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ABSTRACT This paper examines popular narratives used to discuss magnetic resonance imaging (MRI) examinations in the USA. It shows that these narratives equate the image with the physical body, progress, and authoritative knowledge. This work also traces the political and social effects of these accounts. Drawing from ethnographic research at three imaging sites and in-depth interviews with 48 physicians and technologists, I show how these discourses erase physicians' and technologists' knowledge about and use of MRI technology and images. Analysis of work practices in imaging units and hospitals demonstrates how each image intertwines aspects of a patient's body, socio-technical features, and economic priorities in locally specific ways to constitute the body in medical practice and social life. Despite the tendency of popular narratives to position MRI examinations as objective knowledge, these images are not neutral nor are they equivalent to the physical body. I also show how erasure of physicians' and technologists' everyday work practices reinforces current imaging routines and policies, helping to sustain activities such as direct marketing to potential patients or the placement of imaging technologies in shopping malls.

Keywords magnetic resonance imaging, medical technology, policy, tacit knowledge

Appealing Images:

Magnetic Resonance Imaging and the Production of Authoritative Knowledge

Kelly Joyce

Images of the internal body produced by medical imaging technology occupy a significant place in the cultural imagination. These pictures often evoke a sense of wonder and excitement, as well as the idea that the fleshy, unruly material known as the body has been directly accessed. As a physician explained, 'I always go, "Wow" [when I see an MRI examination]. It's as if you sliced a person in half and looked at them.' Awe, delight, and the idea that the image reveals the inner body are themes typically found in common narratives about medical images.

Alongside these accounts are counter-narratives that challenge this view. Listening to individuals who operate or use imaging technology talk about their work practices allows another understanding of medical images of the body to emerge. An examination of the relationships that surround and inform the production of medical images demonstrates that these pictures are highly mediated representations that are influenced by decisions and values during all aspects of the production process. The images

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do not 'reveal' the inner body, but instead produce the body, bringing together aspects of physical bodies and cultural, social, and economic factors in unique and locally specific ways.

In this paper, I examine tropes used to discuss the anatomical pictures produced by magnetic resonance imaging (MRI) technology – one of the imaging technologies currently used in medical practice – in the media, popular science texts, and hospitals. My analysis shows that there are three dominant ways of discussing MRI examinations in these spheres. These rhetorical practices produce a construction of MRI in which the image and the physical body are seen as interchangeable, the MRI image is seen as superior to other ways of knowing the body, and the technology itself is portrayed as an agent. Like the microbes in Latour's (1993 [1988]) analysis of the 'Pasteurization' of France, the MRI machine is made to speak and act for itself.

When analyzing these tropes, I attend not only to the most visible discourse, but also to processes rendered invisible by these narratives, showing how popular accounts 'black-box' crucial decisions and practices that shape the use and quality of MRI examinations in medical practice.[1] To attend to such black-boxing, I contrast common accounts with ethnographic research conducted at three imaging sites in the north-east USA. The ethnographic material provides thick descriptions of the work practices and social relations in MRI units; it allows different stories about medical imaging to emerge, rendering visible the local knowledge and practices that support and situate the production of MRI examinations.

Analysis of these embodied practices, performed 'in situ' (Lynch, 1985a: 14, 85), demonstrates how MRI examinations represent an intertwining of economic interests, physical bodies, machines, and cultural and institutional practices. Drawing from Elizabeth Grosz's work (1994), I argue that anatomical images 'etch together' local decisions and priorities, technology, and aspects of the physical body to produce what is perceived as cutting-edge, authoritative knowledge. 'Etching', as developed by Grosz, emphasizes how representations of the body always include and merge parts of the physical body with political hierarchies and technical practices to produce what counts as the body in social life.[2] In the case of MRI, popular perceptions of the image as authoritative and transparent reinforce current practices that privilege the image over other diagnostic techniques, and neglect the importance of interpretation in the production of health and illness.

This paper draws from semiotic analyses of the visual cultures produced by medical practice and research. Work in this area demonstrates how beliefs about gender, race, and family shape narratives about particular medical images, such as ultrasound images of the fetus or the Visible Human Project.[3] This type of analysis focuses on the finished image, examining closely the political contexts that shape its interpretation. In addition, the rich tradition of qualitative research in science and technology studies (STS) also informs this analysis.[4] This body of work uses

ethnography and ethnomethodology to gain insight into the meaning scientists attach to their work as well as a deeper understanding of the social forces and networks that shape scientific research and the production of artifacts. It brings into view the practices that create scientific images.

In this paper, I demonstrate how popular accounts produce and magnify particular ideas about MRI examinations while simultaneously erasing or marginalizing other possible ways of understanding them. The combination of textual analysis with ethnographic research shows how current medical practices rely upon the invisibility of physicians' and technologists' knowledge about and use of MRI. Imaging policies that require only one interpretation of an image or promote the idea that the image alone offers the 'truth' about a patient's condition are sustained and maintained through this erasure of everyday work practices.

Discourse analysis and fieldwork also demonstrate just how radiologists, referring physicians, and technologists make sense of MRI images. Physicians and technologists – when explaining work practices or describing what they perceive of as error or intrusions in the image – use narratives that illustrate how human actions and values influence the content and use of an image. However, when talking about MRI examinations with each other and patients, they also use tropes that identify the image with transparency, objectivity, and progress. The continual use of such tropes, combined with broader cultural views that link mechanically produced pictures to the 'revelation' of the physical world and the production of truth, enhances the status of anatomical images, thereby increasing their significance in the construction and assertion of authoritative knowledge in contemporary medicine and culture.

Background

MRI is one of many medical imaging technologies used in contemporary medicine. Ultrasound, computer-assisted tomography (CT), and X-ray also comprise the imaging 'armamentarium' commonly used by physicians and healthcare workers. Among these technologies, MRI is considered a desirable technique. It is thought to provide high-quality images and medical professionals consider it to be the 'gold standard' of imaging technology. It is also one of the most expensive imaging technologies – a new machine can cost 1 to 2 million US dollars.

MRI technology was introduced to clinical practice in the 1980s. Medical professionals use this technique to quantitatively measure the activity of hydrogen atoms in a particular area of a patient's body. To begin an examination, a technologist – the individual who works directly with both patients and the MRI technology – places the patient into the machine. The technologist then uses computer programs to divide the section of the body to be evaluated into discrete, consecutive slices, and to measure how long it takes for hydrogen atoms in each of these slices to release the energy absorbed from radio-frequency waves. The original

information produced by MRI is thus numeric, not visual. These numerical measurements are transformed via computer software into a series of anatomical pictures.

