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What has really happened in radiology since 1985?

Peter A. Rinck

PRO ACADEMIA EMRF THE ROUND TABLE FOUNDATION

These days, the 20th anniversary of a journal is something special. Most journals die younger, particularly those that are not taken seriously by serious readers.

Many people in the field read the journal *Diagnostic Imaging*, with pleasure and for information they do not get elsewhere. They read it superficially perhaps, as many things are covered and have to be treated superficially. *Diagnostic Imaging Europe* might not be unique, but it's good. Above all, it is honest, in spite of the highly competitive commercial environment, and it reflects the trends in radiological thinking. Furthermore, it's a European platform reflecting European approaches to medical imaging.

"We live in a global village" is a stupid phrase happily repeated by politicians and the like. However, even such a marginal occupation as ours varies in some respects from one country to another. French radiology is different from German radiology, although the pictures are also produced in black and white. *DI Europe* allows readers a glimpse across borders, which other journals do not necessarily offer.

To celebrate the anniversary, the editor has asked me to contribute something fitting, perhaps slightly personal. Of course, I rejected this offer. Why talk about myself?

I decided to become a radiologist in the mid-1970s, when I was still at medical school. A major reason for entering the field was my collection of several hundred crime novels. Radiology involved a touch of detection. At that time, radiology was about x-rays, not computing. Years later, most of my crime novels were destroyed in a mudslide, and the rest were lost some weeks later when a hot water pipe in the ceiling of the storage room exploded. But I still liked the "sleuth touch" of radiology.

In the hot summer of 1975, I tried to get my first radiological bearings in a small Swiss hospital. I read a book by Zdansky called "Roentgen Diagnosis of the Heart", which was probably not the best introduction to radiology but was one of the best books on cardiac imaging. [1,2] It was very difficult to understand how the shape of the shadow of the heart on a chest x-ray changed according to various acute or chronic diseases. I blamed my limited knowledge of medicine. Only later did I realize that there is no exactness in medicine, and that in radiology sometimes you see what you believe.

There is no exactness in medicine, and in radiology sometimes you see what you believe.

This remains true today. If you can take pictures of something and show them to people, they'll believe that what they see in these pictures is important, one of the leading examples being a CT scan of the heart. The question is whether the information obtained has any influence on possible therapy and the health outcome of a patient.

Let's skip some years, countries, and inclinations during my circuitous career in radiology and return to the main topic: What has changed in radiology between 1985 and 2005?

The common answer is nearly everything. The days of plain x-rays have passed for most of us in Europe. Everything is computed, and new modalities have moved in and on. A radiologist with the knowledge that was current in 1985 would not be able to practice in Europe today, whereas a radiologist from 1960 would have had no major problem performing examinations and reading images in 1980.

Breast imaging is the outstanding example of how radiological techniques have changed. Plain x-ray mammography has been the gold standard for decades, although it has improved on a regular basis. In between, we saw xeroradiography and thermography come and go. Xeroradiography seemed to be a promising and more efficient method, but it lacked spatial resolution. Thermography was even worse, and it was unreliable in detecting early carcinoma. Today, conventional x-ray mammography coexists side by side with digital mammography, and MR mammography waits in the wings.

The human body and its diseases and ailments are still the same. Therefore, the medical subspecialties are still the same. Several modalities and techniques are different, however, as the imaging indications have been adapted to new modalities, and the referring physicians ask novel diagnostic questions.

During the last 20 years, ultrasound and MR have been the major new advances in medical imaging, ultrasound dating some years further back than MR. Ultrasound has become a valuable addition to the stethoscope for many physicians, and MR imaging is a clean and elegant modality for answering diagnostic questions in formerly inaccessible parts of the body.

Other developments, among them PACS and spiral CT, are only accessories in the application of computers in medicine, rather than new technologies themselves. Praised as innovations, they are not scientifically innovative.

Other developments, among them PACS and spiral CT, are only accessories in the application of computers in medicine, rather than new technologies themselves. Praised as innovations, they are not scientifically innovative.

In many instances, there is little critical analysis. Thinking spoils illusions and is not good for sales.

