RINCKSIDE

Volume 33 • 2022

Science
Medicine
Imaging
Academia
Philosophy
Ethics
Satire
Advice

ISSN 2364-3889

RINCKSIDE

ISSN 2364-3889 • Volume 33, 2022

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RINCKSIDE is published by The Round Table Foundation (www.trtf.eu).
It is listed by the German National Library.

Not being wired properly?

Peter A. Rinck

PRO ACADEMIA EMRF THE ROUND TABLE FOUNDATION

For some time, new developments in MR imaging have been mostly apps and gadgets playing with the data acquired. Seldom the actual usefulness of these appendages is being validated. Such outcome research is neither trendy nor attractive — nor does it fill pockets with ready cash. It is more work to milk a cow and make cheese than watch it digesting.

The development of MRI during the last five decades has been accompanied by paradigm shifts and changes in basic assumptions of what was regarded as conventional wisdom and predictable commercial reward. The new move to low and medium field equipment follows this rule [1].

At present the question for potential buyers of low-field equipment is: Do I want the latest but apparently still immature technology or established and functioning technology that is not that sexy [2]?

When one studies the recent scientific developments one finds that the research branch of the Japanese company Hitachi recently presented an MRI machine that can be switched on and off rapidly, so that it could be used in operation theaters. It is an open 1.1-m-diameter system based on a superconducting magnet made with company-produced high-temperature superconducting magnesium diboride (MgB2) wire. Its length is 5.6 kilometers.

Hitachi stated that it will proceed with the development of various superconducting magnets that use magnesium diboride wires and aim to be refrigerant-free and reduce power consumption.

To date, in most cases these wires are very brittle and the connection of one wire to the next seems to be a major problem. The specialists in the field claim that the high stability of the magnetic field necessary to create high-quality MR images cannot be guaranteed and might deteriorate over time. From this point of view the excitement at the prospect of novel wire technologies for superconductive nearly helium-free magnetic resonance imaging equipment seems to be a little premature [3,4].

With their technology the Japanese are one step ahead of an Italian company that already tries to market magnesium diboride superconducting magnets.

A detailed internal scientific memorandum pointed out some difficult steps not yet overcome in the development of a reliable long-term solution, among them the best composition of the kilometers-long wires for the magnets' coils. Apparently the magnet is not operated in the persistent mode due to a lack of reliable superconducting joining technique of reacted magnesium diboride conductors. Therefore, the magnet is continuously charged using a precise power supply during imaging and has a relatively high power consumption, which is perhaps one of the reasons for the limited deployment of this MRI system in hospitals and private practices. Another setback is the weight of the system: 28 tons. Users also complain that the sophisticated multi-position patient examination couch is difficult to clean and disinfect. However, a great advantage of this MR system is the option that patients can be moved from a supine, lying down, to a standing position, allowing imaging under the effects of gravity.

The "old-fashioned" competition might be more reliable

In this, the magnesium diboride manufacturer competes with a well-established company producing MRI equipment in the same Italian city. They also have a tilting weight-bearing MRI system permitting multi-position imaging for instance for musculoskeletal applications. It has a proven conventional "old-fashioned" permanent magnet that doesn't suck much energy, doesn't need helium, and its weight is only 7.9 tons.

For decades the euphoria over new offspring techniques of MRI has been reliably followed by disillusionment. Exaggerations are and were widespread. There has been progress but much of the trust of the people who actually count on the developers and researchers was lost. They were taken on a constant roller coaster ride into nowhere.

Many patients, politicians and, to some extent, physicians believe that higher medical performance and novel medical equipment are a sign of higher quality in care. Very often new diagnostic technologies are claimed to be more cost efficient and faster – but then early adopters are annoyed by malfunctioning or badly thought-out equipment. We do not know yet what the outcome in this case will be. It's another wait-and-see situation.

By the way, both manufacturers compete also with pictures of healthy-looking young female patients in their commercials … I know which one I prefer.

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Rinckside, ISSN 2364-3889

Citation: Rinck PA. Not being wired properly? Rinckside 2022; 33,1. 1-2.