After the numerical data are transformed into images, they are sent electronically or on film to a physician. The physician – typically a radiologist, but legally it can be any licensed MD – creates a written interpretation of the content of the images. This written report becomes an important part of each examination, and is sent – usually along with the actual images – to the referring doctor or medical provider who initially ordered it. Although there are many layers of translation that occur in the production of MRI examinations – bodies are transformed into numbers, which are converted into images, which are then interpreted in a written report – it is typically the machine itself and the images produced that are the focus of attention in media and popular culture narratives.

Popular Narratives about Magnetic Resonance Imaging

The Image as Transparent Knowledge

Medical imaging is a source of fascination for news media and popular science, and is frequently featured in science exhibits at museums and other sites. MRI is often included in such accounts, and is understood by healthcare workers, research scientists, and the public as one of the best and most expensive imaging technologies. Popular narratives construct a singular understanding of MRI images – one that emphasizes their ability to render the body transparent – while simultaneously erasing or marginalizing other ways of comprehending these artifacts.[5]

This understanding of MRI involves three rhetorical moves that I found to be used recurrently to discuss MRI examinations by news media and popular culture.[6] The first move positions the image as interchangeable with the real thing depicted instead of a construction of it. This narrative practice assumes that there is an a priori body that exists outside of human mediation, and that MRI provides access to this material body. Here both language and text as well as human and non-human interaction are effaced as the 'reality' of an a priori body emerges. These accounts then forge links between medical images and the production of authoritative knowledge: MRI examinations are thought to eliminate the uncertainty of disease and to provide a definitive explanation of a person's condition as located in their body.

Articles in *Life* and *FDA Consumer* magazines demonstrate this way of understanding anatomical images. For example, in the February 1997 issue, *Life* announced that MRI and other medical imaging techniques 'allow us to see, and to know ourselves in ways unthinkable a century ago' (Dowling, 1997: 56). Similarly, *FDA Consumer* reported that MRI 'provides a look into the body' (Nordenberg, 1999: 10). The language used in these accounts 'black boxes' the work of computer software as it creates numerical codes and images, and the work of humans as they produce and

interpret the images. In doing so, the narrative construction erases the difference between the image and the body. The picture of the body and the body itself are made to seem interchangeable and equivalent instead of divergent and different. In addition, these examples show how representations of imaging technologies tend to connect pictures with the production of expert knowledge. Medical images allow us 'to know' ourselves in a manner that is portrayed as new and important.

Academic science texts written for a popular audience also construct the view of medical imaging characterized earlier. In *Looking Within: How X-Ray, CT, MRI, Ultrasound, and Other Medical Images Are Created and How They Help Save Lives,* for example, author Anthony Wobarst uses language that conflates the body with the MRI image; he also links these images to the production of truth and certainty. Wobarst notes that MRI 'reveals the structural details of the various organs' (1999: 19). The distinction between the flesh and the image is collapsed; the image becomes interchangeable with *instead of a construction of the real.* Wobarst concludes his discussion of MRI with a possible patient scenario. This imaginary case study demonstrates how the patient's ruptured disk is 'unveiled' by the use of MRI. The image reveals the truth of this person's back condition, allowing him to be 'back on his feet' within days (Wobarst, 1999: 167). In this text the images are said to provide the knowledge that enables a cure and a return to a normal life.

This first rhetorical move or way of talking about medical imaging is found in a variety of non-fictional, popular texts about science and technology.[7] In all, narratives about MRI images are saturated with the notion that they represent unmediated access to a body that exists outside of language and human actions, and that they provide certainty and definitive answers about a person's physical condition.

Magnetic Resonance Imaging as Progress

The second rhetorical move found in popular narratives about MRI examinations involves the use of contrast between medical images and the clinical examination. This move further strengthens the idea that MRI examinations represent neutral knowledge that renders the body transparent. Clinical examinations and other 'low-tech' tools such as stethoscopes, touch, and patient histories are always positioned as subjective and inaccurate sources of knowledge, while the MRI or medical image represents a better, more objective, neutral technique. Furthermore, the clinical examination is labeled as (or implied to be) 'primitive' in contrast to an image that is taken as a sign of 'progress'.

An article about medical imaging in *FDA Consumer* illustrates this rhetorical practice. Tamar Nordenberg, the author of this article, concludes her discussion of medical imaging with the following passage:

> Wanda Diak's ovarian cancer has not been evident for almost three years. During her follow-up exams, she says, her doctor sometimes taps on her stomach to check for signs of reoccurrence. The method seemed primitive

> to Diak, but her doctor pointed out that before CT scans and other imaging, different sounds were all doctors had to clue them in to an abnormality. 'I think about someone tapping on your stomach rather than having this image that essentially slices you in half so you can see inside', Diak says. 'It's like the caveman to the year 2000.' (Nordenberg, 1999: 12)

This narrative contrasts medical imaging with the physical examination, suggesting that imaging is superior to other ways of knowing the body. The use of the phrase 'different sounds were all doctors had' implies that the knowledge obtained by the physical examination is not as valuable as that provided by medical imaging. This belief is further enforced by the labeling of the physical examination as 'primitive'; it is thought to come from the time of 'cavemen'. In contrast, medical images are linked to the year 2000, which positions them as part of modernity or progress.

This comparison – which is crucial to the positioning of MRI images as unbiased and the producer of certainty – is relied on in many cultural sites. A recent exhibit at Epcot co-sponsored by the Radiological Society of North America (RSNA) and Disney, for example, illuminates this type of narrative strategy. The video that featured MRI – called 'an adventure' by the Disney Imagineers – provides an important example of how MRI examinations get positioned as true and objective while the clinical examination and other 'low-tech' procedures often get labeled as misleading and subjective.

The Epcot 'adventure' begins with a voiceover that says, 'Let's let the MRI tell the story. With it we've eliminated guesswork from diagnosis.' After this statement, the film moves to an enactment of a short discussion between an Olympic athlete and her doctor. In this conversation, the athlete expresses concern and anxiety about her ability to compete in the upcoming events. She had injured her ankle and was unsure about the extent of the damage. The physician looks at the MRI examination to answer this athlete's questions. After studying the images, the doctor declares that the ankle injury is not a problem. The athlete responds to this information with a broad smile. As the video concludes, an image of the athlete competing in an Olympic event flashes across the screen.

This video illustrates MRI's positioning in the public realm as objective and as the primary producer of knowledge, not only of a patient's condition, but also of the human body. Other techniques, such as the patient history and the physical examination, are relegated to the margins as potential, yet less accurate, forms of knowledge. The opening narrative makes this clear: 'With [MRI] we have eliminated the guesswork from diagnosis.' This statement positions MRI as true, accurate knowledge and other techniques as subjective interpretation. The video includes no reference to the use of the patient's history or clinical evaluation as a way to diagnose the ankle problem. Instead, viewers are led to believe that MRI images provide the answer and reduce the risk of a wrong diagnosis, thus

enhancing a person's ability to be in control and compete in life's challenges.[8]

This way of framing MRI examinations is repeated throughout popular culture and mass media narratives. The use of comparison bolsters the view that MRI provides a superior form of knowledge – one that is objective and complete. It also reinforces the notion that use of MRI technology removes subjectivity from the process of diagnosis.

