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Tiago Moreira

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ABSTRACT Blood pressure is one of the key measurements taken in standard clinical examinations. Its importance has long been associated with the instrumental precision offered by the sphygmomanometer, which is supposed to have replaced other, more imprecise methods of blood pressure measurement, such as feeling the pulse with the finger. Drawing on ethnographic fieldwork in a neurosurgical clinic, this paper explores the co-existence of the sphygmomanometer and the finger methods in practice. I argue that in neurosurgery these methods are both independent from and interdependent with each other: independent in the way they achieve different assessments of the patient's blood pressure at the same time; and interdependent in the way the surgeon's and anaesthetist's measurements are dynamically linked with each other. The paper suggests that this particular form of coordination through heterogeneity might be described, borrowing from Michel Serres' work, as *mutual parasitism*, and that this metaphor might be useful in rethinking the role of science – research, or 'evidence' – in medical practice.

Keywords anaesthetics, ethnography, knowledge practices, *Le Parasite*, neurosurgery

Heterogeneity and Coordination of Blood Pressure in Neurosurgery

Tiago Moreira

During a routine neurosurgical intervention, the following sequence of events occurred:

> Excerpt 1 (Operating Room 2 – Day 43)
>
> Dr Carvalhosa's first incision on the dura mater pricked a small artery at the surface of the brain. Seeing the blood release, Dr Carvalhosa immediately tweaked the artery with the bipolar pincers and looked at the anaesthetist Dr Amaro.
>
> 'How much has he got?', he asked.
>
> Dr Amaro, looking at the monitor, said:
>
> 'Seems normal, he's quite hypertensive though'.
>
> Dr Carvalhosa felt the cortex again with one hand while keeping the artery tweaked with the other.
>
> 'It's still very tense', he added.

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'He's been lowering for the past ten minutes or so. The [drug] is doing its thing', Dr Amaro replied.

'Well, until I feel something here I'm not doing anything . . . besides we should wait for Dr Soares', Dr Carvalhosa said.

'Go ahead', concluded Dr Amaro.

This field note was written about an operation on a cerebral tumour performed in the operating room of the neurosurgical unit of a Portuguese university hospital during the summer of 1999.[1] It starts at a moment when the surgeon, having cut through skin and muscle, and trepanned and removed the bone flap, is about to start a delicate moment of any intra-cerebral intervention: the lifting and incision of the dura mater, the outermost membranous envelope of the brain and spinal cord.

While it is frequent for surgeons to accidentally puncture surface arteries at this point, Dr Carvalhosa was surprised by the amount of blood released by the artery he had just inadvertently pierced. His first question to Dr Amaro, the anaesthetist, is an attempt to figure out the cause of the bleeding. He seems to think that the bleeding might be connected with raised blood pressure. Dr Amaro's answer does not confirm this expectation: the blood pressure shown in the monitor is within the patient's 'normal' range. She adds, however, that this normal blood pressure is relative to someone who is a diagnosed hypertensive – that is, a person who, in repeated measurements, has shown levels of both systolic and diastolic arterial tension that are above the 'normal range' shown in epidemiological studies of populations.

Dr Carvalhosa, nonetheless, maintains his own assessment of the patient's blood pressure, as estimated from the feel of the patient's brain and its vessels.[2] He seems to expect that the patient's brain will feel differently at that point in the operation; his use of 'still' – *ainda*, in Portuguese – indicates that his expectation has to do with timing. Thus, Dr Amaro informs him that the patient's blood pressure has been decreasing 'for the past ten minutes or so' and links this process with a previous injection of a drug into the patient's blood stream. With this, she reassures Dr Carvalhosa that there is nothing extraordinary about this patient's blood pressure. Dr Carvalhosa announces that he is not going forward with the operation until the drug shows some effect on the way the patient's brain feels. With her last remark, Dr Amaro not only informs the surgeon that she cannot see any problem with his decision, but also makes clear that it is *his* decision.

This episode illustrates two consistent findings of my ethnographic observation of neurosurgery. First, it illustrates a key feature of teamwork in neurosurgical interventions: the collaborative management of blood pressure. While in most surgical specialities the intra-operative management of blood pressure is a crucial factor in maintaining a clean, bloodless plane of dissection, in neurosurgery blood pressure acquires further importance due to the way the cerebral cortex absorbs blood. A small

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haemorrhage at the surface of the cortex can cause brain damage and impair cerebral functions. Thus, it is important for neurosurgeons and neuro-anaesthetists to coordinate their actions in relation to this common aim: the control and correct assessment of the patient's blood pressure.

