KULTUR ANAMNESEN 3

Medical Imaging and Philosophy

Challenges, reflections and actions

EDITED BY HEINER FANGERAU, RETHY CHHEM, IRMGARD MÜLLER AND SHIH-CHANG WANG

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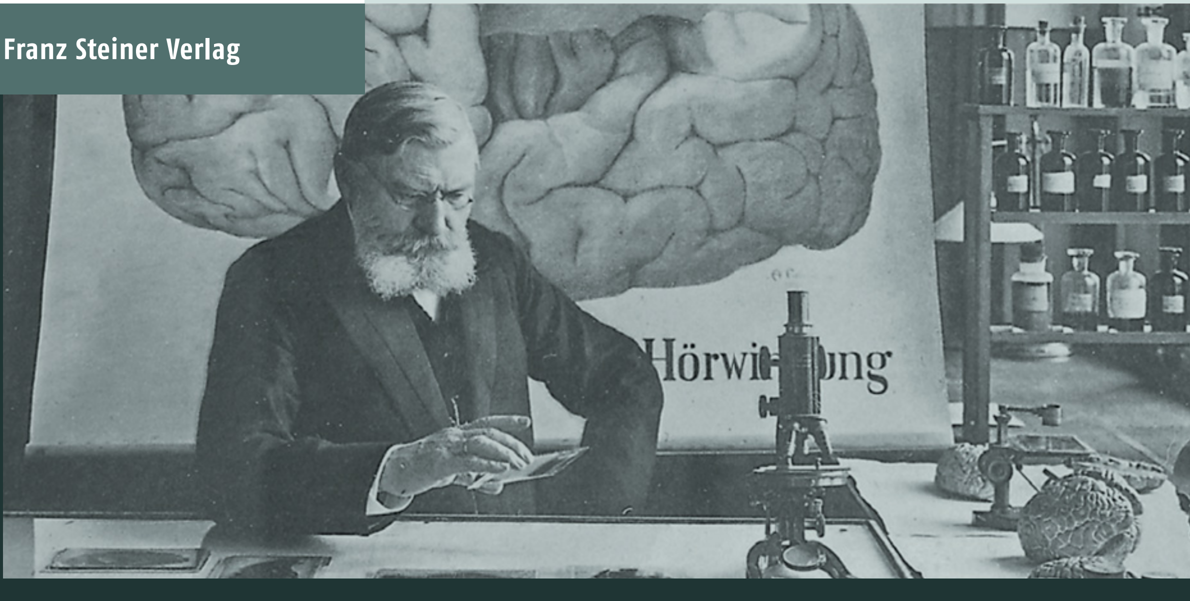

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Conference Proceedings

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INHALTSVERZEICHNIS

FOREWORD: MEDICAL IMAGING: CHALLENGES, REFLECTIONS AND ACTIONS

Rethy Chhem, Heiner Fangerau, Irmgard Müller, Shih-chang Wang

Medical Imaging plays a prominent role in contemporary medical research and practice. At the same time imaging in its broadest sense, including illustration, diagramming, model-making, photography and other forms of image rendering, has a long tradition in medicine.

Imaging has served different purposes ranging from depicting to backing concepts or creating convincing evidence. Thus, imaging the human body has different aspects not only related to techniques or current interpretations of visual representations through medical imaging technologies. Furthermore, the way the human body was and is displayed in images also reflects a range of cultural, historical, artistic and scientific concerns.

Therefore, the editors of this book organized an international interdisciplinary conference in 2010 to bring together perspectives on Medical Imaging from medicine, philosophy, history and arts. The aim of the conference was to discuss medical images as scientific representations, their inherent ontologies and ethical aspects related to representing the human body.

The topics that were discussed included the production of knowledge using imaging techniques and the commonality of that knowledge across imaging modalities, the role of data and data collection for medical diagnosis and communication, the role of formal ontologies in representation and communication with medical images, norms of health and disease and the understanding of body (and mind) as they are shaped by imaging technologies, and the interdependence of technology, medicine and information science.