The state of Artificial Intelligence in medical imaging – Part 1

Looking into the future with blinkers on

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PRO ACADEMIA EMRF THE ROUND TABLE FOUNDATION

At a TRTF Round-Table Colloquium intrinsic and essential aspects of artificial intelligence were discussed by a number of invited professionals in the field. This column and another one to follow will present some of the essential points that were touched upon.

First and foremost, there is no clear and generally accepted definition of what is considered AI. One fundamental outcome of the colloquium is the statement that there is no artificial intelligence and never will be. There are "limited-intelligence" expert systems for dedicated applications, for instance aimed at computer-assisted diagnoses (CAD), chess playing software or self-driving cars – better described as brainpower and knowledge replacement software.

But the chess software cannot knit and a self driving car cannot write novels. They cannot learn to knit and they cannot learn to write. Artificial diagnostic systems can diagnose a fracture but they cannot put the arm in a cast. These softwares will be permanent apprentices, biased and subjective, never neutral and objective, reflecting the ideas, ways of thinking and the input of their creators.

They are not transparent but in most cases completely opaque. If you are a referring physician and you want to know how the radiologist came to a diagnosis, the human image reader can explain it to you. Getting such an explanation from a machine will be difficult; it is unable to scrutinize and challenge the veracity of the data it digests. Deep learning AI cannot explain how it draws a conclusion – in particular if its "learning" is augmented with surrogate data collected from the internet. The number of trained radiologists is shrinking. If there is no trained radiologist around you have to live with the machine outcome: you have to believe its validity.

Algorithms can also be written in a way that the outcome is determined in advance by built-in bias, and certain procedures are recommended or even performed without further human deliberation and approval. Considering the state of the world one cannot trust a machine-intelligent system that is a black box. More so, increasingly, doltish and blundering dilettantes have access to research facilities – single-minded nerds, data autists – and unqualified "soft scientists".

Opposition is building up against empty promises of what AI will be able to deliver

Radiologists taking care of patients every day have a rather negative view of these nerds. Some years ago they would still consider computer geeks as part of academia, but now they are placed into the drawer of "technicians". What used to be computer or information science has lost its scientific standing and is simply informatics now, IT – the nerds are computer or network technicians. They meddle in medical or scientific questions without having any knowledge or comprehension of practical medicine.

The technocratic attitude to develop novel data collection strategies and image reconstruction techniques does not relate to dealing with sick people. It is part of a wild goose chase like many quantitative applications in medical imaging.

Medicine is about human beings. The advocates of AI in medicine and particularly in diagnostic imaging no longer consider people. They are under the misconception that one can reconstruct a living person using data: Humans are reduced to data-delivering objects to be administered and processed by health care desk jockeys.

The emphasis of artificial intelligence is on a collective rather than individual description. It works with statistics, with averages. It's assembly line health care, not the medicine that has been the ethical base of being a medical doctor until a while ago. The idealistic goal of personalized medicine is being trampled on by the same people who propagated it as our goal some years ago.

AI will have the position of a middleman between medical doctor and patient, giving little but making a profit for the manufacturer. It will definitely be a major new cost factor in medicine, not only in development but also in maintenance costs. And there is no proof whatsoever if the value of AI outweighs the value of a trained medical doctor. Except if the medical training in the rich countries gets even worse than it's now. Is it *Work in Progress* or *Work in Regress*?

Rinckside, ISSN 2364-3889

Citation: Rinck PA. The state of Artificial Intelligence in medical imaging • Part I – Looking into the future with blinkers on. Rinckside 2022; 33,2. 3-4.

The state of Artificial Intelligence in medical imaging – Part 2

Are radiologists' neurons faster and cheaper?

Peter A. Rinck

PRO ACADEMIA EMRF THE ROUND TABLE FOUNDATION

The overall positive picture of AI painted in many presentations at the European Congress of Radiology in Vienna this summer and at other conferences is not necessarily mirrored outside the IT business and technologists' world of medical imaging. Features are seen in a different light by radiologists in hospitals and private offices as well as independent expert AI scientists and major consulting companies.

Reservations are building up against naive and simplistic promises of what AI will be able to deliver. The often described neural networks are clearly gross oversimplifications of the actual neurons of a human brain. The neurons of a well-trained radiologist work faster and more efficient — although computer assistance can facilitate administrative, diagnostic, and research routines.

