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The AI-powered radiologist

Imaging acquisition advances & big data envision a bright future for diagnostic imaging, which should continue to be led by the AI-powered radiologist.

Technical advances in imaging acquisition and big data envision a bright future for diagnostic imaging. Radiologists working as data scientists can play a central role in precision medicine, leading as AI-powered radiologists.

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There is a special interest in the AI automation of interpretation of medical imaging, since radiologists' costs is one of the biggest expenses in radiology. But AI implementation in radiology faces many challenges, being the standardisation of AI algorithms the main one.

It is envisioned that radiologists, working as data scientists, could play a central role in the so called precision medicine, into a kind of "precision radiology" to which radiomics could add important information. But there is a lot of work to be done, especially to demonstrate that the implementation of AI and Big Data in Radiology is capable of improving the outcome of our patients and the efficiency of healthcare systems.

Technical advances in imaging acquisition and big data envision a bright future for diagnostic imaging, which should continue to be led by the AI-powered radiologist.

As a consequence of artificial intelligence (AI) advances, a revolution is expected in Medicine. There is huge pressure to get the help of AI to deliver more efficient care to the increasingly complex, ageing and demanding patients, in our data-overloaded and many times obsolete healthcare systems. AI appears to be the solution for every problem, reducing costs and increasing efficiency, from primary care to surgery. Of course, diagnostic imaging is being included in this hope: it is said AI implementation would soon imply a radical transformation of radiology.

I'm trying to figure out what radiology will be like in a few years, from the point of view of a radiologist, and how the progressive implementation of AI will affect our daily work.

According to experts, it will take a long time for artificial intelligence to transform our way of performing radiology. Maybe significant changes will start in 10-15 years, after the main AI trials are finished and published, something necessary before clinical real world AI adoption happens. In 25 years a total disruption in medical diagnosis is expected.

There is a special interest in the automation of medical imaging interpretation, but it is considered AI will modify most aspects of the speciality (Dewey 2018).

We will assume the name of our specialty will be maintained, despite the intrusion of the AI, the overlap with/invasion of other specialties (cardiology, vascular surgery...), and the possible fusion with others (pathology, genomics). For decades, radiology has not been only based on X-rays, but this 'classic' name continues to define us. Even after becoming the authentic data scientists of hospitals, the "diagnosticians" par excellence, we will keep our name.

I guess we will continue doing our work mainly in front of computer screens. I imagine myself most of the time in front a workstation. Of course, a futuristic and ergonomic one -music included, please-, with a curved and huge multiscreen with a lot of information, including not only images, but genomic information and other vast data extracted from the electronic health records (EHR), flowing in a way more

similar to that of stockbrokers' screens than to that of the current radiologists' ones.

AI will make medical imaging easier, faster and cheaper

By extracting data from EHR patient's relevant clinical, genomic etc, information- AI will help in the entire so called **workflow orchestration:** from patient scheduling and triaging, to making the choice of the most convenient radiology study to be performed, avoiding overuse.

> ❝ THANKS TO THE TOOLS OF ARTIFICIAL INTELLIGENCE THE ROLE OF THE RADIOLOGIST WILL REMAIN FUNDAMENTAL ❞

For artificial intelligence to be able to extract information from EHRs, previous input of data is needed. Most of these data, mainly clinical history and physical examination, must be previously inserted by human beings (mostly physicians). Although AI is improving in the extraction of conventional data, to be readable and useful for AI deep learning (DL) natural language processing (NLP), doctors' data must be entered using a standardised terminology. This does not seem to be occurring soon.

AI will also help personalising protocols and imaging acquisition parameters to every patient, as well as detecting technical problems, notifying radiologists when it is necessary to repeat or complete a particular study.

Even the MRI scans will be faster: 3D sequences will soon be the norm and the "less profitable" sequences in terms of diagnosis will be eliminated, reducing costs.