Now we are proud to present with this book the proceedings of this interdisciplinary conference including representative examples of what was presented and discussed. We will start with two papers by Rethy Chhem and Shih-chang Wang reflecting on Medical Imaging from the perspective of medicine and radiology. We will then delve into questions of representing ontologies and "scientific truth" with the help of images. The papers by Irmgard Müller and Heiner Fangerau, James Overton and Cesare Romagnoli, Kirsten Brukamp, Frederick Gilbert and Heiner Fangerau and Robert Lindenberg examine the evidentiary status of images, ontological structures in radiology, processing procedures, brain reading metaphors and chains of representation in medical imaging. This more epistemologically oriented section is followed by a section focusing practices and media in imaging the body. Fabio Zampieri, Alberto Zanatta and Maurizio Rippa Bonati reflect upon Iconography and Wax models in the promotion of vaccination Katsiaryna Laryionava examines how contemporary art redefines the human body, Richard Hoppe-Sailer, Rainer-M. E. Jacobi and Sarah Sandfort critically analyse the interconnections between the spheres of visual representations, the body and knowledge and Kathrin Friedrich displays how the practices of a "sight collective" influence diagnostic procedures in computed tomography. In a final section Santiago Sia is "looking behind the image" and is raising in an outlook philosophical and ethical issues in medical imaging that might be in the focus of a following conference.

We hope that these conference proceedings with their wide scope are stimulating to readers interested in the status of medical images and their interpretation by different disciplines and that this book fosters further discussions. We wish to express our gratefulness to all the authors for their participation and to the German Research Foundation and the Centre for Medicine & Society, Ulm University for generously funding the publication of these conference proceedings.

The editors, July 2011

I. MEDICAL PERSPECTIVES – USE AND REFLECTION

MEDICAL IMAGE: IMAGING OR IMAGINING?

Rethy K Chhem

INTRODUCTION

The rapid developments and progresses in medical imaging in the last three decades have radically improved and transformed the way physicians perceive and see the human body. These changes have totally revolutionized medical practice. Many organs and structures, which were in the past invisible to conventional X-ray examinations, are now revealed through sophisticated imaging modalities such as computed tomography (CT), ultrasound (US) or magnetic resonance imaging (MRI). Furthermore, nuclear imaging such as positron emission tomography (PET), is used together with CT or MRI to form "hybrid imaging" (i.e. PET/CT, PET/MRI) and enables a simultaneous study of both structure and function (or dysfunction). The pace and scope of such scientific and technologic progresses have brought a new paradigm to the generation of new knowledge, and resulted in a range of philosophical questions in both epistemic and ethical issues. In this paper, the reflection will focus mainly on these epistemological issues relating to the formation of medical images, which now play a pivotal role in medical decision-making. For examples, such issues are applicable to the diagnosis and therapy in cancer care: i.e. X-rays and MRI are used not only to detect a bone tumour, but also to establish its extension to the surrounding tissues, or to exclude metastasis from its original site to the distant organs such as the lungs or brain.

MEDICAL IMAGE: THE HISTORICAL PERSPECTIVE

The historical roots of this quest to look at the inside of the human body can be found in the ancient story of the Buddhist doctor, Jivaka who was known as "The legend of Jivaka and the King of Physician's tree". Jivika was a physician in the royal court of King Bimbisara (558BC–491BC) of Maghada in Ancient India, a thousand years ago. One day, outside the royal palace, Jivaka met a boy carrying a bundle of wood sticks on his back. Jivaka was surprised that he could see the boy's internal organs through his body. He recalled the magical property of the King-Doctor's tree, which would make the inside of the body visible. Jivaka bought the wood sticks from the boy, who then dropped the bundle to the ground. Suddenly, the intense light that illuminated the boy's internal organs faded away and his body returned back to normal. Jivaka pursued an "experiment" by applying each one of these sticks to the boy in turn until he has found the famous King-Doctor's wood stick. Jivaka kept this stick as a diagnostic tool for his medical practice (De Saint

Firmin 1916). This may be be the origin of the "ultrasound probe" as dreamed of by many other doctors of the ancient Buddhist kingdoms of Asia.