Jack Copeland, a cutting-edge AI researcher and leading professor in the field, wrote about artificial intelligence:

> "Exaggerated claims of success, in professional journals as well as the popular press, have damaged its reputation. At the present time even an embodied system displaying the overall intelligence of a cockroach is proving elusive, let alone a system that can rival a human being. The difficulty of scaling up AI's modest achievements cannot be overstated [1]."

Eric Daimler, the chief executive of Conexus AI in San Francisco, shares that opinion:

> "The trendy foundational models of deep learning are not software composable. This is a limitation of the models and means that they will always have weaknesses that are more appropriate to jobs with low-consequence outcomes. Deploying this tech alone in life-critical environments in not currently solvable with just bigger models [2]."

The classification of AI

AI research attempts to reach one of three goals:

- (1) *Strong AI* which aims to build machines that think;
- (2) *Cognitive Simulation* — here computers are used to test theories about how the human mind works — for example, theories about how people recognize faces or recall memories; and
- (3) *Applied AI*, also known as advanced information processing, which aims to produce commercially viable 'smart' systems — for example, expert medical diagnosis systems such as supervised or unsupervised *computer assisted detection or diagnosis (CAD)* [3] or *machine (deep) learning (ML)* [4].

Software designs offered for medical imaging are not genuine AI, but rather basic or sophisticated CAD or ML systems. Machine learning is concerned with the question of how to construct computer programs that automatically improve with experience. Their aim in radiology is that more routine imaging, including diagnosis and reporting, be done in an automated way.

For this purpose four prerequisites must be met:

- data of sufficient quantity and quality,
- a powerful algorithm,
- a narrowly defined task area,
- a concrete goal to be achieved.

Of the four prerequisites, sufficient amounts of *data* will be easily available; however, its quality is and will remain imprecise, inadequate, and often irreproducible as described for instance by Lloret [5]:

> "One of the problems comes from the variability of the data itself (e.g., contrast, resolution, signal-to-noise) which make the Deep Learning models suffer from a poor generalization when the training data come from different machines (different vendor, model, etc.) with different acquisition parametrization or any underlying component that can cause the data distribution to shift."

More so, it is well known that scanner effects can be subtly yet significantly affect machine learning [6]. This holds for both quantification and detection, the most common AI/ML applications that prospective vendors apply for approval to the FDA. We have discussed the pitfalls of such quantifications earlier [7].

Data quality is and will remain imprecise, inadequate, and often irreproducible

Suitable *algorithms* will be obtainable — yet each AI vendor is producing its individual AI variants. Some will be better than others and all will presumably deliver — slightly or distinctly — different results.

As far as the *task areas* and *concrete goals*, there will be dozens, perhaps hundreds of different softwares for different organs or diagnostic questions. There won't be one general algorithm based on training datasets for the whole human body — with all the variations from children to old people [8] and covering sufficient geographic locations representing diverse cohorts [9,10].

At the end, the software should be able to draw inferences relevant to the solution of the particular task or situation. Often validation of the CAD and ML systems is missing [11]. As one example for many, a group from the University of Cambridge scrutinized several thousand publications and concluded:

> "Despite the huge efforts of researchers to develop machine learning models for COVID-19 diagnosis and prognosis, we found methodological flaws and many biases throughout the literature, leading to highly optimistic reported performance [12]."

Fast Science

AI in medicine and particularly in medical imaging, has long slipped out of dependable scientists' control. Looking at the publications and talks at meetings, there are more unqualified than qualified contributions. Similar to the frenzied hype with functional imaging (fMRI) that led to some 40,000 fMRI papers of 'questionable validity' [13,14], it is to be feared that the way applied AI is used in medical imaging carries an analogous risk.

A new approach to research is catching on: Fast Science. All and sundry presume to have an expertise in anything, including AI, but most lack the competence to explain and judge. There is a quasi-religious belief in artificial intelligence with science fiction fantasies. Everybody wants to beat a possible financial or career competitor by a whisker. Often the arguments are not scientific but *ad hominem*:

> "… beneficial AI applications run the risk of not being adopted because of a lack of proven health and economic benefits and may lead to potential health loss and unnecessary costs, which are likely to persist until AI, with its seemingly endless possibilities, is recognized as an intervention that can and should be properly assessed [15]."

