"Am I about to Lose my Job?!": A Comment on "Computer-Extracted Texture Features to Distinguish Cerebral Radiation Necrosis from Recurrent Brain Tumors on Multiparametric MRI: A Feasibility Study"

After reading the accompanying article,[1] and especially the sensationalistic comments that will inevitably appear in the lay press, more than one neuroradiologist will ask the terrifying question, "If computers are now superior to human radiologists, am I about to lose my job?"

In this exceptionally interesting paper, the authors addressed a question that has vexed neuroradiologists since MR was first implemented: namely, how to differentiate recurrent brain tumors from radiation necrosis. The authors used a technique called machine learning. Their programs analyzed a set of 43 proved cases, from which they were able to discern specific characteristics that could distinguish between recurrent tumors and radiation necrosis. The authors then took a new set of 15 cases and matched the computer program and what it was able to "learn" from the test cases against 2 neuroradiologists. The computer won hands down: 12/15 correct for the computer versus 7/15 for neuroradiologist #1 and 8/15 for neuroradiologist #2. These results raise a very uncomfortable question for practicing radiologists: if computers are able to "discover" new imaging characteristics and act upon them to make a very difficult diagnosis, how long do we have until computers "learn" to make every other neuroradiologic diagnosis and make us obsolete?

Since the Industrial Revolution, automation has led to the creation of more (not fewer) jobs. An excellent example is the auto industry. Even though some jobs were lost (first in taking care of horses and later on the assembly line), in fact, ultimately, many more jobs were created.

In the past, the jobs that were eliminated tended to be repetitive, low-end jobs, which freed up human talent for more meaningful and creative endeavors. However, the advent of more sophisticated artificial intelligence has already led to computers doing the jobs that were previously the purview of the human intellectual elite. For example, many stock trades are now executed by computers. A recent sobering commentary by Wall Street analysts predicted the demise of their own field because of computer advances.[2]

Is the current paper a harbinger of our imminent demise? How can human radiologists survive in the world of advancing artificial intelligence? I do not believe that the prognosis is so grim. Clearly, our profession will undergo substantial adjustments; however, this is a continuous process and has always been the case. In the following brief review, I hope to show that working with computers, rather than some apocalyptical struggle against them, will lead to optimal results for the patients we serve.

A recent thoughtful book by a specialist in advanced computer systems made a number of points apt to our discussion.[3] It is axiomatic that no system is perfect. This is also true of any computer system. Complex modern computer code is almost inevitably written upon much older code. Modern systems are so complicated that no single person understands them in their totality. Such complicated overlapping systems lead to unexpected results and failures, which are impossible to predict. Consequently, code is always being updated and needs to be evaluated "in the field" by human "users." Think of the Galaxy 7 phone (Samsung, Suwon, South Korea). Inevitably unexpected problems or failures are detected, which require further debugging, updates, and patches. As programs get more complicated, things will probably get worse. A corollary point made by the author of *Overcomplicated* is that computers are not good at figuring out when they are wrong, which often entails the participation of another system or human intervention.[3]

"Augmentation, not automation" is the mantra of another book on this subject by Harvard Business School professor Thomas Davenport and Julia Kirby.[4] Their point is that even in the age of "smart machines," the optimal result is when humans work together with a computer rather than one or the other separately. I see myself doing this all of the time now: looking up differential diagnoses on the Internet, using advanced analysis of perfusion, MRA, CTA, or fMRI data, using the PACS, etc. Could you image reviewing 3000 images (not an unusual number per case currently) on printed film? Can I use additional help now in my clinical practice? Absolutely! Examples include a reliable automated way to evaluate a patient with neurofibromatosis and dozens of irregularly shaped tumors or a patient with multiple MS lesions; an automated multiparametric way to evaluate the growth of a brain tumor; automated searches for additional metastases; and many, many more. Having a system that can automate routine work and check for my mistakes will allow me to work faster and more efficiently.