Magnetic Resonance Imaging as Agent: It Talks, It Knows, and It Reveals

The third rhetorical strategy used to discuss images positions the images themselves as actors; MRI becomes a core participant in the production of knowledge. As Haraway and Latour have argued, humans are *not* the only ones represented as actors in discussions about science and technology. Non-humans are ascribed agency in these narratives as well. Transformed into agents, these non-human actors are then able to do work for the advancement of different positions (Latour, 1993 [1988]: 38–40; Haraway, 1997: 143). In cultural narratives, MRI is given an almost magical power; the distinction between machine and image is often blurred as MRI speaks, reveals, and expresses knowledge. The Epcot exhibit begins, for example, with a statement about 'MRI telling the story'. In this example, MRI 'talks': it acts.

Other narratives recreate this personification as well. An article in the *New York Times*, for example, noted, 'But John Abraham was not so lucky today when a magnetic resonance imaging examination revealed a partial tear of the medial collateral ligament in his left knee' (Battista, 2002: D1). In this passage, MRI 'reveals' the condition of Abraham's knee. This way of talking about MRI gives it agency. Through these rhetorical practices, MRI becomes an actor – one who creates authoritative knowledge and provides access to unseen parts of the body. Human beings are nowhere to be found in these accounts.

In this case, the positioning of MRI as an actor further supports the idea that the technology provides neutral knowledge. It reinforces the notion that it is the machine and the images produced by it that reveal the truth about a person's body. This encourages the idea that human values and social contexts do not 'taint' this form of information about health and illness.

These three ways of talking about MRI examinations and technology were common across a diverse set of texts in the public realm. These tropes were also utilized by members of the medical community during my fieldwork and interviews. These narratives, however, were not the only ones used by physicians and technologists. Physicians and technologists are flexible, discursive actors who occupy multiple social worlds. These locations – which include various local cultures within the clinic and the broader social milieu – allow physicians and technologists to speak about the image and the technology in a variety of ways.[9]

Medical Narratives about Magnetic Resonance Imaging

In my research, radiologists, technologists, and referring physicians used multiple narratives to discuss MRI. The three tropes observed in popular culture and media accounts were one set of discursive strategies mobilized by physicians and technologists to discuss MRI with colleagues, patients, and observers such as myself. While the physicians and technologists understood – through their work practices and training – that the image does not render the body transparent, they often used popular rhetorical practices to articulate observations about MRI examinations in everyday conversations with each other and patients.

First, physicians and technologists at the research sites used narratives that conflated the anatomical image with the body. One physician stated, for example, 'MRI is really the same as the anatomy labs. You can look at the anatomy perfectly, see everything.' Another explained, 'Now with MRI you are going to be seeing the heart in real time. You are going to be seeing the lungs in real time. You are going to be marching through the body with MRI.' As in the public discourse, MRI images are discussed in a way that suggests these examinations provide unmediated access to the truth of the body. In this way, the virtual becomes the real.

Second, these same medical professionals also utilized the comparison of MRI images to other techniques to bolster the view that medical images represent objective knowledge. One radiologist noted, for example, 'Physical examinations are guesses as to what is going on. The imaging is really key.' Another doctor stated that 'Using MRI, one can easily look and see that there is a disc [problem in the back]. It's all very cut and dry. It's not like, "Oh well. I can do an examination on you and [tell you that] you have some sort of lower back pain. We don't know exactly what's causing it. It's probably a disc".' In these narratives, the contrast between MRI and other techniques is used to emphasize the authority of medical images. The MRI examination is considered to be 'very cut and dry'; it is the 'key' that leads to certainty and knowledge. In contrast, the physical examination is positioned as subjective and unreliable through the use of words such as 'guesses', 'probably', and 'we don't know exactly'.

Finally, the physicians and technologists also employed language practices that position MRI technology and the images produced by it as agents. This practice was not as common in my fieldwork and interviews as it was in the mass media accounts, but it did occur. One radiologist explained, for example, 'It was MRI that diagnosed that problem. MRI has told me that the patient has had strokes, but I don't know what caused it.' Or, as another noted, 'Why is MRI used? Because it gives an answer. It gives a more definitive answer than other modalities do.' In this way, MRI is positioned as an actor in the production of knowledge.

In all, these three tropes were an integral component of language practices in imaging units. The use of these narratives demonstrates how medicine is a social practice that is influenced by and influences cultural ideologies and narratives about identity, knowledge, and health.[10] Radi-

ologists, technologists, and referring physicians – as social actors – use available interpretations and frames to explain the images and technology. The physicians' and technologists' use of these narrative techniques in turn reinforces their use in other social fields such as the media and popular culture. Biomedicine is culture; the two cannot be separated.

The decision to use these tropes is further bolstered by the location of these particular physicians and technologists in clinical medical practice. As Anne Beaulieu (2002) demonstrates in her work, there are multiple ways to discuss medical images of the brain; local contexts support the choice of particular rhetorical practices over others. Beaulieu's research shows that neuroscientists in research laboratories use narratives that emphasize the numerical components of MRI and PET scans. In contrast, practicing radiologists rely on pictorial tropes to describe the same types of images (Beaulieu, 2002: 63).

The physicians and technologists interviewed and observed for this project are located within clinical practice. Narratives that equate the anatomical image with the body and transparency emphasize the pictorial presentation of MRI data; they do not call attention to the numerical measurements that are also part of MRI technology and examinations. The local culture of clinical medicine thus reinforces the physicians' and technologists' tendency to embrace the tropes discussed earlier as these narratives highlight the visual component of MRI examinations.

The epistemological effects of the recurrent use of all three tropes by physicians, technologists, journalists, and popular science writers are significant. The use of these tropes shores up the authority of images as an objective source of knowledge that is crucial to the production of definitions of health and illness. These narratives construct one possible way to understand MRI images: a view of it as providing unmediated access to the physical body, a body that exists outside of human relations and can be known. Further, they also produce the notion that these examinations are neutral and authoritative and that they represent progress.

Physicians and technologists are flexible, discursive actors, however, who employ a range of narratives to discuss both the image and the technology. Although they often used the three tropes to talk about MRI in general, physicians and technologists also used narratives that highlighted how the image is mediated by human decisions and differs from the body in the machine. These accounts – which were articulated when the physicians and technologists explained their work practices or when they described what they perceived of as errors or anomalies in the image – emphasize the instability of MRI, and provide an avenue for the critique of popular discourses.