In Europe, until the 17^{th} and 18^{th} centuries, a doctor remained "at a distance" from a patient, because visual inspection alone seemed to be the most appropriate way to establish a diagnosis. By the end of the 18^{th} century, this "clinical gap" was reduced as a result of the development of new clinical tools (Foucault 1989: 167), e. g. the auscultation of lungs and heart with a stethoscope. Because there is no disease without a seat (i. e. the origin of the disease), a closer "gaze" is necessary to establish a diagnosis. It was Giovanni Battista Morgagni from the University of Padua, who pioneered this approach, when he published his seminal work in 1761, on the "The seats and causes of diseases". While the distance between physician and patient was bridged by auscultation in the early 19th century, the pre-auscultation "clinical gap" was restored through medical imaging when radiologist assessed a patient "at a distance" using X-rays examination.

The process as described by Foucault by studying the body from the "symptomatic surface" to the "tissue surface" through the dissection of corpses (Foucault 1989: 166) was no longer necessary following the emergence of medical imaging, which started with the discovery of X-rays by Roentgen in 1896. The internal organs (the subject) are now "visible" by medical imaging. The Foucauldian "medical gaze" from the anatomo-clinical dimension (i. e. the surface of the human body) to a pathological anatomy dimension (i. e. the internal organ as the seat of disease) no longer requires an opening of the body. X-rays, ultrasound, magnetic fields and radio-frequency waves have replaced the scalpel. The invisible part of the human body is now revealed with great details through medical imaging.

MEDICAL IMAGE: THE PRODUCTION LINE

Modern medical imaging allows us to study the inside of the body. However, the many complex mathematical and technical processes for image acquisition and manipulation could lead to the generation of other signals, which do not seem (at least a priori) to be a reliable representation of the specimen. Such signals are called "artefacts". These artefacts could lead to interpretation errors and could increase the risk of making a wrong diagnosis. However, in other situations, these "artefacts" may in fact contribute to diagnosis, e. g. by delineating a blurred anatomical boundary between a tendon and the surrounding fatty tissues, i. e. the "anisotropic artefact" for an ultrasound procedure.

The key question is: "Does the image displayed on the monitor accurately represent reality, e. g. does this truly reflect the structures of a patient's knee in the MRI room"? The image displayed is the result of an interaction between an X-ray beam or an electro-magnetic and radiofrequency wave and the body. More recently, PET/CT (Positron Emission Tomography/Computed Tomography) was introduced to clinical practice as a major tool for cancer imaging. This innovative technology allows not only an accurate delineation of anatomy, but also an assessment of an organ's functional and metabolic pattern. A radio-active tracer is injected intravenously before scanning. An image is obtained following a number of complex steps. To quote Dr. Vibhu Kapoor, “PET provides images of quantitative uptake of the radionuclide injected …. However, for accurate results, the images must be corrected for the effects of attenuation of the 511-keV photons as they pass through the patient. In contrast to PET, which used an external radioactive transmission scan, PET-CT uses CT transmission data to correct for attenuation differences. After reconstruction, the CT, attenuation-corrected, and attenuation-uncorrected images obtained from the unified PET and CT protocol are transferred to, integrated at, and displayed on the syngo software platform. Differential PET to CT weighting, cross-hairs linking of the axial, coronal, and sagittal reformatted images, and interactive viewing of the CT, PET, and fused images are possible” (Kapoor et al, 2004). This lengthy excerpt from an article published in the radiology literature was selected purposely to show the complex process of image generation for a PET/CT procedure. The image is produced through a series of physical processes, which involve mathematical transformations and complex computations.

The black and white image obtained is conventionally “displayed” as a variation of tissue densities (CT), signal intensities (MRI) or echogenicity (ultrasound). To make this “scientific image” to resemble closer to the actual knee, computer programs enable the manipulations of cross-sectional 2-D images into a volumetric image. This is “post-processing”, i.e. processing after the data set was acquired. The result is a “3-D reconstruction” of the 2-D images. This terminology sheds light on this new paradigm in the “visualization” of the human body, which clearly implies that such image is artificially created as a “scientific representation” of the body part being examined. The next step in this quest towards a more realistic image, with a closer resemblance to the original, is to process the data set by “virtual reality”. However, the term “image” must be firstly defined. How “real” is this image when compared to the body part being examined? After all, the final image is the result of numerous image processing steps!

