Innovative image reconstruction for extremely low-dose PET/CT imaging

Interview with Prof. Charalampos Tsoumpas, UMC Groningen

Charalampos Tsoumpas is a full professor on Quantification in Molecular Diagnostics and Radionuclide Therapy at the Department of Nuclear Medicine and Molecular Imaging of UMCG. He studied Physics (BSc, 2002) at the National Kapodistrian University of Athens, Biomedical Engineering (MSc, 2004) at the National Technical University of Athens. In 2008, he received his PhD for his research on direct parametric image reconstruction from Imperial College London. He has been active in several domains of clinical medicine and research. Recently, he received a prestigious NWO VICI award by NWO TTW, to work towards innovative approaches for ultralow dose PET/CT imaging. VICI is one of the largest scientific grants in the Netherlands and enables advanced researchers to set up their own innovative research line.

'Innovative image reconstruction for extremely low-dose PET/CT imaging' sounds like a challenging research proposal. Can you briefly explain the project?

The photon coincidences a PET scanner measures are sufficient to create astonishing images within a few minutes. However, the acquired data can provide a lot more information than currently utilised when we perform more advanced image reconstruction with the assistance of artificial intelligence and the utilisation of physical phenomena like quantum entanglement.

What inspired you to write this project?

I was fascinated with PET imaging as early as the second year of my undergraduate studies. Using positrons, i.e. antimatter, to advance medicine is such a beautiful example on how particle physics and nuclear physics can help our society. Thus, I have been always intrinsically motivated on how we can further advance medical imaging by transferring more recent technological and scientific advances. Specifically, this year, 2025, is celebrated as the International Year of Quantum Science & Technology, so it was quite natural to write a project that would include quantum entanglement, a peculiar fundamental physical phenomenon that is not utilised in PET imaging. The entanglement effect of the annihilation photon pairs means that the two photons remain interconnected independent of how far they are from each other – even at the end of the universe. In practice it means that the direction the first photon scatters, confines the direction of the other photon scattering direction. This property may be useful in extracting additional information from Compton scattered photons, which are normally disregarded by the hardware and software of a PET scanner.

The project contains a lot of technical and fundamental research, but at the same time it is very relevant for clinical research and patient care. What kind of impact do you expect to realise on the short and long term?

One of my aims is to enable the use of PET in many more clinical indications and many more tracers. Thus, the targeted outcomes of the VICI project, especially the potential of dose reduction, can facilitate this. In long term, I would love to see PET imaging playing an even more important role in paediatric and

perinatal medicine, where its use especially in research context is rather limited, e.g. when compared to MRI, because of the radiation exposure.

How does this specific research project fit into your broader research strategy?

The aims of the research project have not changed since my undergraduate studies, back in 2002, when I proposed and developed an artificial neural network to advance image reconstruction with the ultimate goal to reduce without image degradation. The use of concepts like the quantum entanglement also resonates with my enthusiasm in utilising fundamental physical concepts in advancing nuclear medicine.

What do you consider the biggest challenge in this project?

There are several layers of challenge in such projects. I think that the computational demands related to the manipulation of every single count (i.e. not only every coincidence) makes the project difficult but, at the same time, quite attractive.

Artificial Intelligence (AI) is gaining a lot of attention worldwide, also in nuclear medicine research. What is your view on AI? Will it play a role in your research?

I enjoy AI as I believe that it holds a significant place in accelerating scientific advances. However, I am at the same time sceptical on how AI is utilised. For example, training on [^{18}F]FDG data doesn't mean that it can be useful for other tracers, thus narrowing their use. In our research, we anticipate using AI to accelerate the solution of difficult mathematical problems, e.g. image registration and image reconstruction to produce images with better resolution and lower noise.

The VENI-VIDI-VICI scheme of NWO is very competitive and besides scientific excellence, it also takes a lot of dedication, time, and perseverance to get such a grant. How much time did you spend on the proposal until it finally got awarded?

Indeed, preparing a winning research proposal is challenging. I had several negative results previously, which were very useful in training how to make a competitive one. So, in principle, I spent a lot more time thinking about the story rather than writing the proposal. That means that I had to think straight from the start how to convince the panel members and not only the referees. It had to include elements that were high risk – high gain, but also elements that are low risk – high gain. Showing already some preliminary results was important, as well. All in all, I knew that I had to do my best, yet I had to be very lucky with the referees and the panel and the competition. In this instance, it worked out, but equally the same project could have been rated slightly lower and deemed unfunded. I mention this because there are many excellent ideas that are not awarded due to poor luck and limited funding. More research funding is needed to maintain our competitiveness in this fast-changing world.

A VICI grant is an important milestone in the career of a scientist. What does it mean to you?

I knew about this scheme even before I moved to the Netherlands, and it was a personal bet and aim to receive it. Coming from abroad at a relatively young age and straight as a full Professor with focus on research, raises the expectations, so it was important for me, to prove that those who have chosen me did really a good job. Furthermore, the department had invested on me and my ideas by hiring three PhD students to boost my research. Therefore, I am greatly thankful to Prof. Rudi Dierckx, Prof. Adriaan Lammertsma and the other professors and colleagues of NGMB at UMCG – I hope the VICI serves as one small token of appreciation.

If we look five years into the future, what do you hope to have achieved with this VICI project? In other words, what would you be most proud of?

From a clinical point of view, I would be very happy if we are able to scan healthy volunteers, or young adults, pregnant women and even children without being concerned of the radiation. Seeing also some of our work featuring in clinical systems would also be a very nice outcome. ♦