This coordination is done, however, as the excerpt exemplifies, without a shared assessment of the patient's blood pressure: while, for the surgeon, blood pressure corresponds to the tension produced in the external wall of the artery as felt by his gloved fingers; for the anaesthetist, blood pressure is assessed by the count of mercury units shown in the sphygmomanometer monitor. This leads to my second theme of interest: that surgeons and anaesthetists can collaborate in the management of blood pressure while employing different ways of measuring, of *doing* the patient's blood pressure.

Blood pressure measurement is considered to be an unproblematic practice, performed every day by thousands of clinicians on thousands of patients. It is one of the central measurements in a standard clinical examination. This measurement entails the use of an inflatable cuff that, when filled, closes the blood flow in the artery of the arm. The pressure is determined by listening though a stethoscope and observing the level of mercury in the sphygmomanometer, or by electronic sensing. Rarely is feeling the pulse with the finger mentioned as an appropriate method of assessing blood pressure. When it is mentioned, it appears as an imprecise antecedent of the sphygmomanometer method. Yet in the excerpt given earlier, these two methods co-exist. Furthermore, they appear to be both independent from and interdependent with each other: independent in the way they achieve different assessments of the patient's blood pressure at the same time; and interdependent in the way the surgeon's and anaesthetist's measurements are dynamically linked with each other. How are we to think about this relationship of simultaneous externality and intersection of two measurement practices? In this paper, I describe this particular form of coordination through heterogeneity as mutual parasitism, after the philosophical figure created by Michel Serres (1980). Mutual parasitism, I argue, is a general form of socio-technical coordination through which different knowledge practices are both harmonized and continuously distinguished. This argument is put together by two main lines of enquiry.

The first section explores how historical interpretations of the evolution of blood pressure measurement have led to the assumption that instrumental measurement, much like in other areas of medicine, has replaced the method of feeling the pulse at the wrist (Reiser, 1993). In that section, I question the assumed discrepancy in precision and clinical importance between the instrumental and the finger methods. I do so by drawing on ethnographic evidence about the parity between the two forms of measurement in the operating room. This parity suggests the possibility of developing a symmetrical exploration of the knowledge practices within which each of these measurements is embedded (Bloor, 1991). This

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symmetrical exploration of the knowledge practices of surgery and anaesthetics is developed in the fourth and fifth sections of the paper.

In the world of medical opinion and theory, the precision shown by instruments such as the sphygmomanometer is seen as an example of a long-term vision of medicine becoming more of a science and less of an art; a vision that has gained strength and recognition with the emergence of the evidence-based movement in the 1990s (Nordin, 1999; Timmermans & Berg, 2003: Ch. 1). In contrast to that vision, the story that I shall tell does not hierarchize instrumental and non-instrumental diagnostic medical practices. It shows that embodied diagnostic skills co-exist alongside with technologically advanced methods. I argue that the value ascribed to a diagnostic technique should not be based on whether or not it is done with an instrument, but on how it relates to the actual practice of patient care. I suggest that a sociological analysis of the knowledge practices of surgeons and anaesthetists in neurosurgery is a good way to reveal the value of diverse blood pressure measuring practices.

In the third section of the paper, I introduce the concept of mutual parasitism. The section addresses the following question: how are we to describe the relation between different knowledge practices without privileging one over the other? How are we to understand their relations to each other without using concepts or metaphors that invoke asymmetrical relationships? This exploration aims to develop a concept that best encapsulates the local collaborative dynamics established between different methods of measuring blood pressure; methods that never lose their separate identities as forms of practice. Drawing on Serres' philosophy of the 'parasite', as well as contemporary developments in actor-network theory (Law & Hassard, 1999) and the sociology of translation (which was, in part, developed from Serres' work), I present mutual parasitism as a general form of coordination through heterogeneity. I recommend that mutual parasitism should be added to the list of key concepts elaborated in Science and Technology Studies – translation, boundary object, trading zones, partial connections and so forth – which address the tension between difference and similarity between technoscientific languages, domains, and ontological statuses.

Blood Pressure: Science, Precision and Neurosurgery

What is Blood Pressure?

According to a commonly accepted definition, blood pressure is the pressure exerted by the blood upon the walls of the vessels, primarily produced by the contraction of the heart muscle. Another, more technical, definition is found in *Black's Medical Dictionary* (McPherson, 1999) – one of the most commonly used medical dictionaries: 'Blood pressure is that pressure which must be applied to an artery in order to stop the pulse beyond the point of pressure. It may be roughly estimated by feeling the

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pulse at the wrist or more accurately measured using a sphygmomanometer' (p. 70).