MEDICAL IMAGE: THE DEFINITIONS

Before discussing “medical image” further, it is important defining the term first. According to the Cambridge International Dictionary of English, an image is a “picture that is formed by a mirror or a lens” (1995: 704), or a “picture in the mind of what something or someone is like”. This is far from how doctors define a medical image. The definition given by the French dictionary, “Le Petit Robert”, is much closer to what we conceive as a medical image; i.e. a “representation of an object by graphic or plastic arts” (Le Petit Robert 1990: 960), which can be applied to the representation of an object by a “radiological process”.

Of course, a medical image differs from a traditional painting. The latter is used by an artist to “communicate” his perception of an object through a drawing. Medical images are also construed, but in such case these “paintings” were generated, not by an artist, but by mathematical and physical processes. By this definition, a CT scan of the brain is a digital representation (CT image) of the brain (object).

A range of media is used to display these images, e. g. by films or workstation monitor. By extending this concept, a technique that allows the generation of images by using different types of radiation is called medical imaging (Le Petit Robert 1990: 961). The immense progress in medical imaging science and technology has provided scientists and physicians with a myriad of new ways to visualize the inside of the body and to evaluate both normal and abnormal internal organs. These advances raise a few original epistemic questions. For example, the images have become the centre of physicians' attention, who have requested imaging to identify the internal seat of disease. This leads to a kind of "image worship" of what Crowe referred to as the "icon of medicine" (Crowe 2008: 1627–1630). The patient's body part is displaced behind such construed medical images on which the medical gaze is now focused. Each radiologist should look beyond the image itself, as behind each set of images, there is a patient! It would be of interest to reflect on Plato's cave allegory in which the philosopher believed that those who would find freedom from the cave would only be those who understand that the shadows do not constitute reality. What then is the link between the patient's body part and the image displayed on the monitor? Do the MRI or CT images alone provide sufficient information to achieve a diagnosis? For example, when a radiologist identifies a mass on a CT scan, he then uses his knowledge and clinical judgement to raise the possibility of a tumour. Indeed, such medical imaging-based diagnosis must be confirmed by biopsy and histology of the specimen obtained.

How do these medical images, as a representation of the body, contribute to medical reasoning and judgments in the context of clinical practice? For instance, how can an image that is only a representation of a body part carry any value in the decision-making, which will affect a patient's welfare? These philosophical questions are even more relevant considering the current developments in medical imaging technology. These have reached a level of complexity and sophistication that have revolutionized digital images display on PACS (Pictures Archiving and Communication System) workstations, leading to a new paradigm of image interpretation.

In the late 1970s, a CT scan of the brain produced a dozen of images, while a current CT scan generates thousand of images, making the interpretation very challenging due to the large number of images to be reviewed. Furthermore, the increased complexity from all these technological advances in medical imaging has created an imperative to design computer-assisted diagnostic (CAD) systems and new image display strategies to assist radiologists in their diagnostic task in the future. (Jacobson 2006).

How accurate is the image a representation of the patient? How reliable is the medical image when it is used as a basis for important clinical decision-making? Are we imaging or imagining? As Dyson said, "blind men imagine what they don't see". (Dyson, in Lightman 2005: 254). Both radiologists and theoretical physicists are on the same deep enquiry journey: "seeing the unseen" to quote Dyson. During my two-decade tenure in academic radiology departments, I used to tease my trainees on whether they were "doing imaging" or "imagining" when I taught them the systematic analysis of medical images for diagnostic purpose. This central philosophical question about medical image, with a special focus on neuroscience, was addressed by Illes and Racine (2005).