The German radiologist, Gunter W. Kauffmann, stated in a long and well-founded 1999 article defending radiology:

"It is the declared intention of radiologists and their learned societies to intensively stimulate the development and utilization of alternative examination methods without ionizing radiation to minimize the radiation exposition of the population according to the patient guidelines of the European Union." [3]

Today we see an explosion of powerful CT equipment. It can be argued, however, that multislice CT is a step back into invasiveness. A technology that potentially does bodily harm to the patient should be avoided at all costs [4], unless there is proof of its superiority. But there is no proof. The last 20 years have seen the rise of outcome studies and their decline.

Outcome studies are strenuous and bad for business. Perhaps science, combined with ethics, will overcome developments that are not called for. On the other hand, science should be open and, within ethical rules, unrestricted.

The last 20 years were also characterized by the growth of the diagnostic business. Increasing commercialization and competition for patients have turned many a radiologist into a businessperson. The boundaries between being a medical doctor and a merchant often blur in the same way that boundaries between medical tools and toys merge.

Checking the contents of radiological journals from the last 20 years reveals that few learned papers seem to have survived or to be relevant today. This is how science is supposed to work. Ideas come and go, but only the fittest ideas survive. Unfortunately "fit" does not automatically mean useful for the patient.

This is nothing new, as Moliere demonstrated in his play *A Doctor Despite Himself* 350 years ago:

> Geronte: "It seems to me that you are locating them wrongly: the heart is on the left and the liver is on the right."
>
> Sganarelle: "Yes, in the old days that was so, but we have changed all that, and we now practise medicine by a completely new method." [5]

For more than 20 years, the Nobel Prize Committee did not consider radiology to be a major innovative performer in medicine "for the benefit of mankind." Allan M. Cormack and Godfrey N. Hounsfield received the Nobel Prize in Medicine or Physiology for the development of CT in 1979. In 2003, the medical Nobel Prize went to Paul C. Lauterbur and Peter Mansfield for their pioneering research in MRI. Interestingly, among those people involved in their research and invited to the presentation in Stockholm there was, to my knowledge, only one radiologist.

It seems that radiologists are not the source of technological progress in radiology. Of course, this claim is not completely true, but it keeps readers agitated and they will read this entire article.

What happened to radiologists during the last two decades? Not many of them can perform a small bowel enema, an enteroclysis, any more. When did you perform your last lumbar puncture? Everybody, however, knows anatomic structures that radiologists were unaware of 20 years ago. The style of work has changed. Classical x-ray radiology was a craft, often dealing hands-on with the patient. This has been replaced by interventional therapeutic radiology, which also has evolved enormously during this period.

Most of diagnostic medical imaging today is a sedentary occupation that involves pushing buttons and watching pictures on a screen. The techniques have become more intellectually challenging, although interpretation of the hundreds of images created per patient can be more like reading coffee grounds than interpreting a chest x-ray.

I recently gave my archive of early issues of *DI Europe* to the editorial office. I donated to a library more than 20 years of scientific journals, weighing nearly 1.5 tons. The journals spanned from the very beginning of clinical MRI until the turn of the millennium. Among all those copies of *Magnetic Resonance in Medicine, Radiology, European Radiology,* I found the 30th anniversary issue of *Playboy*, dating from 1984.

It has a black cover, like *European Radiology,* and contained interesting articles. I kept it.

I am looking forward to the 30th anniversary issue of *DI Europe* – for its color pictures, of course.

Note: Some time after this column was written, the journal was sold and its format changed. And I stopped writing for it.

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Functional imaging leads hunt for 'buy' trigger

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In 1990, Dr. Jack Belliveau and colleagues at Massachusetts General Hospital in Boston published the results of a successful experiment designed to observe and image stimulation of the human visual cortex on MRI [1]. Using the first-pass effect after bolus injection of a contrast agent, they demonstrated changes in cortical perfusion upon activation with a photic stimulus.

The use of bolus tracking to study changes in perfusion was an exact analog of previous experiments involving PET or SPECT to observe radioisotope tracers. Performing such a function-related experiment with MRI instead of nuclear medicine techniques offered vastly superior spatial and temporal resolution, without administering radioactive materials. The need for dual injection of contrast, however, posed a problem, especially for studies of brain activation in normal individuals.

This disadvantage was resolved by the BOLD-contrast mechanism, first described by Dr. Seiji Ogawa [2].