AI is already 'reading' medical imaging

Imaging analysis and interpretation (diagnosis and reporting) is the most appealing opportunity of AI in radiology, since radiologists' work is a well-paid job in most countries.

AI apps, theoretically, succeed in 'diagnosing' in many medical imaging areas, (Topol 2019) mainly in the brain, lung, breast and heart, but also in others such as eyes, liver, bones, joints, prostate and kidneys diseases. Almost all diagnostic modalities

are included: ultrasound, CT, MRI, PET, X-ray and mammography. AI can diagnose not only pneumonias; the list of possible automatic diagnoses is large, and includes characterisation of pulmonary nodules, bone diseases, fractures, oncologic diseases, Alzheimer's disease, brain haemorrhages and pulmonary thromboembolisms. Automatic monitoring of the volume of tumours can be carried out. The possibility of AI elaborating the sometimes tedious scoring classifications of lesions will be welcomed.

One of the first main roles of AI will be the **triage of normal studies**. This is specially relevant in **screening**. A comprehensive multispeciality radiology screening programme could be developed with the help of AI, instead of screening for individual diseases. Triage is also useful in the emergency setting, such as in trauma or neuroradiology studies, prioritising relevant studies.

Furthermore, automated body segmentation of CT and MRI scans could automatically routinely extract information about **body composition** from routine studies, such as bone density, lung volume, muscle mass, fat volume or cortical kidney volume. Diagnosis and control of obesity or sarcopenia, for example, could be automatically done.

Precision radiology and radiomics

As Paul J. Chang said at the RSNA 2018 congress, "machine learning can and should be applied to radiology, not to replace radiologists but to enable us to provide precision medicine."

Precision medicine uses non-invasive medical tools to define the phenotype associated with every patients' individual health, resulting from its genetic risk and environmental exposure. The interpretation of medical imaging findings by radiologists traditionally relied on the contribution of clinical and laboratory data. Currently, and increasingly in the future, much more information will be available from the radiologist to refine the diagnosis, from physiologic metrics from wearable biosensors to genomics.

All that information converges on the radiologists' workstation together with the high resolution advanced imaging pictures, who when working together with pathologists become the main real health care 'diagnosticians.' We always have been, but soon in a much greater capacity. We could talk about the 'empowered' radiologist. As these AI apps are embedded in our workstations, in many cases we will not be aware they are acting. AI will help to delineate the most plausible diagnosis from a

list of differential diagnoses giving a percentage of probability of a large list of diseases. AI will also help to decide the most appropriate follow-up, anticipate a prognosis and recommend the best treatment for every patient.

Precision Medicine allows for more accurate and personalised diagnoses, prognosis as well as therapy response prediction. In this regard, radiomics is an exciting radiology field, together with other 'omics' such as genomics, proteomics, metabolomics etc. Radiologists evaluate medical images extracting features describing patterns of pixels, such as signal intensity or attenuation, shape and size. Thanks to AI, radiomics would be able to perform "precision radiology" by mining hundreds, or even thousands of quantitative features from medical imaging (CT, PET and MRI) pixels, including 'texture analysis', features derived from the analysis of pixel-to-pixel relationships, sub-visual to the human eye (Gillies 2016). Radiomics could quantify intra- and intertumoral heterogeneity, differentiate phenotypes of interstitial lung disease, and even predict patient's life expectancy.

A workflow integration between radiology, pathology, (Sorace 2012; Jha 2016) and genomics in the so called "**integrated diagnostics**" or "**diagnostic institute**" (Lundström 2017) has been proposed. Integrated reports including clinical, imaging, pathology and genomic features could provide not only more accurate diagnoses but also prognostic information. There are several fields where pathology-radiology integration is useful, not only in oncology. Also in interstitial lung disease, bone and soft-tissue disease diagnoses, including vascular tumors and malformations.