Invisible Practices: The Social Production of Magnetic Resonance Images

An MRI examination – like all representations – is a constructed artifact.[11] Despite common narratives that position these examinations as existing

outside of social relations, there are many sites in their production, interpretation, and use that transform them from conveyers of objective, authoritative knowledge into socially situated objects that construct the body in complicated ways. In the following sections, I examine three sites in detail – the production of the examinations, the transformation of the image into a written report, and the use of the examinations and the written report by the referring physicians – to illustrate how MRI examinations produce a 'located, embodied, and contingent' truth that merges bodies, machines, and work practices to constitute a particular body in medical practice and social life (Haraway, 1997: 230).[12]

This discussion draws on extensive analysis of referring physicians', radiologists', and technologists' tacit knowledge. As Harry Collins (1974) has pointed out in his work on building a transversely excited atmospheric (TEA) laser, knowledge is acquired through the *doing* of science.[13] While this knowledge can be articulated, it seldom is: instead, it remains a form of 'tacit knowledge' that is crucial to the practice of scientific work. The production and use of MRI images also involve the employment of knowledge that is accumulated through working with the technology, and, while an integral component of everyday work practices, is normally unarticulated. Indeed, it is difficult, if not impossible, to fully formulate. Discussion of physicians' and technologists' tacit knowledge creates an understanding of the instability of MRI examinations, countering the definitiveness and certainty constructed by common rhetorical practices.

The language used by physicians and technologists to describe variation in and problems with the content and interpretation of images is also used to analyze the translation processes involved in the production and use of MRI examinations. The processes through which scientists translate knowledge into narrative discussions for other actors' understanding is central to scientific work (Latour, 1987). Drawing on Michael Lynch's (1985a) analysis of shop talk in a research laboratory, I show how the presence of and talk about artifacts – while understood by medical professionals as distortions of the real – challenge the view that images 'reveal' the body. Artifacts provide a visible symbol of the always-occurring interpretation work of medical science, illustrating how the real can only be constructed through action and practice. Similarly, discussions about overinterpretation, underdiagnosis, old friends, and unidentified bright objects (UBOs) – while positioned as error or anomaly by medical actors – signal how the creation and use of images are embedded in social relations, and cannot exist outside these networks.

This turn to a discussion of image production and use demonstrates the importance of methods such as ethnomethodology and ethnography for getting access to the multiple discourses and the tacit knowledge used by physicians and technologists as they translate their work practices. While social scientists are not 'ventriloquists' who speak for these actors or 'reveal' these social spaces, use of these techniques produces situated analyses of work practices, which, in the case of MRI, complicates popular

accounts that produce the view that anatomical images provide authoritative knowledge about the body and health.

Bodies and Machines

To begin the production process, a technologist assists the patient into the MRI machine. The person typically lies on his or her back in a narrow tube during the procedure, which can last 20 to 50 minutes. Once the patient is accurately positioned in the machine, the technologist – although occasionally a radiologist might intervene and do this work – leaves the room and enters another where the computer screens and terminals are located. The technologist sits at a computer screen; he or she uses computer programs to decide the width of a particular picture, the total amount of the area being scanned, the resolution of a particular image, and so on. Like filmmakers or photographers, technologists have to frame the area that will be included in each picture. These decisions, or parameters, create the images, shaping the content in particular and significant ways.

The effects of a particular parameter – slice thickness – illustrate this point. To create an MRI examination, technologists have to divide the area of the body being imaged into sections and decide the width or thickness of these sections. These decisions change the content of each resulting image produced. With MRI technology, large, thick slices have less spatial resolution than smaller, thin ones. The use of wide slices can therefore erase small lesions or pathologies that might have shown up in images made from thinner segments. These choices therefore hold consequences for what the image looks like.

There are many other choices, such as field of view and number of slices, that support the construction of each anatomical picture. Technologists must select values for a range of parameters – each of which will influence what is made to appear and disappear in an image. In my research, technologists – in response to questions about their actions at the computer keyboard and screen – explained how their decisions about parameter values shaped the content of an image. One technologist noted, 'It's easy to tweak the parameters to make something that's not there. You can also hide lesions. If you knew where a lesion was and you pointed it out to me, I could make it so that the lesion can be in the gap. And you could go through the liver or the brain and you would never see it.' Another technologist reinforced this view, noting that MRI images are all 'smoke and mirrors'.

The body is already in a process of translation and interpretation. Decisions made by technologists constitute via productions and erasures, pathology and its absence in each given image. These visible symbols of 'disease' or 'health' may have no physical referent in the body being scanned. Discussion of the technologists' tacit knowledge demonstrates how the anatomical image does not provide a transparent 'window' into the inner body, but instead *produces* the body. Examining medical practice and understanding the use of tacit knowledge make this clear.

Another moment in the production process – the creation and presence of artifacts – also troubles language practices that equate the MRI image with transparency. Artifacts are forms or shapes that appear in an image. In an MRI image these can appear as black spots, white spots, wavy lines, or double-images of the area of the body under scrutiny. Artifacts are considered *effects* of the technology by technologists and radiologists, and are not perceived as useful for understanding the condition of a particular body. However, as noted earlier, Lynch's (1985a: 82–84) research shows how artifacts can undermine a claim that a given scientific representation reveals particular features of the natural world. The accountability of artifacts reverses the figure–ground relation between the socio-technical relations that produce an image and the real object made visible through those practices.

The combination of MRI machines, bodies, and decisions by technologists and radiologists produces an array of artifactual forms. *Cross talk* is one of many artifacts that can be generated during the production of an examination. This particular artifact – which appears as tiny white dots in the image – occurs when technologists or radiologists place the sections of the body being measured too close together. One technologist described this phenomenon when she noted, 'If you slice sequentially, which is how most MRI examinations are done, and you have really thin slices, the slices kind of overlap, so there's excitation [of hydrogen protons] above and below and that creates the misinformation we call cross talk. You get these little white dots [in the image] and you're like, "What the hell is that?"'.

'What the hell is that?' may be the response to the identification of some kinds of artifact, but artifacts can also be interpreted as anatomy. The interpretation of artifacts as features of the body – later ascribed to distortion – occurs in the next stage of production: the translation of the image into words.

Written Reports: Physicians 'Read' the Image

After an MRI examination is created, it is sent to a physician who produces a written report that translates the content of the images into words. Physicians – through this act of interpretation – ascribe health or illness to particular images and by extension to particular patients. Usually the physicians who 'read' or interpret MRI images are radiologists. Legally, however, any physician is allowed to interpret medical images.

Most imaging sites employ one radiologist who primarily works on his or her own. This doctor is responsible for interpreting the examinations produced by a particular facility. Large hospitals provide an exception to this practice when they hire multiple radiologists who work similar hours. These physicians typically transcribe images on their own, however. A particularly challenging case may lead a radiologist to consult others in his or her unit. For the most part, though, these physicians labor alone, translating visual anatomy into written text day in and day out.