His elegant technique for demonstrating brain activation has led to a rapid proliferation of functional MRI over the past few years. BOLD-contrast relies on the fact that paramagnetic deoxyhemoglobin possesses a far stronger magnetic moment than diamagnetic oxyhemoglobin. Interaction of the bulk magnetization of deoxygenated blood with the external field sets up local field variations in and around blood vessels. These susceptibility effects can be measured using appropriate MRI sequences.

The only energy source in normal brain cells is the oxidation of glucose. Because the glucose storage capacity of brain cells is negligible, the brain depends heavily on a constant supply of glucose and oxygen via the capillaries. This increased demand leads to more blood flowing to the activated area. This, in turn, decreases the local susceptibility effect, which can be visualized with susceptibility-sensitive imaging techniques.

Both approaches try to determine how the brain reacts when certain stimuli reach its owner. Today an increasing number of institutions perform fMRI. Most of this work is done for research purposes, though routine applications are on their way.

Results from fMRI continue to tickle the imagination of researchers and the population at large.

fMRI has replaced MR spectroscopy as the favorite MR research modality. MRS fascinated researchers, but this early enthusiasm has faded. Results from fMRI, on the other hand, continue to tickle the imagination of researchers and the population at large because it shows the brain at work and reacting to the environment. MR imaging can detect changes in brain hemodynamics that correspond to mental operations.

fMRI has fascinated me from its very beginning. Suddenly, we had access to a noninvasive safe technique that could be repeated in the same person. One could see almost real-time cerebral responses to a range of activities, including viewing a picture (activation of the occipital lobe), listening to music (activation of the area around the Sylvian fissure in the temporal lobe), and physical interaction (activation mostly in the contralateral temporal lobe).

Today, fMRI maps that show brain regions responsible for speech help presurgical planning. They enable estimation of the risk of postoperative deficits and appropriate selection of treatment: surgery versus radiation or chemotherapy.

The technique may also play a role in the assessment of psychiatric disorders. Cognitive scientists are at the forefront of research applying fMRI to better understand brain function.

One such study cast doubt on the belief that a group of severely brain-damaged people were unaware of their surroundings. The researchers discovered that these individuals could, in fact, register what was going on around them, but they could not respond [3].

The technology could be a powerful tool to help doctors and family members determine whether a person has lost all awareness.

Consumer industries are also harnessing fMRI. Automobile manufacturer Daimler-Chrysler, in collaboration with the University Hospital in Ulm, Germany, discovered that male test subjects tend to use a different thought process than females when navigating a maze. Comparison of fMRI maps revealed that most men try to configure a map of the maze in their mind, while women are more likely to use landmarks for orientation.

Other studies of *in vivo* brain activity have looked at gamblers and the process of deciding between options. Researchers at Baylor College of Medicine in Houston, Texas, used fMRI to examine the mental activity of people drinking cola. Images indicated that Pepsi activated parts of the brain linked to pleasure, while Coca-Cola activated areas dealing with trust and memory [4]. In another study, Daimler-Chrysler concluded that the reward centers in men's brains are activated when they look at racy sports cars [5].

These and similar studies form part of neuroeconomics and neuromarketing, a fascinating offshoot of economic science. Neuroeconomics combines psychology, economics, and the medical neurosciences. James Montier has written an entertaining review of state-of-the-art neuroeconomics [6]. I decided to read some of the original articles that Montier cited. The authors of one paper describe their results:

"This study examines the bold response one TR (1.5 s) before the results screen, because decision making for cooperation is likely to be salient at this TR independent of the subject's position in the game." [7]

This sentence does not actually describe the results of a study. Basically, it does not make sense at all.

The combination of medical sciences (particularly imaging) and economics has created a hybrid discipline that lacks a solid scientific basis. Economic theories are based on observations, and, in this respect, they are close to history and philosophy. Economic science uses mathematics to create models of social processes or speculative predictions of the stock markets. Such models are prone to failure. If you take "scientifically created" pictures, however, people believe that the pictures show something relevant. The higher the color signal on the fMRI image, the better the product must be. Yet, unlike electroencephalography and magnetoencephalography, it does not provide a direct measure of neural or synaptic activity.

