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Investing in Hybrid Imaging Technology

Choosing a hybrid system is like buying a new car. In both cases, customers ask:

1. Does it improve something for me?
2. Is its technology mature?
3. Is it cost-effective?
4. Is it easy to operate?
5. Is it more fun to drive?
6. Does it make me more attractive?

This article discusses investments in clinical hybrid imaging technology in general and PET-MR in particular, and examines the extent to which each option meets the six criteria listed above. It will focus on oncologic, neurologic, and cardiac imaging.

PET-CT a Mature Offering

PET-CT is useful in between 20 and 50 percent of oncology patients. Its almost simultaneous data acquisition is particularly useful in the abdomen, where patient repositioning between scans, bowel motion, and variable bladder filling can hamper fusion of data sets from separately acquired scans. PET-CT is infrequently used in brain imaging because software data fusion is easy and MRI is the mainstay. In cardiac imaging the advantages of PET over SPECT perfusion imaging are limited and software integration is adequate. PET-CT technology is mature and easy to operate, and its cost-effectiveness can be demonstrated (see further reading for more information).

The synergies of PET and CT in oncology were understood early. Not only is there an important clinical need for anatomic referencing of the metabolic images, but the speedily acquired CT data can also be used for attenuation correction of the PET images, thus obviating the slow PET attenuation correction systems. This has led to consistent semiquantitative PET images, which is important mainly in therapy monitoring. Technically, integration of PET and CT saves money in comparison with independent systems. A single operating console, table, and room are needed rather than two. As a PET scanner is considerably more expensive than a CT scanner and PET scanner use for attenuation scanning takes much longer than CT data acquisition, integration of PET and CT makes sense clinically and economically.

Thus the first four criteria outlined above are largely satisfied by the integration of PET and CT, with use of FDG (fluorodeoxyglucose) or other tracers of value in oncology. The "soft factors" five and six have some importance with regards to the choice of the PET and CT device in a PETCT scanner. In oncology the use of a 64-slice CT hardly confers any advantage over a 16-slice or multislice CT with an even lower slice number. The type of detector crystal is used in PET scanners may also be more of a soft than a hard factor in oncologic PET as long as time of flight technology is used. Hence, emotionally induced over-investment definitely may influence the choice of the CT in PET-CT, but also some impact on the choice of the PET system.

Where is SPECT-CT?

SPECT-CT differs in important respects from PET-CT. It has a lower spatial resolution than PET and is relatively low cost compared with a state-of-the-art CT scanner. In addition, the need for attenuation correction is less established than in PET. This means that during SPECT data acquisition a CT scanner that is comparatively expensive is idle for long periods. The most clinically relevant SPECT exams are bone scanning and myocardial perfusion imaging. Anatomic referencing is not critical in a bone scan as it has an adequate anatomic reference in itself. Still, superimposed CT data are helpful for the distinction e.g. between degenerative and metastatic lesions, and thus SPECT-CT appears useful in this setting. In myocardial perfusion imaging, attenuation correction can be done by software fusion of CT data.

The problem of one system idling during data acquisition is exacerbated in cardiac patients undergoing SPECTCT because CT coronary angiography has to be possible and this requires a 64-slice CT or better. In a high-throughput cardiac setting, integrating one of the new, very fast – but expensive – CZT cameras with a high-end CT scanner may make economic sense. In summary, SPECT-CT is not as successful in meeting criteria one to four, above, as PET-CT. The emotional factors five and six, are important because many nuclear medicine sites that do not have PET-CT will opt to display their power by purchasing a SPECT camera with a good CT scanner, an "overkill" in most settings.

PET-MR: Too Early to Tell?

The lack of clinical data makes a discussion of PET-MR largely speculative. To justify adding MR to PET we have to identify tasks for which PET-MR may be superior to PETCT, which in turn requires identification of those areas where MR performs better than CT. MR is better than CT in the brain, the musculoskeletal system, some head and neck applications, the pelvis and liver disease. In the chest, CT excels and in the heart MR has yet to prove its clinical usefulness in a broad sense. In the brain, software fusion is very easy and so there the sole argument for integrated PET-MR imaging is simultaneous data acquisition, which can only be provided in fully integrated PET-MR systems.

