The Evolution of PET And How It Will Save Us All

Brookhaven National Laboratory Essay Contest

3/23/17

It seems with the genes I've inherited, I'm going to go out of this world with Alzheimer's, prostate cancer, and baldness. And there's plenty of time for more to go wrong.

But there's increasing hope for people like me, and, really, most other Americans who are suffering or will eventually suffer from various diseases and disorders. That's because Brookhaven National Labs (BNL) pioneered the positron emission tomography imaging technique, or PET, and continues to make major advancements with it.

PET is an imaging technique in a similar class as scanners such as MRI and CT. It can create an image of internal structures or organs, including the brain, heart, and tumors. It involves injecting a patient with radioactive substances called radiotracers that attach to the targeted area and by passing the patient through a large, donut-shaped device lined with radiation detectors, it produces an image on photographic plates, which can then be mapped on a computer. It is like an x-ray but from the inside out.

Medical diagnostic applications of PET include mapping infectious diseases, heart problems, brain disorders and central nervous system issues, and research initiatives include studying neuroimagery, cardiology, small animal imagery (with a microPET) and cancer. It aids in drug research, addiction treatments, and determining if therapies are working. It's difficult to imagine anyone who has not been impacted by this machine and, from what I'm seeing, the direction this machine is heading will impact our lives even more.

To try to predict what's ahead for PET, I looked at how it's been evolving since its invention. While the PET scanner was born in 1951 at Massachusetts General Hospital [1], it wasn't until 1961 that BNL pioneered the first single plane PET scanner, which could initially only create a cross section of a human brain [1]. From there, I noticed that PET began evolving mainly along three paths. The detectors became more sensitive, the radiotracers (which emit the gamma rays picked up by the detectors) became more plentiful, and, later, other kinds of imaging technology were incorporated into the machines. These paths will continue to see future developments, especially with the exciting opportunities our digital age is presenting.

The detectors, for example, were first made out of sodium iodide (NaI). The problem was, however, that NaI was too sensitive to moisture in air. So, by the 80's, Bismuth (BGO) was the detector of choice for those with larger budgets and also absorbed more radiation, improving sensitivity [7]. Now, an even better material used for sensors is a substance called lutetium oxy-orthosilicate. As even more efficient sensors are discovered, experts believe we'll see "PET tomographs reach the theoretical limit of resolution (approximately 2 mm)" [21], further expanding the effectiveness and versatility of the PET. Some scientists predict PET radiation will decrease by nearly 50% [13]. This will make tests using BNL-developed radiotracers even safer in the future, as the current radiation output by PET is the equivalent of three years of normal sun exposure [20]. This will be especially helpful in identifying breast cancer, as breasts are one of the most radiosensitive organs, especially during pregnancy [23].

The second path in which PET is evolving appears to be that the number of actual radiotracers available for this kind of imaging will continue to expand as well, which will have a huge impact on our future. The first and most popular radiotracer to this day was developed by BNL, but PET machines had somewhat limited uses. In 1978, scientists Joanna Fowler and Al Wolf solved this problem and changed the world forever with the development of the radiotracer fluorodeoxyglucose [24], which was exceptionally good at being absorbed by, and therefore detecting, a wide variety of tumors. Also, the increasing variety of radiotracers is just as important. For example, when imaging the brain and tumors, the radiotracer used for imaging is irradiated glucose since the brain and tumors consume a lot of glucose. Other organs and tissues need other kinds of “tagged” radiotracers based on what they consume. BNL produces 20 of them including ones specific to addiction, psychiatric disorders, blood flow, nicotine, depression, drug research, brain injuries, and even some related to plant research [24]. As recent as February of this year, scientists found a new radiotracer which is a gallium-68-labeled peptide [12] that is a key step in catching prostate cancer early and may eventually help identify and find a cure. That’s good news for me and countless others.

