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Editorial

Image fusion in cardiology

Otakar Belohlavek[1], Jana Votrubova[1], Hana Malikova[2], Jiri Weichet[2]

[1]PET Centre, Na Homolce Hospital, Prague, Czech Republic
[2]Department of Radiodiagnostics, Na Homolce Hospital, Prague, Czech Republic

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Nuclear medicine pioneered image fusion decades ago, as we can see from the dual isotope studies, where different information concerning two independent processes could be extracted from a single image. This approach was seldom exploited clinically and is still only used by a very small proportion of centres, predominantly for the simultaneous assessment of myocardial perfusion and viability by heavy collimated SPECT, using 99mTc-based perfusion tracers and 18F-fluorodeoxyglucose (FDG) as a marker of metabolism.

During the last decade, the rapid development of computer science has enabled three essential methods of manipulating two different tomographic datasets:

— registration, i.e. the fitting of one dataset onto another;
— normalisation for appropriate scaling;
— fusion for displaying.

Free software called Statistical Parametric Mapping [1] became the informal standard for image registration and the analysis of brain studies within the same modality for research purposes, while Hermes software by Nuclear Diagnostics introduced the possibility of image fusion of different modalities to the broad clinical community. Nowadays, all vendors offer powerful software for image fusion, allowing nuclear medicine to overcome its major limitation — the lack of anatomical detail, as well as poor spatial resolution. Brain and oncological studies are the primary substrate for today's fusions. Further progress in promoting widespread image fusion is currently being supported by inline hybrid PET/CT and SPECT/CT scanners.

Unlike oncology or neurology, nuclear cardiology still remains aloof from image fusion, even though the comparison of two datasets (stress/rest) comprises its daily bread and butter. However, another approach is exploited here: the analysis of datasets and the detection of structures such as left ventricle axes and endo- and epicardial surfaces. Rather than image fusion, statistical comparison of extracted corresponding structures is performed after normalisation. Despite this, there are a few situations where image fusion can be helpful. Some aspects of these will be discussed below.

Technical considerations: The general problem facing cardiac acquisition by any modality is motion: the movement of the heart during its cycle as well as respiratory movement. All modalities use ECG gated acquisition to record the cardiac cycle. MRI and CT are able to manage acquisition while the breath is being held, while SPECT and PET are not. A theoretical solution (two-way gating by ECG as well as by breathing signals) is not currently applied in practice to SPECT and PET scanning. Identical problems such as the motion during acquisition must be treated during registration and image fusion. When registering PET or SPECT (typically not gated) with MRI or CT (typically gated and at breath hold), one must expect rather more blurry PET and SPECT images and their suboptimal alignment with CT and MRI.

There are few examples of clinically relevant cardiological image fusion: Cardiac neoplasm is an extremely rare condition, which FDG-PET has a strong potential to discover, but insufficient anatomical details limit this method. When MRI is available, the comparison of both investigations and even image fusion can increase diagnostic certainty (Figure 1), but due to the low frequency of these tumours, this type of fusion will never become routine.

Infectious endocarditis is unlikely to form masses detectable by contemporary PET scanners. To our knowledge, only one example has been reported in literature [2], when image fusion of FDG-PET with CT detected infection of an aortic valve replacement. This is promising information for the future, when one can expect the increasing spatial resolution of PET scanners and two-way gated acquisition using ECG as well as respiration. Image fusion with contrast enhanced CT will be mandatory in these cas-

Correspondence to: Otakar Belohlavek
PET Centre, Na Homolce Hospital
Roentgenova 2, 15030, Prague-5, Czech Republic
Tel: (+420) 257 272 165, fax: (+420) 257 272 163
e-mail: otakar.belohlavek@homolka.cz

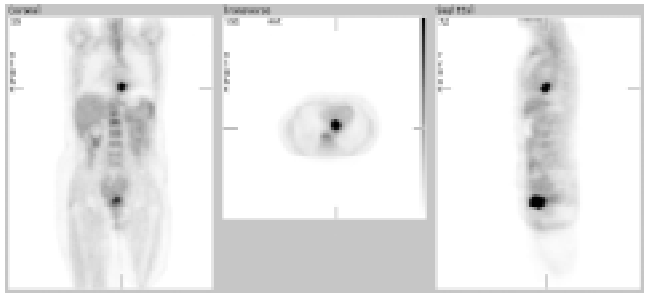

Figure 1A. High FDG uptake in the mediastinum shows a suspected neoplasm. PET alone is hardly able to localise that focus.

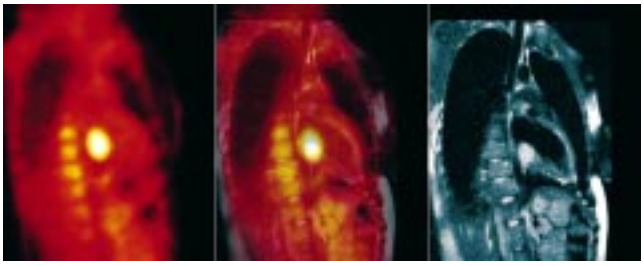

Figure 1B. A plane along the vertical long axis of the left ventricle by PET (left), what is known as a two-chamber projection by MRI (TSE T2 FAT SAT) on the right hand side and their fusion in the middle. MRI alone or its image fusion with PET enables localisation of the tumour into the lower wall of left atrium. Rhabdomyosarcoma was approved histologically.