Radiologists will have a very important role in precision medicine. We can talk about 'precision radiology' in which radiomics, still in development, can play a large role. Given that in the interpretation of the imaging findings a huge amount of other data converges, thanks to the tools of artificial intelligence the role of the radiologist will remain fundamental.

The radiologists role in the AI implementation

The radiologists' role in the AI advances in our field is crucial, helping AI developers to know what tools we need to work more efficiently, training algorithms that later will be implemented in the hospital workflow.

For AI apps being developed, big data (in this case, large amounts of images with their respective radiology reports and patient's data) information extraction by training deep learning (DL) models are needed.

These AI tools will be only effective if they have been developed with **the right data**. Some see an interest for AI developers in the standardisation of radiology reports, facilitating DL extraction of data by means of structured and contextual reporting.

Is it really necessary for every radiologists to be experts about artificial intelligence? Only those radiologists working with application developers should have a more deep knowledge about AI coding, but it is crucial that radiologists know the expectations and limitations of artificial intelligence in our field.

Paradoxically, many of us are already working with AI, by providing our own reports to artificial intelligence developers. That means we are inadvertently collaborating with those who hypothetically can destroy radiologists' job positions. Radiologists have not yet complained, but others (mainly these app developers) are benefiting from our work. The situation could be similar to what has happened with Sloan Kettering pathologists, who have seen how their contribution to the development of the specialty has been taken advantage of by AI developers- and by some colleagues. Patients are also displaying privacy concerns, as happened at the British NHS, where Google has access to patients' data.

There is a great deal of hope in big data, but positive effects in medicine derived from the use of big data remain to be demonstrated. As in Borges's book, (Borges 1941) an "infinite library" (as big data could be considered) is not capable of solving the mystery. The same goes for big data. The classical work of the radiologist is to separate signal from noise in imaging perception. Now the noise with big data (Taleb 2012) at the theoretically personalised medicine field is huge. No doubt time will clarify what is really relevant in big data, and there is a crucial role for radiologists here.

The future role of radiologists would be to check the diagnostic results produced by algorithms embedded within our imaging reading workflow. As data science specialists, radiologists will maintain the control of diagnosis by integrating the EHR information and accepting, rejecting or tweaking the AI diagnostic work. It will persist for many years, the need to review and validate the diagnoses made by AI so that the role of radiologists will persist for a long time.

Radiologists "stepping out of the dark" thanks to AI

Another theoretical advantage of AI in imaging will be the readiness of diagnosis, being able to simultaneously read innumerable studies. This rapidity should

be exploited by radiologists to increase our almost nonexistent relationship with patients. This relationship already exists, for example, in breast imaging and in interventional radiology, maybe because in these cases a 'final' diagnosis is reached, including the pathological diagnosis of the lesions. In fact, we currently make many diagnoses quickly and in front of the patient, ultrasound being the paradigm, and in few occasions we proportionate the diagnosis immediately to the patient. It would be interesting to change this practice, since the patient's work-up would be streamlined, avoiding unnecessary appointments based only on the communication of imaging results.

> **" MRI WILL BE FASTER, 3D SEQUENCES WILL SOON BE THE NORM & 'LESS PROFITABLE' DIAGNOSTIC SEQUENCES WILL BE ELIMINATED, REDUCING COSTS "**

It has been proposed that this type of consultations could be done by robots/bots, but humans (normally) have the advantage over robots in qualities such as empathy. Nevertheless, there are signs of human-like **intuition**, **creativity and imagination** in AI, creating 'digital humans', robots able to talk to patients face-to-face. Despite these expectations, there is no doubt patients would rather prefer to communicate for long with a human (radiologist) being.

We must offer as often as possible the results of imaging tests directly to the patient. As a matter of fact, patients have increasingly greater access to their web-based/portal electronic medical records, and more and more times that includes not only the radiology reports but images. It makes sense radiologists being organised into "**reporting hubs**", so that every radiological study is carried out and 'read' by the most expert radiologists in every field, many times thanks to teleradiology. Radiology consultations must be the norm in clinical complex cases. Real debates about complicated cases could theoretically be performed.