The third path that seems to be evolving is the combination of PET with other kinds of imaging technology. In the 1970’s, BNL first improved the PET’s sensors by simply including more rings of NaI sensors--24 of them. But the newest and most widespread combination machine is the PET/CT scanner developed in 1998 [14]. The PET/CT is a singular combined PET and CT machine that results in shorter scan times and much lower false positives and an equally safe scan. Because a CT shows what an organ or tumor looks like structurally and a PET explores it on the cellular level, the result is a higher definition and more accurate picture [19]. PET machines incorporating other existing and future scanning technologies will make them even more precise and versatile machines, helping us in even more areas.

The combination of advances along these fronts are leading to monumental breakthroughs. For example, we are now able to improve the early detection of breast cancer using estrogen receptors acting as tumor markers [22].

As recently as the past few months, Dr. Sandra Black of the University of Toronto explains, “We can spot the signature buildup of amyloid and tau proteins in brain scans” [11].

Which means that using PET, scientists can monitor amounts of proteins and can accurately predict the onset of Alzheimer's. That's more good news for me and other countless Americans as the average lifespan is increasing and Alzheimer's and prostate cancer are on the rise. BNL, by the way, produces radiotracers for both of these.

Even if only the variety of radiotracers, the sensitivity of the detectors, and the different kinds of scanners built into these machines are the things that continue to improve, the impact of PET on humanity will continue to expand significantly.

But when you begin to imagine the applications of the PET scanner combined with emerging digital technology, the possibilities are staggering. For example, with reduced radiation being used and higher resolution scans, perhaps surgeons and other doctors will be using real-time PET scans during procedures by overlaying images on augmented reality glasses. Artificial intelligence could help guide and even avoid mistakes in surgery and other treatments, just as cars can now automatically stop to avoid collisions. Organs could be printed from PET scans that would be too complex to model alone. Perhaps most exciting would be the possibility that with the inevitable falling costs of technology, PET scanners can become accessible to even the smallest, most remote, poorest areas, perhaps even enabling whole body PET/CT scans during annual checkups and other visits where diagnosis or the the progress of recovery is in question.

Since BNL's invention of the PET scanner in 1961, along with BNL's breakthroughs in developing and producing the radiotracers the PET detects, it's hard to imagine a human being that can move through life without benefitting from it in at least one major way. Thanks to BNL's incredible work in this area, all of us will have better lives.

Works Cited

[1] Bernal, Gabriella. “History of PET Scanners” *Stanford University,* Web 3 Mar. 2014 http://large.stanford.edu/courses/2014/ph241/bernal1/

[2]“Positron Emission Tomography (PET Scan)” *HopkinsMedicine.* The Johns Hopkins University, JH Hospital, and JH Health System, Undated. http://www.hopkinsmedicine.org/healthlibrary/test_procedures/neurological/positron_emission_tomography_pet_scan_92,p07654/

[3] “Understanding Attenuation Correction” *Digirad*. Digirad Corporation, Web 11 Feb. 2016 http://www.digirad.com/understanding-attenuation-correction/

[4] Mark Hammer “Explanation of Backprojection” *xrayphysics.* CTSim, Web 2014 http://xrayphysics.com/ctsim.html

[5] Krans, Brian. “PET Scan” *Healthline.* Health on the Net, Web 2 Nov. 2015 http://www.healthline.com/health/pet-scan?s_con_rec=false&r=00

[6] “Detectors” Guide to the Nuclear Wallchart. lbl.gov (Berkeley lab), Web 9 Aug. 2000 http://www2.lbl.gov/abc/wallchart/chapters/12/2.html

[7] “The AAPM/RSNA Physics Tutorial for Residents Radiation Detectors in Nuclear Medicine” *Radiographics,* Radiological Society of North America, 30 October 1998 http://pubs.rsna.org/doi/full/10.1148/radiographics.19.2.g99mr30481

[8] Dale L. Bailey, David W. Townsend, Peter E. Valk, Michael N. Maisey, “Positron Emission Tomography: Basic Sciences” *Google Books.* Book Publisher- Springer, Web 2003 https://books.google.com/books?id=svliBnNd2LcC&pg=PA12&lpg=PA12&dq=what+is+a+single+plane+pet+scanner&source=bl&ots=pf2xi11rv9&sig=auixsAXVy0dK6N_pQ7VOe8naP68&hl=en&sa=X&ved=0ahUKEwiG7pHH9OLSAhWCf5AKHSy0Dt4Q6AEILDAD#v=onepage&q=what%20is%20a%20single%20plane%20pet%20scanner&f=false