In other words, if you don't jump on the AI train immediately you are guilty — you hurt patients and waste their money. You are coerced into jumping on the train of 'endless possibilities'. Crowd psychology teaches that there is a human desire to be member of a group, thinking, behaving and deciding the same way without individual critical evaluation — to minimize conflict and not be excluded: don't check whether AI works and has proven positive impact — just be part of it.

Medicine is on its way back to arbitrary research without questioning its understanding of scientific groundwork. Thus, half-baked layman's wishes determine the direction — and in most cases IT specialists, health administrators, even natural scientists getting involved in medicine are these laymen. A wave of *hocus-pocus* and *hocus-bogus* is rolling.

However, reassessment during the last years has led to a certain pensiveness. It seems as if many of the promised benefits are missing. Will the results and the outcome be cheaper, faster, more reliable and better than the evaluation of medical images by a trained radiologist?

Surveys of radiological associations and acceptance by potential users

Surveys by radiological societies and consulting firms are sobering: artificial intelligence faces a slow acceptance and is achieving fairly limited success. One of the conclusions of an analysis of the news magazine The Economist together with the Swiss Pictet Banking Group reads:

> "Findings suggest that AI investment is increasingly concentrated in a narrowing field of commercial applications, which may come at the expense of more exploratory and foundational research [16]."

The acceptance by radiologists is guarded and slack as both the European Society of Radiology (ESR) and the American College of Radiology (ACR) reveal:

> ESR: "In the previous ESR survey conducted in 2018, 51% of respondents expected that the use of AI tools would lead to a reduced reporting workload. The actual contributions of AI to the workload of diagnostic radiologists were assessed in a recent analysis based on large number of published studies. It was concluded that although there was often added value to patient care, workload was decreased in only 4% but increased in 48% and remained unchanged in 46% institutions. In summary, this survey suggests that, compared with initial expectations, the use of AI-powered algorithms in practical clinical radiology today is limited, most importantly because the impact of these tools on the reduction of radiologists' workload remains unproven [17]."

> ACR: "Approximately 30% of radiologists [in the U.S.A.] are currently using AI as part of their practice. Large practices were more likely to use AI than smaller ones, and of those using AI in clinical practice, most were using AI to enhance interpretation, most commonly detection of intracranial hemorrhage, pulmonary emboli, and mammographic abnormalities. Of practices not currently using AI, 20% plan to purchase AI tools in the next 1 to 5 years. … Conclusion: … The survey results indicate a modest penetrance of AI in clinical practice [18]."

AI is mostly used and tried out in university and other teaching hospitals — to produce articles and talks to promote the career of younger doctors. The increase of the number of examinations particularly at high-throughput institutions doesn't necessarily go hand in glove with quality.

"Recently published medical imaging studies often add value to radiological patient care. However, they likely increase the overall workload of diagnostic radiologists, and this particularly applies to AI studies [19]."

Risks

There are numerous risks, 'second-order' effects, and unexpected, uncontrollable implications of employing AI/CAD/ML.

■ With only small amounts of training data, deep learning models can figure out demographic features such as age, sex, body-mass index, and race even from corrupted, cropped, and noisy anonymous chest x-rays and CT images with high discriminative performance — often when clinical experts are unable to pinpoint these features.

This ability creates an enormous risk for all possible deployments in in medical imaging because the AI software could run amok invisibly in the background. It is a bias that might lead to wrong diagnoses and therapy, as well as to discrimination of patients [20,21,22].

The results are artificial 'gossip' and 'rumors'. You can't trust this secondary outcome and it has nothing to do with the task the software has been asked to perform. Artificial intelligence of this kind is not intelligent enough to distinguish real facts from self-created fiction.

■ A report by the US-American consulting company McKinsey discusses other potential risks of AI in detail. It claims on the one hand that AI will improve our lives by "enhancing our healthcare experiences" — whatever that might mean — but also sees:

> "There also are second-order effects, such as the atrophy of skills (for example, the diagnostic skills of medical professionals) as AI systems grow in importance [23]."