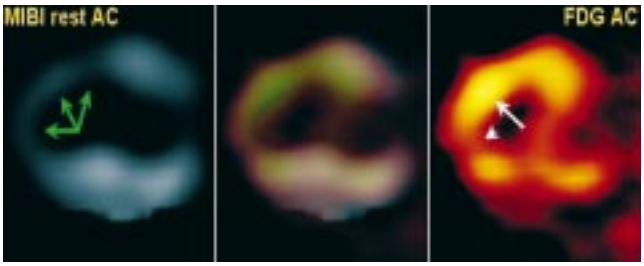

Figure 2A. A vertical long axis plane of the left ventricle: Substantial hypoperfusion is clearly apparent in the apex and apical half of the anterior wall (green arrows on the left hand side). In the same region one can recognize glucose hypermetabolism (white arrow) representing a viable hibernating myocardium as well as hypometabolism (arrowhead on the right hand side) representing a nonviable myocardial scar. The image fusion in the middle is difficult to assess, because both modalities are of similar spatial resolution. All images are attenuation corrected; the quality of the FDG-PET is lower because of the generally low glucose myocardial uptake in a diabetic.

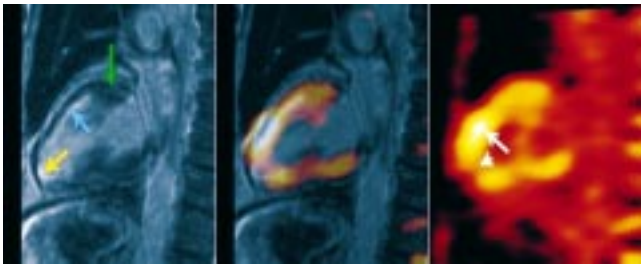

Figure 2B. On the other hand when fusing the FDG-PET functional image (right) with the inversion recovery post contrast MRI anatomical image (left), the fused image (middle) could be easily assessed. Note that more details are visible from MRI that correspond excellently to the perfusion/metabolic images in Figure 2A: no or minimal contrast enhancement in the basal part of the anterior wall (green arrow) is typical of a viable myocardium; the clear rim of contrast enhancement in the apical 2/3 of the anterior wall represents a subendocardial scar (blue arrow), while the subepicardial myocardium is still viable and hibernating (white arrow); transmural deposits of the contrast medium in the apex (yellow arrow) represent nonviable myocardium (white arrowhead).

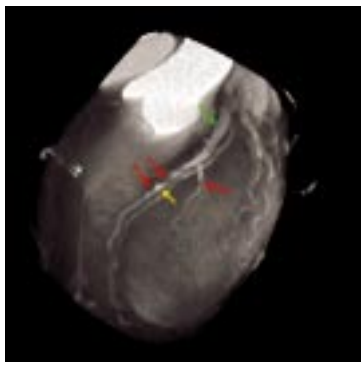

Figure 3A. Volume rendering technique (VRT) showing the left anterior descendent coronary artery and its branches acquired by 16 rows of detector cCTA. Orange arrows point out stenoses of the left anterior descendent artery (LAD) and its diagonal branch, the yellow arrow points to calcification and the green arrow points out the prestenotic dilatation.

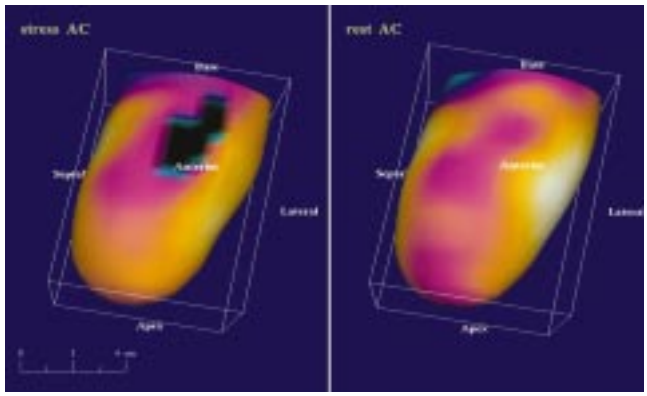

Figure 3B. A 3D model of perfusion of the left ventricle in the same patient in a similar orientation to that of Figure 3A in stress and rest conditions (attenuation corrected SPECT). The area of significant stress hypoperfusion is picked out in black.