The higher the color signal on the fMRI image, the better the product must be.

Good luck with this idea. Some people even believe that fMRI can be used to read thoughts, allowing market researchers to pry a little. Companies regard the chance to find out what their customers really think as a great opportunity. But fMRI does not show what people think. Most people do not remember which product or person is featured in a given commercial.

When confronted with a certain endeavor, I sometimes ask myself whether it is scientifically sound and whether I would invest my personal money in it. Neuroeconomics is not at all scientifically sound. The combination of a reasonably exact science with a "rubber" science will always produce nonscientific results. On the other hand, people will invest in it.

Nearly 50 years ago, Vance Packard wrote in his best-selling book *The Hidden Persuaders*:

"This book is about the large-scale efforts being made, often with impressive success, to channel our unthinking habits, our purchasing decisions, and our thought processes by the use of insights gleaned from psychiatry and the social sciences. Typically these efforts take place beneath our level of awareness; so that the appeals, which move us, are often, in a sense, 'hidden.' The result is that many of us are being influenced and manipulated, far more than we realize, in the patterns of our everyday lives [8].

"We still have a strong defense against such persuaders: we can choose not to be persuaded. In virtually all situations we still have the choice, and we cannot be too seriously manipulated if we know what is going on. It is my hope that this book may contribute to the general awareness. As Clyde Miller pointed out in The Process of Persuasion, when we learn to recognize the devices of the persuaders, we build up a 'recognition reflex.' Such a recognition reflex, he said, 'can protect us against the petty trickery of small-time persuaders operating in the commonplace affairs of everyday life, but also against the mistaken or false persuasion of powerful leaders."

Packard knew nothing about "reading the brain" with fMRI. Yet he predicted that what you see in those images might not really reflect the "buy button." His book is still worth reading today. Only the scientific toys have changed. But even methods like fMRI and PET will not create a major step forward in understanding how the human brain deals with marketing.

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Radiology must regain initiative in research

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Looking into the future always means interpreting mystical signs. We never know what will really happen because calculated reasoning plays only a small role in progress, and many medical procedures are founded on fallacies or financial interests. More than 10% of the population works in medical care, the pharmaceutical industry, or allied professions in some European countries [1].

Healthcare costs to society vary considerably. The United States spent 13% of its gross domestic product on healthcare in 2000, and Japan spent 7.8%. Yet Japanese life expectancy is the best in the world, while the U.S. is ranked 33rd [2]. By comparison, Spain spent 7.7% of its GDP, Sweden 8.4%, and Germany/Switzerland 10.6%.

The contribution of medical imaging to healthcare costs is estimated to be less than 5% in the U.S. and from 1% to 3% elsewhere in the world [3,4]. The number of imaging procedures performed is rising by 10% each year, due mainly to increased utilization of x-ray angiography, CT, MRI, and PET. The technology with the largest expenditure is ultrasound because of the enormous number of ultrasound examinations.

More than a decade ago, in 1994, I posed the question: “Do radiologists have a future?” [5]

Radiology's future depends on more patient-oriented research and development of applications.

Some readers responded to the article, and together we concluded that while radiology does have a future, radiologists do not. Diagnostic imaging devices are no longer the exclusive province of radiologists. That is, if they ever were.

This verdict covers both routine clinical radiology and medical imaging research. Medical imaging has a rosy future ahead, and radiology will contribute to its success.

But radiologists do not own it. Radiologists depend on referrals from-and interaction with-other physicians. Meanwhile, other medical disciplines have established strongholds within medical imaging. In Germany, for instance, 70% of imaging examinations are performed by non-radiologists [6].

Radiologists must focus on clinical relevance and subspecialization to survive. They must become MR specialists or gastrointestinal radiologists, for example, if they are to be equal partners with clinical physicians and not simply their photographers.

Non-radiologists are more likely to use diagnostic imaging inappropriately and to select less suitable approaches than imaging specialists. Understanding constantly changing techniques and equipment is nearly impossible for somebody who is not completely dedicated to medical imaging.

Fighting the “amateur radiologists” is difficult and exhausting. Patients may be better served if radiologists educate their rivals instead. Careful preservation of existing radiological know-how for plain x-ray examinations, for example, might save future radiologists from having to learn these techniques from general practitioners.