However, trained radiologists are essential: While the likes of the regulatory authorities may develop a series of testing cases to compare products from different vendors these cases will only reflect a limited range of pathologies — rarer pathologies may not be included. The end user has no concept of how good or bad the particular algorithm is at making a correct diagnosis in a particular case and the system is likely to provide a black or white response.

Can the software say 'I don't know, I am not sure — we need an expert opinion in this area'? The user of the software will be unaware that there may be a degree of uncertainty or bias.

Radiologists tend to know colleagues who have particular expertise in certain fields. They can refer difficult cases to them up for a second opinion. Does this referral request have any equivalent place in AI? The pundits will say that AI will improve as the training data increases — but what happens when radiologists providing difficult or rare diagnostic solutions no longer exist because AI has superseded them?

What happens if a health system fails (in this case the British NHS) and there are no radiologists available? Then it is: any port in a storm. For most European countries it was an unthinkable development although even on the continent this was brought up earlier [24]. Now we read:

> "Radiographer reporting is accepted practice in the UK. With a national shortage of radiographers and radiologists, artificial intelligence (AI) support in reporting may help minimise the backlog of unreported images [25]."

The authors explain that a minimum of 50% of plain x-ray images should be reported by a radiographer with the help of computed diagnosis. They admit that the complexity of these systems means that the processes are not transparent, sometimes even to the developers.

Meanwhile, of all institutions, the European Union has woken up and wants 'a risk-based approach' to AI [26].

The commercial side and conflicts of interest

Preconceived ideas deceive the senses. Who is credible and trustworthy in AI development? A study of industry ties reveals:

> "We found that the prevalence of financial ties to industry … was high. For nearly 30% of comments, we were unable to determine whether or not there was a financial tie, and disclosure of ties was non-existent. The proportion of academic submitters was relatively low, and the use of scientific evidence to support comments was sparse. We recommend that the FDA requires disclosure of potential conflict-of-interest, and encourages greater academic participation and use of scientific evidence in public comments [27]."

There are several hundred vendors of "AI" for medical imaging applications, among them a large number of start-ups and spin-offs. There is no place in the market for more than 90% of them. They will not stay alive and disappear because there will be no return on investment — be it government or European Union money, venture capital or other sources. Some have already merged with competitors because they cannot survive as standalone companies. What will happen to their employees, their founders, the venture capital invested, the state grants given?

One of the taboo topics in AI sales in medicine is the question of accountability: Who is liable if a computer's decision causes damage? Is it the manufacturer or the user? If a company tries to sell you an AI program you have to insist that in the sales contract the company underwrites its use and that it takes all responsibilities for possible performance failures.

The end — if and what to buy

A long time ago I wrote a column 'How to purchase an MR machine • In ten easy lessons.' It began with this sentence:

> "Murphy's Law is the most reliable guideline when buying an MR machine: anything that can go wrong usually does [28]."

The column could be easily adapted to AI/CAD/ML. Thus, I was not not puzzled when a 'saleswoman scientist' I knew well confessed to me: "I know that our software doesn't work, but we sell it anyway."

What was taken for granted yesterday will change today. The high-technology wonderland needs permanent change to earn money.

My advice to department heads: Train your people even better than today, and wait and see until the method is established and proven — or not. Don't waste time and money. And never forget: Neither radiologists nor AI are infallible.

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Rinckside, ISSN 2364-3889

Citation: Rinck PA. The state of Artificial Intelligence in medical imaging • Part II. Are radiologists' neurons faster and cheaper? Rinckside 2022; 33,3. 5-9.

Follow-up – Columns Readers Liked

Re-read: The price of it all

Peter A. Rinck

PRO ACADEMIA EMRF THE ROUND TABLE FOUNDATION

It's always a painful sensation when one realizes that a service or a product one pays for is overpriced and of inferior quality. At times I am asked to give a second opinion about imaging examinations, mostly magnetic resonance studies made in private offices in the U.S.A.. It's usually patients from Latin America who traveled to the US because they believe that the health system in Miami, New York or Chicago is better than in their home country. Many among them would be aptly and correctly served at home by well trained radiologists, even better than in the U.S.A..

Usually the quality of the studies I see is sufficient to make a diagnosis, but in a number of cases there is no reason to be proud of the radiological work. Equipment maintenance is not written with a capital M and image artifacts are common — it seems that the more expensive the apparatus is the more artifacts you get.