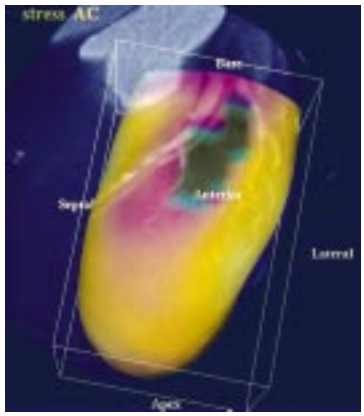

Figure 3C. Because of the lack of software for suitable visualisation of fused cCTA and perfusion SPECT, we can only make a collage of Figure 3A and Figure 3B using a graphic editor (Corel Photo-Paint 9). This example urges real image fusion, because there is uncertainty over whether the hypoperfusion is only caused by tight stenosis of the diagonal branch (a probable misalignment of the collage). On the other hand, conspicuous multiple stenoses of LAD exert a minimal impact on perfusion (probably due to collateral flow). Appropriate visualisation of a true fusion could elucidate these doubts.

es. Variable physiological FDG uptake in the myocardium will probably limit hybrid investigation to valvular involvement alone.

Myocardial viability can be traditionally assessed by metabolic FDG-PET in combination with either NH3-PET or sestamibi/ /tetrofosmin SPECT perfusion studies. In a clinical setting, the display of three perpendicular planes, which intersect the axes of the left ventricle, is used in parallel for both investigations. Visual analysis of these images is usually sufficient. Semi-quantitative assessment known from cardiac software packages for stress/rest perfusion studies is seldom used. Image fusion of perfusion/metabolic information is not used because it is of little benefit. Moreover, as the fusion of perfusion and metabolic information comprises the superposition of two blurred images, they are almost impossible to assess (Figure 2A).

The most advantageous method of image fusion is the combination of a sharp anatomical modality (MRI or CT) in a black and white scale, with a blurred functional one (PET or SPECT) in a so-called "hot body" or "hot iron" colour scale (Figure 2B). Nowadays MRI can produce more detailed information about myocardial viability and other cardiac pathology [3], even without the radiation burden, than the two (perfusion/metabolic) studies provided by nuclear medicine. This means that there is probably no future for this type of fusion becoming routine, even though it would be very interesting.

Stress/rest myocardial perfusion scintigraphy represents the standard in myocardial ischemia diagnostics. On the other hand, coronary angiography is the gold standard for the assessment of coronary-artery disease and moreover, it has a curative potential; the major disadvantage is the invasiveness of this method. The latest development of a multidetector CT (up to 64 rows of detectors) with 3 rotations per second achieves an isotropic spatial resolution of 0.4 mm and time resolution of 165 ms [4], thereby constituting a prerequisite for diagnostic coronary CT angiography (cCTA). Thus there are two modalities, cCTA (Figure 3A) and SPECT (Figure 3B), which are capable of giving a detailed account of the myocardial blood supply without the necessity of catheterization. The major difference is that cCTA assesses the morphology of the main coronary branches, while SPECT evaluates tissue perfusion a more important aspect of myocardial function, but strongly dependent on the blood flow through the coronary arteries. Both modalities could play a complementary role rather than a competitive one. This opinion could be advocated by the knowledge that both cCTA and SPECT are partially compromised by their not negligible rate of false positive and negative findings. A combination of both modalities could reduce doubts in some cases and lower the numbers of invasive coronary angiographies. An optimal therapeutic approach could be predicted by non-invasive means.

These ideas open the field for image fusion of perfusion SPECT and cCTA. The technology is already available, but its implementation into daily routine will take time. Very fast CT scanners (even stand-alone) are still not common, the first hybrid SPECT/CT16 scanners have only been contracted, while the software to visualise the coronary arteries is not automated and must be operated by a skilled physician. The nature of such visualisation is extremely complex and it is not easy to present a hybrid 3D perfusion model of the myocardium and the extracted vessels on its surface (Figure 3C). There are as yet few qualified personnel capable of operating both modalities, and it might prove problematic to attract skilled radiologists to nuclear medicine, as it might also be a problem to train nuclear physicians in cCTA.

The difficulties we have mentioned above are challenging. The first hybrid SPECT/CT16 scanner is already on the market. Close collaboration between radiologists and nuclear physicians or even cross-training in both specializations has already begun thanks to the growing spread of PET/CT. The future will show whether the benefits of hybrid SPECT/cCTA will prevail over its cost and overall complexity. We believe that this proposed method is in the same situation as hybrid PET/CT was only a few years ago. Nowadays PET/CT has completely prevailed over PET in the field of oncology and we can look forward to a similar future for SPECT/ /cCTA.

References

1. Statistical parametrical mapping. Internet. http://www.fil.ion.ucl.ac.uk/ /spm/ (last access 26.10.2005).
2. Belohlavek O, Votrubova J, Skopalova M, Fencl P. The detection of aortic valve infection by FDG-PET/CT in a patient with infection following total knee replacement. Eur J Nucl Med Mol Imag 2005; 32: 518.
3. Bogaert J, Dymarkowski S. Delayed contrast-enhanced MRI: use in myocardial viability assessment and other cardiac pathology. Eur Radiol 2005;15 (Suppl 2): B52–B58.
4. Wintersperger BJ, Nikolaou K. Basics of cardiac MDCT: techniques and contrast application. Eur Radiol 2005;15 (Supl 2): B2–B9.