorithm can be found in [9].

Results

Eighty-one studies were scheduled for fusion. In 11 cases fusion could not be performed because of missing markers on CT scan (marker or markers out of the field of view). Six fusions were rejected due to respiratory movements (lesions localized near diaphragm). In two cases markers were placed in one plane thus point-based method failed.

Image fusion error values were carried out for each examination. Taking into account the spatial resolution values (for ^{131}I SPECT — 13,1 mm), patients were divided into three groups.

We have noticed an increase of mean error in patients who had CT and SPECT on different days, but this difference was not statistically significant.

Discussion

In our study, different imaging modalities provided different but complementary information. Both CT and MRI are used primarily for imaging anatomic changes associated with an underlying pathology, whereas the molecular imaging techniques of PET and SPECT capture functional or metabolic changes associated with the investigated pathology. The use of anatomic and functional image fusion is increasing in nuclear medicine, and especially in oncology [10–12]. Anatomic and func-

Table I
Results of fusion procedures, with errors and anatomical localizations

Tabela I
Resultaty stosowania fuzji z uwzględnieniem błędów i lokalizacji

Result	# Studies	Err max (mm)	Localization
Good fusion: Err max < 10 mm	30 (48.4%)	7.0 ± 2.4	Abdomen: 16 Chest: 11 Head & neck: 3
Acceptable fusion: Err max > 10 mm < 15 mm	16 (25.8%)	12.7 ± 1.3	Abdomen: 11 Chest: 5
Not acceptable fusion: Err max > 15 mm	16 (25.8%)	19.4 ± 5.3	Abdomen: 7 Chest: 6 Head & neck: 3

tional information are combined to aid diagnosis, allow accurate tumor localization, and improve the outcome of treatment planning [13, 14]. However, correlation of anatomic and metabolic images is usually done visually by separate readings of CT/MRI and SPECT images.

Using external markers, we have demonstrated the clinical usefulness of ^{131}I SPECT/CT fusion images in patients with several endocrinologic diseases, both neplastic and non-neoplastic. Fusion imaging allowed precise localization of radioisotope uptake and improved the diagnosis in 56 of 81 patients (70%).

The literature data on fusion imaging in endocrine disease is rather scarce.

Perault et al. [15] assessed the feasibility of registration with CT in 13 patients with endocrine carcinoma evaluated with ^{131}I, ^{123}I-MIBG, and ^{111}In-pentetreotide. The investigators obtained simultaneous dual-isotope acquisitions using these agents and ^{99m}Tc-methylene diphosphonate to get information on skeletal structures that could subsequently be correlated with anatomic data provided by CT. In their study, fused images allowed the detection and correct localization of 6 unsuspected sites of disease.

In another study [16] the clinical value of combined transmission and emission tomography imaging was assessed using ^{131}I, ^{123}I-MIBG, ^{75}Se-cholesterol, ^{111}In-pentetreotide, and ^{99m}Tc-MIBI in 27 patients with endocrine tumors [16]. For 41% of the patients, fused images improved the accuracy of nuclear medicine studies by providing better localization of SPECT-detected lesions. For one third of the patients, image fusion had a clinical impact on management.

Multimodality image coregistration can be achieved by several techniques using external markers or internal landmarks. Most fusion algorithms have been developed for brain imaging [17]. In the present study, the method used external markers placed at specific positions on the patient's body. This method requires CT and SPECT to be performed in short period of time, the patient to be imaged in the same position for both CT and SPECT, and external markers to be carefully matched. Respiration might affect this relationship, thus affecting the reliability and usefulness of the registration process. In our study, CT and SPECT were both performed while the patients were breathing freely.

Realignment is fast when external markers are used and a technologist trained to work with the realignment software can perform the entire procedure in less than 10 min. For clinically oriented settings, establishing such a method may be a cost-effective alternative to investment in a combined SPECT/CT device.