"Smart machines" are far from the only advances made in the field of radiology. Imaging technology is also progressing at an astounding pace, and there is no reason to suspect that things will slow down: PET-MR, hyperpolarized MR, resting-state fMRI, connectivity, molecular imaging, etc. Ultimately, these new technologies will need to be evaluated in human terms, which brings me to the crux of the argument: does "such-and-such" technique improve the lot of humanity? Using the example in the paper above, certainly the difference between tumor recurrence and radiation necrosis is important, but occasionally, the neurosurgeon will operate even when she or he believes that the diagnosis is radiation necrosis: for example, when the patient has become steroid-dependent.

In a recent interview, Freeman Dyson, a world-leading intellectual and physicist, emphasized the difficulty of establishing complementarity between the human (analog) and machine (digital) worlds.[5] It is hard to reduce a person to 1s and 0s. Yes, I realize that this is what we do in radiology, but we also have to understand that this is a rather substantial limitation of our field.

An example of the necessity of "human" input in image interpretation is the clinical history. We all realize that it is suboptimal to read films in a clinical vacuum. A telling example is from the preoperative assessment of language localization in patients with brain tumor by using fMRI. The American Society of Functional Neuroradiology explicitly endorses physical examination of the patient before the fMRI study. Why? Because one will interpret the exact same imaging findings differently based on the clinical examination: if a patient with a left inferior frontal gyrus glioma demonstrates right Broca area lateralization and clinically exhibits signs of expressive aphasia, I will strongly suggest that the result of my fMRI examination is a false-negative.[6] It would be impossible to make such a finding based on the imaging findings alone, no matter how sophisticated the image analysis.

Will computers come up with new and interesting ways to interpret imaging studies (like the present paper)? I am sure that they will, just like they come up with eerily brilliant moves in chess. Will computers be able to assess seemingly unique human characteristics such as empathy or compassion some time in the future? Possibly, but probably not before I retire.

I would like to leave the reader with 2 final thoughts. Automated assembly lines for cars have existed for over a century. Yet, Rolls-Royce still makes cars by hand. Also, recently, Mercedes-Benz actually reverted from robots back to German workers because "robots can't deal with the degree of individualization and the many variants that we have today."[7] An interesting thought.

REFERENCES

1. Tiwari P, Prasanna P, Wolansky L, et al. **Computer-extracted texture features to distinguish cerebral radionecrosis from recurrent brain tumors on multiparametric MRI: a feasibility study.** *AJNR Am J Neuroradiol* 2016 Sep 15. [Epub ahead of print] CrossRef Medline
2. Turner M. Wall Street analysts are predicting their own grim fate. http://www.businessinsider.com/equity-research-analysts-face-uncertain-future-2016-8. Accessed September 23, 2016
3. Arbesman S. *Overcomplicated: Technology at the Limits of Comprehension.* New York: Current; 2016
4. Davenport T, Kirby J. *Only Humans Need Apply: Winners and Losers in the Age of Smart Machines.* New York: Harper Business; 2016
5. Holodny E. Legendary physicist Freeman Dyson talks about math, nuclear rockets, and astounding things about the universe. http://www.businessinsider.com/freeman-dyson-interview-2016-9. Accessed September 23, 2016
6. Fraga de Abreu VH, Peck KK, Petrovich-Brennan NM, et al. **Brain tumors: the influence of tumor type and routine MR imaging characteristics at BOLD functional MR imaging in the primary motor gyrus.** *Radiology* 2016 Jul 7:151951. [Epub ahead of print] CrossRef Medline
7. Behrmann E, Rauwald C. Mercedes boots robots from the production line. http://www.bloomberg.com/news/articles/2016-02-25/why-mercedes-is-halting-robots-reign-on-the-production-line. Accessed September 23, 2016

A.I. Holodny
Department of Radiology
Memorial Sloan-Kettering Cancer Center
New York, New York

http://dx.doi.org/10.3174/ajnr.A5002