[9] “PET/CT vs. PET” *Glendale MRI,* Glendale MRI Institute, Web Undated.

http://glendalemri.com/patient-portal/diagnostic-imaging-options/petct-vs-pet/

[10] Nikhilesh Jasuja, Pooja Sehgal, nishant verma, Hwcjksdad, Haboosh AL-khawaja. "CT Scan vs PET Scan." Diffen.com. Diffen LLC, n.d. Web. 20 Mar 2017.

http://www.diffen.com/difference/CT_Scan_vs_PET_Scan

[11] Black, Sandra “Doctors’ Notes: For Alzheimer’s researchers, the glass is half full” *TheStar.* Toronto Star Newspapers Ltd, Web 13 Mar. 2017

https://www.thestar.com/life/health_wellness/2017/03/13/doctors-notes-for-alzheimers-researchers-the-glass-is-half-full.html

[12] (Article based on study by) Zhang, J., Niu, G., Lang, L., Li, F., et al., “New Type of PET Imaging Identifies Primary and Metastatic Prostate Cancer” *ITNOnline.* Scranton Direct Communications, 2 Feb. 2017

https://www.itnonline.com/content/new-type-pet-imaging-identifies-primary-and-metastatic-prostate-cancer

[13] John Hocter, “The rise of PET/CT: 5 predictions for the future of hybrid imaging”, *Health Imaging*, 2 May 2016

http://www.healthimaging.com/topics/advanced-visualization/rise-petct-5-predictions-future-hybrid-imaging

[14] Munshi N., PH.D., “Imaging Evolution: Hybrid PET/CT Scans”, *ITNOnline.* Scranton Direct Communications, Web 03 May 2012

https://www.itnonline.com/article/imaging-evolution-hybrid-petct-scans

[15]“2015 PET Imaging Market Summary Report” *imv PET products,* imvinfo.com, Web 2015

http://www.imvinfo.com/index.aspx?sec=pet&sub=dis&itemid=200083

[16] "Fast Facts on U.S. Hospitals" *American Hospital Association.* Health Forum LLC, Web Jan. 2017

http://www.aha.org/research/rc/stat-studies/fast-facts.shtml

[17] Nunez, J. "How Much Does A PET Scanner Cost? [2017 Update]" *blockimaging.* Block Imaging, Web 24 Feb. 2017

https://info.blockimaging.com/bid/68875/how-much-does-a-pet-ct-scanner-cost

[18] "How Much Does A PET Scan Cost?" *costhelper.* Web 2016

http://health.costhelper.com/pet-scans.html

[19] Dr. Giles, J. "The Rough Guide to Scanning" *The Spectator.* Disqus and The Spectator, Web 7 May 2016

https://www.spectator.co.uk/2016/05/the-rough-guide-to-scanning/#

[20] "PET Scan" *NHS Choices.* NHS and Gov.uk, Web 2 Nov. 2015

http://www.nhs.uk/Conditions/PET-scan/Pages/Introduction.aspx

[21] Rich, Dayton, "A Brief History of Positron Emission Tomography" *J. Nucl. Med. Technol.* SNMMI, Mar. 1997

http://tech.snmjournals.org/content/25/1/4.full.pdf

[22]Kaplan, Deborah, "Advances in PET Scanning" *DiagnosticImaging.* UBM Medica, Web 13 June 2011

http://www.diagnosticimaging.com/articles/advances-pet-scanning

[23]"Sensitivity of Body Organs to Radiation" *Hong Kong Observatory.* Web Undated

http://www.hko.gov.hk/prtver/html/docs/education/dbcp/rad_health/eng/r4_4.shtml

[24] Brookhaven National Laboratory "Positron Emission Tomography" *bnl.gov.* Battelle and Stony Brook University, Web Undated.

https://www.bnl.gov/pet/