This interpretative work is a socially situated activity; it is not the transparent process constructed by commonly used accounts. Charles Goodwin's work (1994) on the development and use of 'professional vision' is especially pertinent here. In his analysis of archeologists and expert witnesses, Goodwin shows how members of professions learn to code, highlight, and produce and articulate material representations in an occupationally specific manner. Through a process of interaction with colleagues and events, members of each group build professional vision; they learn to order the world in a particular way.[14]

Goodwin's understanding of professional vision is helpful for thinking about the interpretation of medical images as a social practice. Radiologists have to learn – through interaction with other physicians, texts, and machines – to 'see' cross talk and other artifacts as well as variations in spacing, light, and human anatomy in MRI images. They discipline and train their sight over time to code and highlight aspects of the image content.[15]

This disciplining is, of course, a continual process that is enacted each time a physician interprets an image. I extend Goodwin's analysis to theorize the implications of this dynamic. Goodwin explores how members of one occupational group can adopt the professional vision of another group. Lawyers and expert witnesses, for example, can order the world through the coding scheme used by police officers; people are not limited to the use of their occupation's professional vision. Goodwin does not analyze, though, how coding, highlighting, and representing are repetitive actions, and as such remain open to divergent interpretations and contestation from individuals using the same perceptual framework. Indeed, research shows that controversy and discrepancy are common in radiologists' interpretative practices (see, for example, Reiser, 1978; Beam et al., 1996a; Laming & Warren, 2000). The vision of radiologists is thus simultaneously disciplined, ordered, and open to divergent interpretations.

Medical workers have developed language to discuss discrepancies in interpretation. Two terms in particular – underdiagnosis and overinterpretation – are used to describe sources of error. Both 'problems' occur regularly in medical practice, and are integral components of interpretative work. The occurrence of and discussion about interpretation troubles – as with artifacts – demonstrate how the knowledge produced through the use of medical images is continually influenced by human actions and decisions. The always-occurring interpretative work, in other words, is made visible in discursive practices when problems arise.

'Underdiagnosis' is a term used by medical professionals to describe situations in which the radiologist interprets the anatomy in the image as normal but other physicians identify pathology in the same image. All radiologists at times 'underdiagnose' the content of images, producing what is more generally known in medical practice as false negatives or type II errors. As one radiologist explained, 'You hope that you see everything,

but that isn't the case. There have been studies that have suggested that radiologists may miss 35% of the findings on any given image.'

Another interpretative possibility that is discussed by physicians and medical practitioners is overinterpretation. Overinterpretation describes instances in which a radiologist labels the anatomy in the image 'abnormal', but the information produced through a second interpretation of the same image, or through use of other techniques, such as the patient history, blood tests, or surgery, suggests that the anatomy in the image is 'normal' for that particular patient. This produces false positives or type I errors, and occurs in part because radiologists have to continually decide whether the content of an image represents stable anatomy, disease, or artifact. This interpretative work is particularly challenging because a wide range of anatomical details can be considered 'healthy' for potential patients, and because artifacts often resemble the visible indications of disease.

Unidentified Bright Objects and Old Friends

Bodies exhibit a variety of anatomical details in MRI images. Although the majority of patients have similar anatomical features in an image, there is a significant group that falls outside of these normative patterns. These individuals have anatomical anomalies that are considered normal or healthy for these people. Physicians who work with MRI have developed language to identify this diversity. Many of the physicians I interviewed, for instance, discussed the appearance of UBOs. As one physician explained, 'You can find things [in the image] that are difficult to interpret. Like what people call UBOs.' Another physician also commented on UBOs, stating, 'You must have heard of UBOs or unidentified bright objects. Patients will see the radiology report and say, "Well, what does that mean?" I say, "It probably doesn't mean anything. Maybe it is because you hit your head some time ten years ago or you have a migraine or whatever".'

Another physician also referred to UBOs, but called these bright objects 'old friends'. He stated, 'A favorite line of one of my own professors back when I was a resident, was "Well, I don't know what it is but I know that it's not important. It's an old friend".' This physician further explained that 'old friends' appear in images because there is variation among bodies. He noted:

> Some of these old friends are simply anatomic variations from person to person. We all have different noses, different eye color and different looking hair. You know that all those hairs and noses are normal but they all look different. There are variations in the brain as well. When you see these variations day after day, if you are not sure what they are, you work them up, and gradually they become old friends.

When translating an image into text, radiologists have to decide whether to label an anatomical anomaly in the image an 'old friend' or 'disease'. Radiologists – as part of this interpretative process – sometimes view parts of the image as abnormal when they might in fact be old friends for that

particular person. As one physician explained, 'If I were to take 100 outwardly normal people and take MRIs of their brains, maybe 20 people are going to have something that is going to be read out by a very good radiologist as not quite normal.' In this instance 'not quite normal' implies that it will be interpreted as 'disease'. In these cases, the patient with the supposed 'disease' may undergo more tests to determine if there is really a problem or, in the worst-case scenario, they may endure unnecessary treatments for this supposed condition.

Radiologists may also construct the presence of disease by labeling artifacts in an image 'pathology'. Radiologists – when faced with particular shapes in an image – have to decide whether they represent anatomy or an artifact. This interpretative work becomes even more challenging when, as often is the case, artifacts look the same as the visible presentation of pathology. For example, *cross talk*, the artifact discussed earlier, can mimic the anatomical forms associated with multiple sclerosis. Other artifacts mirror the appearance of disease as well.

Radiologists thus can, and do, interpret artifacts as disease. One physician I interviewed described a case in which a patient was diagnosed with a tumor that was later interpreted as an artifact. She stated:

> There was a patient at ... that was scheduled to have a resection of a pineal tumor. It turned out that it was an artifact from a flow void. The neurosurgeon who scheduled the operation for that same day said, 'I just want to make sure that we are looking at the same thing here.' He put the film up in front of me. And I said, 'We are looking at a flow void in the third ventricle.' He said, 'Really? That's not a pineal tumor?' I said, 'No. That's not a pineal tumor.' And he said, 'Oh. Good thing I showed it to you.'

In this example, the radiologist who initially interpreted the image labeled the artifact produced by blood flow 'a tumor' in her report. The neurosurgeon, however, happened to ask for a second opinion before starting the surgery. The second radiologist convinced the surgeon that the supposed 'tumor' was an artifact. This second interpretation was in turn supported by other clinical information, and the patient did not undergo surgery. If the neurosurgeon had not asked for a second view, the patient would have had surgery for a disease he did not have. Although this particular patient was able to avoid this, there are occasions when interpretative discrepancies are not noticed and unnecessary treatment occurs.

In addition to these routine problems, there is also the simple fact that interpretation is performed by people, and as with all jobs, the quality of performance varies. Radiologists and referring physicians – when asked how a patient should evaluate a prospective imaging facility – explained that it is important to choose sites that have highly skilled radiologists. One radiologist I interviewed, for example, noted, 'The accuracy of the MRI exam is heavily dependent on the quality of the radiologists who interpret them.' Another physician cautioned, 'You have got to try to pick places where the radiologists are going to be good. People don't understand that it's not just about the technology. You can get pictures but it's the

interpretation of those pictures that's key.' The radiologists' interpretative work and variability are seldom made visible in commonly used discourses about MRI. Discussion of radiologists' tacit knowledge and narratives about perceived error demonstrate how medical images construct the body; they do not directly reveal it.