While simultaneous data acquisition may be of benefit in resolving some research questions, it probably offers few advantages in a clinical setting. Rather than temporal simultaneity, pharmacokinetic simultaneity should be attained in a PET-MR examination. In other words, if one has an uptake time of 60 minutes or so for FDG and most other clinically useful tracers prior to PET imaging, the meaning of simultaneity becomes somewhat blurred. When does MR have to be acquired to reflect the physiological state of FDG uptake? In fact, FDG uptake reflects a physiological state extended over many minutes and so the question of temporal simultaneity becomes moot. With these considerations in mind, we are left with fully integrated clinical PET-MR applications in the neck, abdomen, pelvis, and musculoskeletal system. While there are technical developments in MR towards whole-body surveying scans, these can be done much more effectively with CT, so extended staging is still a domain of CT scanning. Hence, the first likely clinical applications are focal imaging of PETMR with extended body PET surveys.

Technically we have to distinguish between fully integrated PET-MR systems, which can simultaneously acquire PET and MR data, and sequential systems deployed in one or two rooms and connected by a shuttle. A shuttle would be a table on which the patient can be transferred to the other imaging device without changes in body position. In fact, current PET-CT and SPECT-CT are one-room sequential systems where the system table serves as the shuttle. Full integration of PET-MR is very expensive as completely new PET detectors have to be developed. A whole-body fully integrated PET-MR system would likely cost over four million euros, and nobody currently disposes of any clinical data to argue in favour of or against buying such a system. The advantage of sequential systems connected by a shuttle is that the PET and MR scanners can be placed sufficiently far apart that today's photomultiplier PET detector technology still works. For this reason, the shuttle distances need to be two or more metres.

The advantage of single-room sequential PET-MR is that it requires only one – albeit large – room. A two-room system has the advantage that the systems can be run independently if needed and that the system can be operated in a "pipeline" mode: once the first patient enters the second scanner, the first scanner is free to receive the second patient and so on. All systems consisting of a PET and an MR scanner currently have the problem that there exists no proven solution for extracting attenuation correction data from MR scans. One has either to also incorporate a CT or to revert to the old PET source attenuation correction. Hence, a good starting system would be a two-room shuttle- linked PET-CT-MR system with the CT providing attenuation data or more. Another unsolved problem in PETMR is how to deal with all the MR coil gimmickry when the patient enters the PET. It will cause additional attenuation artifacts, which have to be corrected for. Again, no mature technology is available to deal with this.

In light of these unresolved issues, points one to four above have to be answered as follows. We have few data to prove that PET-MR may be useful and the technology largely does not exist yet. Cost-effectiveness may be present for a tworoom shuttle-connected PET-CT-MR system, as the system can be operated in the "pipeline" mode described above or independently. A single-room PET-MR system will be much less effective, and the fully integrated system – while efficient in the sense that data acquisition is simultaneous – will be extremely costly owing to the major re-engineering efforts needed. Ease of operation is not proven either for shuttle operation or for MR local coil handling. So the tremendous hype around PET-MR is likely due to the soft factors five and six defined at the outset. While PET-MR may be interesting, the "sex appeal" of such a system seems to completely outweigh reason at this point, and in the view of this author PET-MR should remain an academic endeavour until substantial clinical data exist that prove its utility over PET-CT in respect to defined clinical questions.

Conclusions

In summary, PET-CT is of proven utility and has many current clinical indications. SPECT-CT is clinically established, but today's system designs require high investments in technology that is idle for the most part and therefore not cost-effective. The shuttle system concept explained above for PET-MR could also be explored in SPECT-CT. PET-MR is currently surrounded by much hype and no data. Data will have to be acquired and carefully analysed in comparison with PET-CT data. is task is best done in academic centres and so for the next few years the installation and use of such systems should be largely confined to academic centres.

Whether, where, and when PET-MR will see the light of day and be introduced into the wider clinical environment cannot be stated, nor is it possible to draw conclusions on the form that PET-MR would then take, i.e. fully integrated or shuttle integrated. Nevertheless, the soft factors cannot be ignored and may still lead buyers to adopt PET-MR technology much too early and without good clinical or financial arguments. If one radiological practice looks much "sexier" than another with a PET-MR, buying decisions will become irrational. Finally, it is important to note that equipment manufacturers love integrated imaging systems because they can always sell two for one; hence what may be soft factors for the buyers may be clear-cut financial factors for the vendors.

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