In several stages of processing and patient preparation errors can be made. This mainly regards marker dislocation between CT and SPECT examinations, respiratory movements and operator mistakes during the marker localization on the CT and SPECT images.

In our experience 25,8% of performed fusions the results was not clinically acceptable (Err max > 15 mm). These studies had to be rejected or repeated.

Conclusion

Use of SPECT/CT image fusion allows more precise anatomical location of radioisotope uptake increasing specificity and sensitivity of diagnostic. The fusion method with the use of external markers is simple and economic.

References

1. Israel O, Keidar Z, Iosilevsky G et al. The fusion of anatomic and physiologic imaging in the management of patients with cancer. Semin Nucl Med 2001; 31: 191–205.
2. Townsend DW, Cherry SR. Combining anatomy and function: the path to true image fusion. Eur Radiol 2001; 11: 1968–1974.
3. Hilton G, Pochin EE, Cunningham RM et al. The role of radioiodine in the treatment of carcinoma of the thyroid. Br J Radiol 1956; 29: 297–310.
4. Tyson JW, Wilkinson RH Jr, Witherspoon LR et al. False positive 131I total body scans. J Nucl Med 1974; 15: 1052–1053.
5. Lang TF, Hasegawa BH, Liew SC et al. Description of a prototype emission transmission computed tomography imaging system. J Nucl Med 1992; 33: 1881–1887.
6. Hasegawa BH, Wong KH, Iwata K et al. Dual-modality imaging of cancer with SPECT/CT. Technol Cancer Res Treat 2002; 1: 449–458.
7. Beyer T, Townsend DW, Brun T et al. A combined PET/CT scanner for clinical oncology. J Nucl Med 2000; 41: 1369–1379.
8. Fujita A, Hyodoh H, Kawamura Y et al. Use of fusion images of I-131 metaiodobenzylguanidine, SPECT, and magnetic resonance studies to identify a malignant pheochromocytoma. Clin Nucl Med 2000; 25: 440–442.
9. Borys D, Psiuk-Maksymowicz K, Gorczewski K et al. CT/SPECT image fusion in patients treated with Iodine-131. J Med Inf & Tech 2000; 8: II-7–II-13.
10. Vansteenkiste JF, Stroobants SG, Dupont PJ et al. FDG-PET scan in potentially operable non-small cell lung cancer: do anatometabolic PET-CT fusion images improve the localization of regional lymph node metastases? Eur J Nucl Med 1998; 25: 1495—1501.
11. Kretschmer L, Altenvoerde G, Meller J et al. Dynamic lymphoscintigraphy and image fusion of SPECT and pelvic CT-scans allow mapping of aberrant pelvic sentinel lymph nodes in malignant melanoma. Eur J Cancer 2003; 39: 175–183.
12. Somer EJ, Marsden PK, Benatar NA et al. PET-MR image fusion in soft tissue sarcoma: accuracy, reliability and practicality of interactive point-based and automated mutual information techniques. Eur J Nucl Med 2003; 30: 54–62.
13. Kessler ML, Pitluck S, Petti P et al. Integration of multimodality imaging data for radiotherapy treatment planning. Int J Radiat Oncol Biol Phys 1991; 21: 1653–1667.
14. Scott AM, Macapinlac H, Zhang J et al. Image registration of SPECT and CT images using an external fiduciary band and three-dimensional surface fitting inmetastatic thyroid cancer. J Nucl Med 1995; 36: 100–103.
15. Perault C, Schvartz C, Wampach H et al. Thoracic and abdominal SPECT-CT image fusion without external markers in endocrine carcinomas. J Nucl Med 1997; 38: 1234–1242.
16. Even-Sapir E, Keidar Z, Sachs J et al. The new technology of combined transmission and emission tomography in evaluation of endocrine neoplasms. J Nucl Med 2001; 42: 998–1004.
17. Pietrzyk U, Herholz K, Fink G et al. An interactive technique for threedimensional image registration: validation for PET, SPECT, MRI and CT brain studies. J Nucl Med 1994; 35: 2011–2018.