Clinical Practices: Magnetic Resonance Imaging and Other Diagnostic Tests

Narratives that suggest MRI images provide unbiased knowledge, and thus reveal the truth about the health of a person's body also erase how referring physicians – the doctors who initially order the MRI examinations – use medical images in conjunction with other tests to make sense of a person's situation. Referring physicians seldom solely use the information obtained via MRI technology to diagnose a patient. Instead they look at the information provided by an array of methods to better understand a particular individual's body. Through this iterative process, referring physicians integrate the knowledge obtained by the MRI image with other information. In practice, MRI findings can and do contradict information obtained via other tests about a patient's condition. There are two ways that this can occur. In the first situation, the information provided by MRI indicates there is no disease, whereas the information provided by the clinical examination suggests there is disease present. In the second situation, the opposite contradiction occurs. In this instance, the interpretation of the MRI image indicates disease, while the clinical findings suggest that there is no disease.

In interviews, referring physicians – when explaining the tacit knowledge acquired and used in their work practices – provided examples of both possible scenarios. Many physicians mentioned, for example, instances in which the MRI examination indicated no disease, while the clinical examination revealed the opposite. One such example is multiple sclerosis (MS). MS lesions in the brain often show up in an MRI image. Despite this, there are cases in which a patient has all of the clinical findings of MS, yet the MRI image appears normal. As one neurologist pointed out, 'The MRI scan is probably negative up to 25% of the time in [MS] cases, so I would usually trust my exam much more than the MRI scan.' In this situation, the physician has to rely on other indicators to produce a diagnosis. The MRI findings are misleading and inaccurate; it is the clinical examination that provides the useful information about the patient's condition.

In addition to these types of situations, physicians also have to balance indications of abnormality in MRI images with the information provided by other techniques such as the physical examination and patient histories. Throughout my research, referring physicians discussed the importance of the clinical examination to sort out which information in an MRI image is relevant. One noted, for example, 'Say a patient gets an MRI and it shows a lesion that is of no clinical consequence. Now you are left with doing the backtracking and saying, "You're neurologically normal. This bright object

in your brain is of no significance. It has no correlation with the headache that you have. You just have a headache".' For this doctor, the clinical examination and other diagnostic tests provide the framework needed to make sense of the information given by MRI. Without other sources of information, physicians and patients might spend a lot of time treating and watching abnormalities in an image that actually reflect stable pathology or a normal feature of that person's body. As one physician explained, 'Just because the radiologist saw something doesn't mean that it's relevant.'

These examples demonstrate that indications of pathology in an MRI examination do not necessarily reveal the truth about a patient's condition. Deviations that appear on the MRI image may in fact be normal for a particular patient. Without the information provided by the clinical examination and other diagnostic tests, referring physicians would be unable to discern this discrepancy. In medical practice, physicians integrate information from a variety of sources; they seldom rely on only the MRI examination to diagnose a patient. To do so means that they might treat a patient for a 'disease' that exists only in the image. MRI alone cannot therefore 'speak' for a person's body.

The Importance of Social Context: Institutional Practices and Policies

MRI images are thus not equivalent to the inner body; instead they etch together technology, the body, and work practices in complex ways. Tropes that suggest these pictures exist outside of the realm of human actions make it harder to understand the relationships that exist between bodies, technology, decisions and actions in imaging units, and anatomical pictures. They render the local knowledge of those who work with and use MRI technology invisible. The political implications of this erasure become clear when the institutional contexts that shape and influence work practices are examined.

The choices made in the production of MRI examinations – the decisions about parameters, interpretation, and use – occur within larger social fields that influence and weigh upon them. Institutional practices and healthcare policies shape the decisions and activities made in imaging units and hospitals, and these regulations and routines vary according to the regional and temporal location of a particular imaging site. In this section of the paper, I focus on the policies and institutional practices that shape MRI production and use in the USA. These regulations and practices produce a particular type of MRI examination – one that emphasizes revenue and efficiency over quality.

There are currently no policies in the USA that mandate standards for slice thickness, field of view, and other parameters that shape the content of images. The Food and Drug Administration (FDA) permits manufacturers to build a wide range of value choices into the machines, and this allows administrators, physicians, and technologists greater flexibility in their decisions about what to include and exclude in images. The lack of

stringent standards is particularly important because decisions about MRI parameters are also decisions about the length of time required to produce an examination and the degree of spatial resolution. Technological constraints currently require imaging facilities to choose between shorter scan times and increased visibility of anatomical details. These two possibilities cannot occur simultaneously.

A brief discussion of slice thickness – the parameter discussed earlier – provides an example of what this means in practice. With MRI technology, decisions about slice thickness are also decisions about the level of anatomical detail included in an image *and* the length of examination time; short scan times and increased spatial resolution are mutually exclusive effects of the technique. In this case, images based on wide slices simultaneously take less time to produce and include less anatomical detail than images based on thin slices. Wider slices thus potentially erase small lesions or other important anatomical details that would have been included in thinner ones. This same examination, however, takes less time to produce than one based on thinner slices. This trade off between time and increased visibility is true for other parameters as well. Through decisions about how much of the body to include in an image, choices about speed and quality are also enacted.

The flexibility of parameter choices suggests that decisions about time and visibility are particularly open to the values and imperatives of local institutional contexts. Both non-profit and for-profit MRI units in the USA are currently under pressure to increase production and income. Since US healthcare relies on a fee-for-service system of reimbursement, facilities can accommodate the desire for income by increasing the number of examinations performed each day. The combination of the fee-for-service payment system and the pressure to increase revenue creates an environment that encourages administrators to make choices that decrease scan time so that more examinations, and thus more income, are produced each day. The lack of formal regulation about parameter standards supports these decisions, allowing the time required to create an examination to take precedence over the quality of spatial resolution. While other institutional priorities such as concern about lawsuits may temper this tendency, the pressure to produce revenue is strong and the possibility to prioritize time over quality is structured into medical policies and practices.

Institutional contexts and regulations also shape the interpretative work of radiologists. Current policies and practices help produce a particular type of written report – one that varies in quality and is least likely to help patients and medical professionals in their quest for health and knowledge. There are three policies in particular that shape interpretation practices in US medical care. First, despite awareness of variability in radiologists' interpretative skills, there are few regulations that require formal review of their work. Most imaging centers are not legally required to review radiologists' reports to see if their findings are supported by other tests and information.[16] Radiologists often instead rely on informal feedback from colleagues to gauge their 'reading' abilities.