Some treatments, especially imaging-guided ones, could be provided by the radiologists themselves. Also follow-up consultations of some lesions could be done by radiologists.

So, definitely, the implementation of AI is a great opportunity for radiologists to step out of the dark, making the relevance of our work better known and, allowing better patient outcomes. So it is hard to assume that bad times are approaching for radiologists. On the contrary, these are fascinating times.

Radiology AI challenges

Overdiagnosis: The increasing sensitivity of imaging tests, such as whole body MRI or PET-TC studies, able to detect lesions more and more little, combined with the vast wearable, genomic etc. data suggest that there will soon be an overdiagnosis avalanche. We have to get used to handling the overdiagnosis of indolent lesions, to avoid overtreatment. It would be desirable to see parallel advances in the differentiation of indolent lesions from those that imply a vital risk, something also crucial in screening.

Screening: Advances in genomics imply a shift to personalised screening based on risk profiles. Screened diseases must have an effective treatment. Otherwise, the fact of detecting them early would have little sense, as is already happening for example with Alzheimer's disease. It has been proposed that **genetic risks** results could be communicated to the patient via an AI chatbot, but such a complex information should be delivered by expert genetic counselors.

The association of some DNA variants with certain diseases have led to think that polygenic risk scores could be useful to identify people at high risk of a disease that could benefit from screening, avoiding overdiagnosis and overtreatment. But there is a lot of uncertainty about Genomic Medicine. More experience is needed, since progress in big data and genomics does not mean we know the real impact of genetic variants in our health (Vassy 2017).

Explainability: One of the main challenges in imaging AI is its '**black box**' nature. Users need explainability to determine the reliability of the AI models. For instance, it would be possible for AI to perform automatic diagnoses based on MRI raw data, not identified in the images, and not readable for humans, yet we would not know on what basis the diagnoses was performed. The European Union's General Data Protection Regulation made a public requirement for transparency — deconvolution of

an algorithm's black box — before an algorithm can be used for patient care.

Patients are also empowered with AI

The patient is at the centre of the healthcare system, and he/she has access to AI too. Some consider patients will soon be able to control all aspects related to their own health. Quoting Bart De Wittef from IBM: "The idea of algorithms outperforming doctors is growing, so the discussion about automated consumer-based decision-making versus augmented traditional physician based decision-making will intensify." But this is not close to becoming a reality. As a patient and as a doctor I would like to participate in shared decision making with doctors, supported by AI. But we are very far from a robot or an algorithm to replace doctors in the main medical decisions (Lamanna 2018).

Privacy and security of patients' data must be assured, avoiding hacking and data breaches.

Radiology uncertainty

Some believe that the AI implementation in the radiologist workflow could potentially end with uncertainty in radiology, improving the consistency and reducing errors in radiology reports. But the fact that more data will be available does not mean the end of discrepancies and uncertainties. The radiologists' work, even as a data scientist, will continue being subject to nuances for a long time.

Radiology is not anymore only about identifying imaging patterns, but it is increasingly about quantifying. In the same way identifying imaging patterns is subjective, the limit in determining what is pathological or not in numeric terms is not always easy to demarcate. AI apps will be able to calculate individual disease probabilities, but uncertainties remain. Measuring does not constitute an end in itself (Shaywitz 2018). As the historian Jerry Muller said: "Not everything that is important is measurable, and much that is measurable is unimportant" (Muller 2018).

Interoperability

Standardisation of AI algorithms is key, but it will take a long time. Algorithms are not interchangeable among equipments or institutions. It is said AI could reduce radiology biases, but it is not true. Human judgment is biased, but data are not objective either; different AI systems could not interpret the imaging findings in the same way. A patient could be diagnosed using an app, and considered healthy or having one

disease instead of another one. Maybe, in the same way we know some radiologists are more judicious than others, there may come a time when you can also choose one AI system or another (a daring one, or a prudent, conservative approach) to a particular clinical presentation or patient.