Sometimes one also wonders whether there is enough competence, experience and professional integrity to choose certain kinds of studies, and to perform and evaluate them. However, it's not my business to discuss this with a patient or colleague who just wants my opinion concerning a certain study and diagnosis.

Often I am told what the patients were charged for their studies. Again, I don't comment on the prices although sometimes I have to swallow hard. I got a health insurance that covers treatment all over Europe and the rest of the world. It is not cheap. The U.S.A. is the only country that is explicitly excluded: for the US one needs an additional insurance — some insurance brokers even suggest air-evacuation back to Europe in non-life threatening situations: because of the cost. There is a chasm between the US and the rest of the 'developed world' — as well as some 'developing countries' — that cannot be explained by the standard of medicine. There are more than enough studies underlining that US-Americans do not get better health care than patients elsewhere.

Nearly thirty years ago I wrote in one of my columns: "Two terms are important: 'patient-driven', which means that the patient must be the center of medical thinking; and 'outcomes' because that is what is important for the patient. To many administrators, politicians, radiologists and industries, patient outcomes are secondary. We hardly know anything about the outcomes of what we are doing in diagnostics and therapy [1]."

This has not changed. Even worse, today the US spends nearly 20 percent of its gross domestic product (GDP) — reaching $4.1 trillion or $12,530 per person for 2020 — on health care. In the column I mentioned above I referred to the status in 1990: at that time the expenditure was 10.7% of the GDP. In the meantime it nearly doubled.

Hospitals, drug companies, device makers, physicians and other providers benefit by charging inflated prices.

Some years ago, there were several long and alarming articles about this problem in Time Magazine and in the New York Times [2-5].

As Elisabeth Rosenthal in one of her three articles in the New York Times stated:

"Hospitals, drug companies, device makers, physicians and other providers can benefit by charging inflated prices, favoring the most costly treatment options and curbing competition that could give patients more, and cheaper, choices. And almost every interaction can be an opportunity to send multiple, often opaque bills with long lists of charges: $100 for the ice pack applied for 10 minutes after a physical therapy session, or $30,000 for the artificial joint implanted in surgery."

and:

"[US] Americans pay, on average, about four times as much for a hip replacement as patients in Switzerland or France and more than three times as much for a

Cesarean section as those in New Zealand or Britain. The average price for Nasonex, a common nasal spray for allergies, is $108 in the United States compared with $21 in Spain. The costs of hospital stays here are about triple those in other developed countries."

Ten years later the prices have slightly changed: In the United States the price of Nasonex is between $70 and $270, in France, for instance, between $3.50 and $ 5.00. As one says in France: *Vive la petite différence*. And — why do US health outcomes lag other countries?

On the other hand, the trend in Europe is similar. Slowly by surely, medicine turns into a for-profit market segment — radiology being at the forefront, but not the leader. Prices go up, quality goes down: all over Europe the health systems are deteriorating rapidly.

As a potential patient, I have nothing against paying a fee to fellow physicians, also covering the salaries of their assistants and secretaries. However, I object to feeding un- or even counterproductive bureaucratic parasites in hospital administration, state health administration, in a grotesque 'health' industry and — above all — insurance companies and banks. Increasingly and without pity, they bleed sick and helpless people dry — bye, bye Hippocratic oath; what's left is business and self-interest.

As a physician I add: Why should I fatten an overblown administration with my work — why should a single medical doctor work to support a pernicious pack of pencil pushers and con men?

The health system in many European countries is better, but for how long? For the U.S., neither Steven Brill in Time Magazine nor Elisabeth Rosenthal in the New York Times offered a solution to this problem. I guess they know why. Personally, I have never been in favor of a state health system, but what the U.S. needs is a state-regulated system with state-set (low) reimbursement ceilings for medical services, a separation of physicians from the health management and insurance business, and a nationwide obligatory health insurance for all.

In other words, a revolution that would change the entire social structure of the United States of America.

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Rinckside, ISSN 2364-3889

Citation: Rinck PA. Follow-up – Columns Readers Liked. Reread: The price of it all. Rinckside 2022; 33,4. 11-12.