Some institutions do have formal processes of evaluation. At these locations, as one physician explained, 'radiologists may take random samplings, maybe 10% of the cases, and then read each other's images' to estimate the proficiency of radiologists. Other MRI facilities periodically send out images to a third party who then reviews the images for accuracy. These types of systematic review are not required by law. Formal evaluations of radiologists' reading abilities remain up to the particular institution.

Second, most insurance companies reimburse MRI units for one reading fee. This practice occurs even though studies have shown the quality of the interpretation increases significantly if two radiologists interpret each examination (see for example Beam et al., 1996b; Laming & Warren, 2000). Despite these findings, typically only one radiologist is paid to view an examination.

Finally, no federal laws currently mandate that the interpretation of MRI examinations must be done by physicians trained in this practice. Although some states, such as Rhode Island, require minimum training in MRI interpretation, most simply require a medical doctor to produce the official interpretation of an image. Those states do not require physicians to be trained in MRI technology, nor do they require physicians to be trained in the particular body part being imaged. This means that a radiologist who works with X-rays or CT can interpret an MRI image, and that a radiologist who specializes in neuroanatomy can read an MRI examination of the breast. It also means that any physician – even one with no training in imaging – can officially write the report summarizing the content of a medical image.

Although interpretation of images by an unskilled practitioner is uncommon, it does occur. Some of the technologists I interviewed expressed concern over this practice. One technologist recounted a situation in which she had created an examination and was astounded by the obvious misinterpretation of its content. Her concern over the quality of the written report caused her to investigate the identity of its author. She explained, 'I researched who read the examination and it was a neuroradiologist. A neuroradiologist shouldn't be reading a pelvic examination. But he was the radiologist on duty that day and instead of saying that he was incompetent to read it, he read the examination.' There is no current formal regulation that limits physicians from doing this. This regulation, like the other policies that guide interpretation work, produces a particular MRI examination, one that promotes variable interpretative practices. These policies do not encourage the systematic production of high-quality work.

Overall, institutional practices and polices in the USA emphasize speed, revenue, and low-quality interpretations of examinations. Tropes used to frame this technology in the public sphere erase this political and social context. Indeed, all of the relations and decisions that support, constrain, and inform the social construction of MRI examinations are

rendered invisible by hegemonic language practices that position medical images as objective and authoritative knowledge.

STS scholarship has yet to fully investigate how routine healthcare policies are developed and maintained. While work in STS carefully analyzes how various actors construct and mobilize definitions of science and expertise to participate in the creation of policies about controversial technoscientific practices, there is little research that addresses uncontroversial regulations.[17] As Susan Cozzens and Edward Woodhouse (1995: 552) suggest, 'Ought STS to devote more effort to the study of the structural mobilization of bias, that is, to the issues that do *not* become controversial?'. The analysis of MRI provides one approach to the mobilization of bias and the maintenance of routine policies and practices in healthcare.

Linking analyses of institutional contexts, work practices, and public discourses demonstrates how common rhetorical strategies do not stay contained in popular culture or mass media. These narratives have political effects in policy and regulation as well. Tropes that equate the image with transparency, certainty, and progress clearly do not cause current policies and institutional practices, but they do help sustain and reinforce them by obscuring knowledge of the relationships that shape the production and use of MRI images. This erasure contributes to the production of uncontroversial science, making it more difficult for patients, healthcare professionals, and policymakers to question or intervene in current healthcare practices.

While other factors, such as the professional authority of physicians and the pressure to contain healthcare costs, share in the creation and maintenance of current policies, the ideas produced by popular discourses do important cultural work as well. Through the simultaneous production of a particular view of medical images and erasure of other perspectives, they naturalize the idea that images 'reveal' the inner body, making it acceptable that there are no regulations about the choices used to create an MRI examination. These narratives also support policies that imply that interpreting an image is an easy, straightforward process. Regulations in most areas of the USA presently state that any physician, indeed only one physician, is necessary to translate an examination into a written report. This practice can only appear reasonable in a symbolic economy that aligns the image with transparency and truth.

Finally, these discursive practices reinforce imaging consumption practices. In the USA medical imaging has moved into the shopping mall. Companies now offer body scans to consumers willing to pay out of pocket for them and direct advertising to potential patients is beginning to occur (Barnard, 2000: A1). The assumption that the image alone is necessary for diagnosis, that it provides authoritative knowledge and that MRI is itself an actor, supports the incorporation of imaging into everyday life. Without these beliefs, the marketing of and the lack of controversy about imaging would be harder to maintain.

Signifying Truth: Visuality, Technology, and the Body

As we move further into the 21st century, imaging will increasingly occupy both medical practice and cultural imaginations of the body. Today, images produced by 'high-tech' machines have remarkable status, and operate as signifiers of authoritative knowledge. Across social worlds, medical images are thought to represent transparency, impartiality, and truth about the human body. Upon close examination of discursive texts and medical practices, the symbolic positioning of these techno-visual products erases the multiple forces, decisions, and contexts that influence the content and use of medical images. The symbolic positioning further erases how what counts as truth and authoritative knowledge changes across time, disciplinary boundaries, and social contexts.[18]

Popular narratives about MRI images clearly do not draw from local knowledges and technological practices. Instead, these accounts reflect and reinforce popular cultural assumptions about images and machines. MRI examinations, in all their complexity, are represented as accurate anatomical pictures produced through the use of technology. That is, they are embedded in ideologies that equate visual representations with the real and mechanical reproduction with objectivity. Presented as images, MRI examinations are surrounded by beliefs and rhetorical practices that suggest the picture and the real body are interchangeable, instead of co-constitutive of each other.[19] Pictures, no longer understood as representations, are thought to provide, as theorist John Berger explains, 'a mechanical record' of the event or individuals presented (1973: 10). Or, as Susan Sontag notes, while 'photographs are, of course, artifacts, their appeal is that they also seem to have the status of found objects – unpremeditated slices of the world' (1990: 69). MRI images circulate in a cultural context that links visuality to transparency: no longer mediated representation, they are instead mirror images of the real, providing access to a previously unknowable interiority of the body.[20]

The use of the technology itself is, of course, consequential. MRI examinations, or at least the images and meanings they create, are produced through the use of technology. Machines currently occupy a privileged space in the cultural production of objectivity and truth. In an analysis of how definitions of objectivity change over time, Lorraine Daston and Peter Galison demonstrate that since the late 19th century objectivity has been 'tied to a relentless search to replace individual volition and discretion in depiction by the invariable routines of mechanical reproduction' (1992: 98). Human decisions are no longer compatible with notions of objectivity; the machine now provides neutrality in the production of knowledge. This understanding of mechanical reproduction contributes to a cultural climate that links MRI images with objective knowledge; it reinforces rhetorical strategies that equate medical images with truth.