MEDICAL IMAGE: THE "THINKING TOOL"

For centuries, images were used extensively in scientific representations and therefore serve as a tool for thinking. In the 15^{th} century, the iconic genius Leonardo da Vinci, through his artistic and "scientific" work, has extensively used drawings and diagrams to illustrate the morphology and functions of man and nature (Cremante 2010). His innumerable experiments were probably the best examples of "scientific research" long before that methodology was recognized several centuries later. Physicists and mathematicians generally used equations to explain theories or concepts relating to the physical world. Indeed, in some situations, they used diagrams instead to clarify their thoughts or explain abstract concepts. Dirac explained complex and abstract mathematical concepts in quantum mechanics by projective geometry, a skill previously acquired when he was encouraged to develop "visual imagination" in art and drawing classes (Farmelo 2010: 130). Feynman, who was awarded the Nobel Prize in Physics in 1965, used pictorial diagrams instead of mathematical equations not only to describe quantum processes but also an innovative way to understand nature. This pictorial view of nature, which he called the "space-time approach", became a working language for particle physicists around the world (Dyson 2006: 271). Faraday reasoned and constructed his electromagnetic field concept by using schematic lines of force surrounding a magnetic bar (Nersessian 1992). In contrast to most mathematicians and physicists, natural historians of the 17^{th}, 18^{th} and 19^{th} centuries and biologists of the 20^{th} century often acquired knowledge and developed concepts by using pictures and diagrams. Their scientific knowledge was based on illustrations as they thought by visualizing. Imagination and visual thinking were also important in the development of chemistry (Rocke 2010). An excellent example is the use of a drawing to illustrate and explain the molecular structure of nucleic acids as proposed by Watson and Crick (1953). The historical and philosophical values of art in the creation of scientific knowledge have now been addressed actively by numerous scholars (Baigrie 1996). When images are used as a scientific representation in physics, natural history or medicine, they play a dual role. The first is to serve as a model for reasoning, i. e. a "thinking tool", to clarify or establish an emerging theoretical concept, which will lead to the building of new knowledge. The second is to teach a well-established scientific concept by promoting the dissemination of that knowledge.

An example in medical education for this latter role is in the teaching of anatomy to medical students. For the last several decades, anatomy dissection sessions have decreased significantly in medical education programmes (Older 2004). Students now learn human anatomy via web-based courses, cross sectional pictures from medical imaging databases, or models generated from CT images (Marker 2010; Wanibuchi 2010). For these students, who have no or limited dissection exposure, learning through the electronic media may distort the reality of human anatomy. This is a typical situation where "imaging" is transformed into "imagining" as a study of an object (human body) is actually a perception of an image obtained through a chain of man-made processes starting from the interaction of an X-ray beam with matter (human body) and finishing with the re-constructed images. This learning situation illustrates how future physicians will build knowledge: from a set of re-constructed medical images, instead of cadaver dissection-based teaching. On the other hand, one may also argue how a cadaver can reliably represent the true anatomy of a live individual. The key epistemic issue in medical imaging is that knowledge will be built from the study of an image of an object rather than from the observation of the object directly.

Leonardo da Vinci (1452–1519) is probably the best example of an artist and "scientist" who has used images, drawings and diagrams widely to build and disseminate knowledge. For Leonardo, "All our knowledge has its origin in our perception" (Richter 2008: 6). Observations through numerous experiments laid the foundation for this epistemological approach (Richter 2008: 10). Knowledge is gained through the senses, especially by visualization, for Leonardo. For that renaissance iconic polymath, observation and experience were far more important than theories in books" (Cremante 2010: 574). Two centuries later, John Locke (1632–1704) and subsequently David Hume (1711–1776) underwent a systematic study of epistemology that would become known as "empiricism" (Locke 1996; Hume 2008). Both philosophers claimed that knowledge was initially established by perception. Hence for Locke, "Tis no matter how things are: so the man observes but the agreement of his own observations, and talk comfortably, it is all truth, all certainty" (Locke 1996: 250). Along the same line of thinking, Hume firmly believes that "men learned from experience" (Hume 2008: 76). An empiricist's approach can be applied to the epistemological process in medical imaging where the radiologist would observe and study the image on the X-rays film or monitor and process this information before arriving at a most likely diagnosis. A radiologist could see through the body by using imaging equipment (X-rays, Ultrasound, CT or MRI) while Leonardo used his naked eyes to observe the internal organ of a human body by dissection.