Academic Perspective

Despite discussions of turf wars and threatened positions, there is actually a shortage of radiologists. Out of 400 positions for radiologists advertised in the U.K. in 2000, only half could be filled. The U.S. had 330 empty positions for radiologists during the same year, and Sweden had more than 50. The lack of staff is still a problem, and it is a vicious cycle. We have more medical imaging in hospitals and clinics, and fewer trained radiologists.

The situation in medical imaging research looks even bleaker. Research positions command lower salaries than clinical appointments and are less prestigious. Radiology research 30 years ago comprised mainly patient-centered investigations into the improvement of x-ray imaging techniques. The advent of computers and new modalities has broadened the scope of research considerably. Sometimes it seems as if the balance has shifted too far from intelligence and professional craft toward machines.

Today's discipline of “medical imaging” unites conventional radiography (including digital imaging), ultrasound, CT, MRI, interventional radiology, nuclear medicine, and optical imaging, as well as paramedical methods in biosciences, pharmacology, and computing. Boundaries between anatomic and/or metabolic data acquisition, the development of new tracers and/or contrast agents, and data storage and/or distribution have become blurred. Everything is part of medical imaging.

Budding researchers, group leaders, and department managers are faced with a wide range of topics to select from. The decision is not easy. Personal and financial interests may overlap and influence judgment. Driving forces in research are curiosity and ignorance, a hunger for power and money, and the question, “What is best for the patient?” Research by physicians should have a moral and ethical dimension.

Much of today's academic radiological research is solely technology-oriented or a combination of technology and application. There is hardly any “pure” or “basic” research. Sometimes young researchers perform “l'art pour l'art” and confuse method with result. Their results are changes or new versions of existing methods. Instead of keeping their eyes on the goal, they just play around.

Certain kinds of diagnostic screening that rely on indirect signs of malignancy will be replaced by non-imaging laboratory tests once these become available. Researchers should remember this when planning ahead. Screening methods that are morphologically and functionally nonspecific, such as x-ray mammography, will vanish over the next 20 years. It is useless to invest time and money in the development of techniques that are inferior to those that exist already.

A return from technology-focused R&D to simple patient-oriented research may still be possible. This kind of radiological research is not costly and requires little equipment. A change in mental attitude would be needed, however. Actual research requires tenacity and persistence. It is all too easy to become diverted. Not many people have the time, financial resources, or energy to investigate multiple scientific topics. Radiologists usually move into research while acquiring the fundamentals of their craft. Many part-time researchers regard this as a step in their career, not the beginning of a lifelong commitment. Yet this is not entirely bad news. These researchers will still have the opportunity to see and learn how academic life functions.

Anyone planning an academic research project should review his or her own-and the group's-competencies critically. These competencies should include the ability to organize, manage, and follow through on a project from inception to delivery of final results. Radiologists, in common with all other medical doctors, are not scientists *per se.*

The definition of what constitutes research is often in the eye of the beholder.

Most European countries have few, if any, dedicated research positions in radiology. Introductions to and basic training in research activities are scarce. A full-time clinical job cannot be combined with comprehensive research activities. If a department head suggests that research could be performed during evenings and weekends, young would-be researchers should consider moving elsewhere.

The definition of what constitutes research is often in the eye of the beholder. Few European countries have implemented a quality review system that involves visits from external assessors.

Europe is lacking a truly-scientific academy where young radiology researchers could be taught solid research skills. A “European Academy of Medical Imaging Sciences”, for instance, could teach the use of library databases, data analysis using inferential statistics, the design of complex experiments, preparation of formal laboratory reports, and presentation of results, both orally and in written form. A satellite network consisting of existing research laboratories with a proven track record could serve as the foundation for such an academy. The institution should be multidisciplinary but essentially medical rather than a mixture of computer science and industrial applications. Patients should not become oddities in the research scheme.

The nature of presentations given at major radiological meetings has changed over the past 20 years. The main focus is often not radiological skills but supporting technologies and financial management. Some 7,000 or so scientific papers on imaging topics are published every year. This includes 3,000 in North America and the same number in Europe [7].

In 1991, former British Medical Journal editor Dr. Richard Smith stated that fewer than 1% of these papers contain new scientific findings or relevant medical information that has an impact on medical diagnostics and therapy [8]. This statement still holds true.