The visual and the technological evoke broader cultural meanings that bolster and normalize rhetorical patterns and beliefs that equate the MRI

image with transparency and objective knowledge. Indeed, discursive practices that equate the image with the real are so commonplace that even physicians and technologists use them in conversation with colleagues and others. Of course, these practitioners are acutely aware that medical images are shaped by individual decisions and institutional contexts, yet the power of normative beliefs about medical images shapes the discourse of these social actors.[21] Although local contexts may cause scientists, physicians, or consumers to reject hegemonic narratives about images and technology, the general symbolic economy forges links between mechanical reproduction, images, and transparency, which in turn shapes dominant discursive patterns, consumer practices, and policies.

Seeing does not equal truth or unmediated access to the human body. While cultural beliefs equate technologically produced images of the body with both the physical body itself and authoritative knowledge, these beliefs are not immune from instability or critique. Local knowledge of work practices demonstrates how MRI images etch together aspects of the physical body, decisions by technologists and physicians, and economic and social contexts to constitute a particular and situated body in medical practice and social life.

Notes

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1. For a discussion of 'black-boxing', see Latour (1987).
2. In her work, Grosz primarily focuses on written representations of the body. I extend her notion of etching to analyze another site of knowledge production – anatomical pictures.
3. Semiotic analyses of visual artifacts produced by medical researchers and physicians include Beaulieu (2000), Cartwright (1995), Cartwright et al. (1998), Dumit (1999), and Waldby (2000).
4. Examples of qualitative studies of medical practice or research laboratories include Beaulieu (2002), Casper (1998), Guillemin & Holmstrom (1999), Latour & Woolgar (1986 [1979]), Lynch (1985a), Timmermans (1999), and Traweek (1992).
5. It remains uncertain whether writers and reporters actually believe the narratives they publish. It is outside the scope of this project to examine this question. Instead, this paper focuses on the *effects* of these language practices, examining both the beliefs they reinforce and the links between these ideas and current imaging policies and practices.
6. Tropes used to discuss MRI are also used in relation to other imaging technologies such as positron emission tomography (PET), CT, X-ray, and ultrasound. The way they frame each technology varies, however, in subtle ways. Concern about exposure to radiation, for example, is a common trope used in relation to CT and X-ray, whereas concern about safety is not as commonly articulated with other imaging technologies. It

was outside the scope of this work to fully explore the particular discourses used in conjunction with each technique.

7. For other examples of this way of framing medical images, see Stafford (1991) and Kevles (1997).
8. A few popular representations of MRI challenge the idea that the image is superior to the clinical examination. Examples include the 8 August 2000 episode of the sitcom *Becker*. In this show, the main character Dr Becker uses a stethoscope to diagnose a patient's illness. An MRI examination is then ordered to corroborate the diagnosis. In this particular representation, MRI is portrayed as a technique that can only be used in conjunction with others; it is not presented as 'better than' the stethoscope or the clinical examination. An episode of *Providence*, another television show that features a physician, also challenged conventional technological hierarchies. In the 8 September 2000 episode, a neurologist insists on the importance of the patient history. Although he has the information provided by the MRI examination, he notes that 'That's the problem with a patient in a coma. You are missing your star witness.' These examples challenge the view that MRI is superior to the clinical examination, and remain rare in popular culture in the USA.
9. For an excellent discussion of the heterogeneity of medical practice and the multiple identities and narratives used by medical actors, see Berg & Mol (1998).
10. Social science research that examines how physicians and scientists are simultaneously informed by and produce culture includes Clarke et al. (2003), Guillemin & Holmstrom (1999), Martin (1992, 1994), and Oudshoorn (1994).
11. Science and technology studies on the production and use of representations in science include Lynch & Woolgar (1990) and Yoxen (1987).
12. For an extended discussion of situated knowledge, see Haraway (1988).
13. For further discussion of Collins' development and use of the concept tacit knowledge, see also Collins & Kusch (1998).
14. In one of his cases, Goodwin (1994: 615–26) analyzes how an expert witness used coding, highlighting, and articulating to persuade a jury that Rodney King represented a potential threat to police officers in a video clip that showed these same officers beating King with metal clubs. Goodwin's discussion of the interpretation of this seemingly straightforward videotape in court shows how 'seeing' involves a reflexive relationship between talk, gestures, and the material representation, and how interpretation practices have political effects. For further discussion of interpretation as embodied practice, see Goodwin (1995) and Lynch (1985b).
15. The processes and interactions that train and discipline radiologists' sight over time deserve further analysis. In-depth study of how radiologists learn to 'see' or 'read' images would provide insight into how seeing is itself a social practice that is learned through interaction with people, texts, and machines.
16. An exception to this practice is mammography. The Mammography Quality Standards Act (MQSA) allows federal and state inspectors to review 'positive' interpretations of mammograms, that is, the reports that diagnosed cancer in a particular patient, with other clinical information such as biopsies, in order to evaluate a particular facility's interpretation work. This Act was authorized in 1992, and reauthorized in 1998 by the US Congress. The links between the creation of this legislation and various interest groups, such as breast cancer activist organizations, have yet to be fully investigated.
17. For an overview of different STS approaches to policy and controversial science and technology, see Martin & Richards (1995). Recent health-related, controversial policy case studies include Abraham & Sheppard (1999), Allen (2003), and Timmermans & Leiter (2000).
18. For discussion of the social construction of authoritative knowledge, see Daston & Galison (1992), Porter (1995), Shapin (1995), and Timmermans & Berg (2003).
19. Literature that examines the links between sight and knowledge includes Berger (1973), Bryson (1994), Jay (1994), Mirzoeff (1998), and Sontag (1990).
20. Tal Golan (1998) and Bernike Pasveer (1989) demonstrate how the ties between photography and medical images were clearer in the late 19th and early 20th centuries

than they are today. X-rays were known as 'the new photography' and X-ray production was considered a specialty with the field of photography. The links between photography and medical images have been lost in the early 21st century as cultural and professional boundaries were constructed between medicine, media, and art.

21. Joe Dumit (1999) shows how cultural beliefs about mechanically produced pictures influence the discourse and actions of judges in US courtrooms. While some judges control and manage the use of brain images to combat the potential effects of these views on jurors' interpretative practices, other judges are less reflective about the presence and effects of cultural beliefs that equate images with transparency. These judges allow jurors to view brain scans without an explanation of the theories that connect them to medical diagnoses, reinforcing the idea that images provide transparent knowledge about the body and identity (Dumit, 1999: 191).

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Kelly Joyce is an Assistant Professor in the Department of Sociology at the College of William and Mary, VA, USA. She researches issues related to public health, science, and technology, focusing in particular on the uses and perceptions of MRI in the USA. Her current work analyzes perceptions of medical imaging technology in Japan.

Address: Department of Sociology, The College of William and Mary, Box 8795, Williamsburg, VA 23187-8795, USA; email: kajoyc@wm.edu