The theory of knowledge as proposed by British empiricists like Hume and Locke sharply contrasted sharply to that proposed by rationalist philosophers like Rene Descartes (1596–1650) who argued that mental reasoning is more powerful to establish reliable knowledge than by using the senses. Reasoning must prevails over perception (Descartes 1950). For Descartes, real knowledge cannot be established either by senses alone, in particular by the eyes, or by pure imagination, i.e. "to form a mental picture" (Cambridge 1995); but only by a cautious process of mental reasoning. For example, Descartes saw "a number coats and hats moving through the street" when he looked out of a window. It was by reasoning Descartes come to the conclusion that there were actually people (not seen), wearing hats and coats while moving around. Indeed Descartes opposed to empiricism because as a mathematician, he believed objectivity could only be achieved through the use of rational thinking. Also as a dualist, mind and body are distinct and separated.

In modern clinical practice, medical imaging plays an increasing role in decision-making, for both diagnostic and therapeutic purposes. It is reasonable to ask whether medical imaging is an “imaging” or “imagining” process from an epistemological dimension. For me, medical imaging includes and relies on the following processes: the appropriate acquisition of images by the machine, the reliable perception of the images by the eyes of the radiologist, and the accurate interpretation of the images by the radiologist. Once these images have reached the brain and the mind of the radiologist, he or she will “imagine”, i. e. form a mental image of the organ that he or she has learned from past anatomy courses. This mental process will project the image within the clinical context, after taking into consideration of the clinical symptoms and the results of laboratory tests. This evaluation by the assimilation of these data (medical images, clinical symptoms and biological results) requires some imaginative skills. Based on the deduction, these data will be considered as normal or abnormal. If abnormal, a most likely diagnosis will be selected from a gamut of diseases that share similar findings. Hence I would argue that medical imaging in clinical setting is a combination of both “imaging” and “imagining”.

The widespread use of images as a “thinking tool” to establish knowledge leads to multiple ethical issues. Indeed, given the complexity of medical image re-construction and the other questions of accuracy and reality, one can ask what are the ethical issues faced by doctors when they use these images as a basis for important decision-making in daily practice. These ethical issues, although essential to the good practice of medicine, are beyond the scope of this paper.

In essence, lying behind every medical image is a patient. So let’s look beyond these medical images!

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PHILOSOPHICAL ASPECTS OF MEDICAL IMAGING FROM A RADIOLOGIST'S PERSPECTIVE

Shih-chang (Ming) Wang

ABSTRACT

We live in an age of extraordinary and stunningly rapid advances in medical imaging. Barely more than a century after the discovery of x-rays and radioactivity, we are using medical imaging to explore the human body in health and disease in ways that were unimaginable even 20 years ago. The extensive permeation of imaging into the practice of modern medicine has meant that much of medical practice has become dependent on it, almost like a habit-forming drug.

This chapter enumerates the various types of medical imaging technologies currently in widespread usage, highlights the strengths and limitations of these technologies, and hopefully will explain how radiologists and other imaging specialists use such technologies to make diagnoses and thus influence or guide the treatment of patients. It explores the nature of radiological expertise, the process of imaging-based diagnostic decision-making, and raises the need for philosophical understanding in medical imaging today.

MEDICAL IMAGING AND PHILOSOPHY

Imaging has a unique place in modern clinical medicine. It is at the intersection of engineering, physics, chemistry, biology, anatomy, medicine, surgery, pharmacology and physiology. After a relatively leisurely start in the first half of the 20th century, today it is advancing and expanding at a breathtaking pace. Since the discovery of x-rays by Röntgen (Röntgen 1895), medical imaging has revolutionized our understanding of the normal human body and the manner in which disease affects its structure, function and physiology. X-ray devices were rapidly developed for clinical application and their use spread across the globe in an unprecedented and extraordinarily rapid fashion. For the first time it was possible to see inside the human body without incising the skin. The field of clinical radiology emerged within 5 years of Roentgen's discovery, and was solely dependent on various uses of x-rays for over 50 years until the advent of newer imaging modalities in the second half of the 20th century.

The rapid development and clinical application of several new imaging technologies has, in conjunction with x-rays, transformed medical practice and led to better understanding of normal structure and disease, safer treatment and better survival and outcomes for patients. This has only been possible because of the