Radiology research is becoming increasingly competitive and aggressive, due mainly to the huge commercial market. Much of the explosive development in medical imaging is fueled by the enormous power of industrial players and their marketing departments. Most scientific groundwork in medical imaging is performed either by researchers from non-radiological disciplines, such as medical physics, biology, pharmacology, neuroscience, computer science, or the military or by x-ray technologists.

Many people still regard the U.S. as the best country to perform research in. Academic research does progress at the same level in certain countries on this side of the Atlantic, but U.S. institutions offer better working conditions in many instances. Approximately 20,000 German researchers, physicists, medical doctors, and molecular biologists are thought to be carrying out research in the U.S. at present.

Some researchers and research groups, mostly at U.S. universities, work specifically toward grand rewards such as the Nobel Prize. They choose their research topics with this in mind and structure their research teams accordingly. They no doubt perform excellent research. But their main aim is to gain money and power, not to help patients. They lobby widely, recruiting the assistance of their university's public relations department or external agencies. Their results are published in the daily press before they appear in scientific journals.

Europe has excellent facilities and competent researchers. Its main problems are money-sucking state bureaucracies, rigid hierarchical structures, and difficult access to multidisciplinary cooperation. Radiological research used to be the domain of European and North American scientists. Since the end of the 1980s, however, postdoctoral fellows from China and India have held powerful positions in U.S. academia. Some of these researchers have now returned to their home countries and are installing very competitive, low-cost, high-quality academic and commercial research facilities for the life sciences and medical technology.

Many European academics are not aware of this development. Multinational companies, on the other hand, have been watching this move and have created research centers in China and India to tap into the knowledge base of these well-trained and hardworking scientists.

Industry versus Individuals

Medical industry – not academic researchers – can take most of the credit for the explosive progress in medical imaging. Innovation from industry is driven by market needs. But the new developments companies promote are usually oriented toward short-term financial gain. They do not produce medical equipment or accessories for altruistic reasons.

At least 20% of all presentations at the annual RSNA meeting in Chicago have commercial links. It is not necessarily inappropriate for commercial interests to influence the topics of radiological research, but this kind of research might lack a direct impact on disease diagnosis and treatment. Efforts to improve PACS and RIS equipment, for example, will just produce better systems for patient administration. The impact is equivalent to that of a new color sticker code on x-ray envelopes 30 years ago. Working toward the paperless department is not radiological research. Novel computer applications in offices may be good for the economy, but they have no direct bearing on patient care.

Many universities and politicians have pushed third-party research over the past decades. Sponsoring agencies, such as state research foundations and the European Commission, manufacturers of equipment and accessories, and venture capitalists, have all contributed financially to research.

Academic researchers who have reached the “final goal” and cooperate with one of the big commercial companies usually have a fast, crude awakening. One should not harbor great expectations from such liaisons, which are as flexible as semi-democratic state administrations. Collaboration with small companies, however, can be different, and research by itself still counts.

The tremendous upsurge of medical imaging techniques has made it difficult to decide how best to choose between different examinations and how to interpret their results. An innovation may be deemed clinically valuable only after millions of euros have been spent or decades passed after its introduction. Healthcare payers and patients should demand hard evidence that a certain imaging examination is useful, cost-efficient, and beneficial. Outcomes research should govern such decisions if radiologists want to influence how and when these new technologies are used. Radiologists rarely perform this kind of research.

Change for the Better?

The radiologist's professional environment undergoes a slight metamorphosis every year. After 10 years, the entire environment has changed completely. Sometimes we would like to stop things, at least for a while. We would like to say, “That's it. No more change for the next 10 years.” Believing in progress is one engine of humankind. But uncritically believing in progress is stupid.

Try to answer these questions honestly: Do I understand the existing imaging technologies? Can they be used to answer the diagnostic (or therapeutic) questions asked by patients and/or referring physicians? If not, how can research improve my capabilities to answer them? If yes, do we need more diagnostic tools? Or do we need more standardization, better understanding and education, and continued professionalization?

My view is that we need basic research. We need patient-oriented research and development of applications. We do not need more consumer electronics turned into radiological toys.

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