The AI hype

AI in radiology is promising, but it is necessary to be cautious with the surrounding hype. Algorithms can be accurate and technically be validated but, to be implemented in the real patients' world, they must demonstrate they improve both patient outcomes and healthcare systems financial outcomes (Topol 2019). It remains to be seen whether receiving an automatic diagnosis performed by AI has better outcomes than one performed by a radiologist.

> **❝ THE POSSIBILITY OF AI ELABORATING THE SOMETIMES TEDIOUS SCORING CLASSIFICATIONS OF LESIONS WILL BE WELCOMED ❞**

The potential **iatrogenic risk** for an AI algorithm is vast. That has been verified with the IBM Watson Health oncology algorithm issues; many of its recommendations for treatment were shown to be wrong. AI systems must be subject to scrutiny before being incorporated to clinical practice, and that includes radiology.

Peer-reviewed publishing is indispensable for validating innovative products and technologies in biomedicine, but most healthcare start-ups have a limited or non-existent impact in scientific literature.

We can adapt the Frank Pasquale sentence summarising the AI limits: "AI ignores the irreducibly holistic assessments that are hallmarks of good judgment." AI can provide useful partial information, but comprehensive holistic aspects (of patient's imaging care in this case) are better covered by human (radiologist) intelligence.

In spite of the predominant hype, I do not know any fellow radiologist worried about the possibility artificial intelligence taking away her/his job position.

The radiology revolution involves not only AI

Together with the AI implementation, innumerable

technical changes are expected in radiology, which are going to change radiologists' work. For example, a broader use of MRI in emergency settings or even being used in autopsies is expected. Also a much extensive use of ultrasound by other specialists, primary care doctors, physiotherapists and, as it has been suggested, even for patients. This broad ultrasound availability will increase the demand of advanced techniques, that should remain in the hands of radiologists.

Virtual reality (VR), augmented reality (AR) and 3D-printing are fields linked to medical imaging, by using anatomical 3D images from patients. Cardiologists, cardiac surgeons, orthopaedic surgeons and other specialists will need our collaboration, and radiologists have to maintain the control.

Teleradiology also will be upgraded with AI, with "intelligent assistance diagnosis" or "information analysis collaboration." The possibility of fast reporting of millions of studies at the global level is fascinating, but interoperability is key.

Final remarks

In this Brave New World- like radiology's future, an improvement in the ability of artificial intelligence to integrate, process and extract vast information is expected. Explainability, interoperability, privacy, security, and ethical issues must be resolved. In such a new era for diagnostic imaging, AI and technological advances will strengthen radiologists' professionalism.

Even if in the future AI multiplies radiologists' efficiency, given the continuous increase in the demand for imaging tests, the call for radiologists- or for whatever the name of the future data scientist specialised

in imaging diagnosis will be- will continue to increase, making it improbable that the radiologists workforce will shrink.

It has been said in many ways, but we all now agree: it's not the robotic vs the human radiologist; it is the more precise and faster AI-powered radiologist.

Radiologists must take a leadership role in the AI tools development, a guarantee that they will be designed for us, contributing to increase the enjoyment of working in this increasingly exciting specialty. But above all, AI must be optimised for our patients' better outcomes, facilitating an appropriate and fast diagnosis, and for our healthcare systems, which should make health solutions available to everyone. ∎

KEY POINTS

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- ✓ It will take a long time for artificial intelligence to transform radiology.

- ✓ There is a special interest in the AI automation of interpretation of medical imaging.

- ✓ Standardisation of AI algorithms is key, but it does not seem to be easy.

- ✓ AI must be optimised for our patients' better outcomes.

- ✓ Radiologists, as data scientists, could play a very important role in precision medicine.

- ✓ The "AI-powered" radiologists should lead the diagnostic imaging bright future.

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