While the commonly accepted definition takes blood pressure to be something existent at all times in all circumstances, the *Black's Medical Dictionary* definition seems to be written from the perspective of measuring blood pressure. In *Black's* definition, blood pressure is the effect of applying force to an artery and, thus, entering in contact with the pressure exerted by the blood upon the walls of blood vessels. The interaction between these two forces is known as 'blood pressure'. Despite this *enactive* conception of blood pressure, which might seem compatible with a constructionist orientation in science and technology studies, the next sentence makes a positive turn, distinguishing between the precision of different methods of blood pressure measurement in relation to the actual blood pressure. In this, *Black's* differentiates between a 'rough estimation' of blood pressure and an 'accurate measurement' done with a sphygmomanometer.

The sphygmomanometer consists of an inflatable arm-cuff attached to a column of mercury (or a proxy) and a gauge. Like the finger on the wrist, it produces an indirect method of measuring blood pressure.[3] The cuff is wrapped around the upper arm just above the elbow, on top of the brachial artery, the major artery in the arm. The cuff is first inflated to a pressure that shuts off all of the blood flow through the artery. As the cuff is slowly deflated, the person measuring the blood pressure listens through a stethoscope placed on the brachial artery for the first audible beat – the sound of blood rushing back into the compressed artery – and notes the number on the gauge. In electronic 'sphygs', such as the one used by Dr Amaro in the operating room, a computer chip registers and stores this information. This number indicates the systolic blood pressure, i.e. the pressure generated by the heart immediately after it contracts.

As the pressure from the cuff continues to be released, the beats – known as the Korotkoff sounds after the Russian surgeon who first described them in 1905[4] – become stronger and clearer, and then taper off, eventually disappearing. The number at which the last beat is audible indicates the diastolic pressure, i.e. the arterial pressure maintained between heartbeats, when the heart is at rest. The combined ratio of systolic over diastolic reveals the relative pressure generated by the heart as it alternately pumps blood through the arteries and rests. This fraction is expressed in millimetres of mercury (mmHg), which refers to the amount of mercury displaced by the arterial pressure during the procedure. The precision with which the sphygmomanometer measures the resistance offered by the blood inside the artery to the pressure applied to the outside of the artery has come to be encapsulated in this numerical fraction.

Interpreted from the vantage point of instrumental precision, the difference between the surgeon's measurement of blood pressure and the anaesthetist's is a matter of proximity to the real pressure being exerted on the patient's blood vessels at that time. For the exact measurement observed by the anaesthetist on the sphygmomanometer's monitor, the

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surgeon can only offer an approximate, vague assessment of the resistance of the brain's arteries to his touch. The superiority of the sphygmomanometer over the finger can be said to be ingrained in the clinical use of the instrument itself: its precision being exactly the quality used to promote it by those championing the instrumental measurement of blood pressure at the turn of the 19th into the 20th century.[5]

The superiority of the sphygmomanometer can, however, also be seen as the result of a contested social process. In her account of the controversy over the introduction of blood pressure measuring instruments in medicine in the USA, Hughes Evans (1993) describes an opposition between 'physiologically minded' doctors who advocated the precision of mercury measurement and those who thought that the introduction of the sphygmomanometer would distance the doctor from his/her patient. On the one side, there were those promoting the standardization of patient data in hospitals, and wanting to reform medical education and practice towards a more 'scientific' paradigm. On the other side, more clinically minded physicians defended the embodied diagnosing knowledge of the doctor against the deskilling brought by the sphygmomanometer.

One of the central actors in this process of introducing the sphygmomanometer to medical practice was US neurosurgeon Harvey Cushing. Having seen the instrument being used at the bedside in Turin, Cushing realized the potential benefits that instrumental monitoring of blood pressure could bring to neurosurgical practice (Evans, 1993: 789). In a series of lectures and papers, Cushing defended the sphygmomanometer not just as an important aid in surgery, but as a signifier for the medical reforms he advocated (see, for example, Fulton, 1946). Those reforms were focused on the value of physiology in medical practice. The sphygmomanometer, having been developed in physiological laboratories, embodied the standardized precision that Cushing and others attempted to make relevant for medicine. By using the sphygmomanometer, Cushing believed, doctors would be constantly reminded of the physiological principles that lie behind a blood pressure measurement.

Cushing was also one of the central actors in the construction of the concurrence between the values of precision and science and the profession of neurosurgery: the neurosurgeon becoming a figure in 20th-century Western societies that was routinely used to signify accuracy, intelligence and dexterity. Cushing's vision of the neurological surgeon at the turn of the 20th century, which would become central to the profession to this day, was one in which manual dexterity and skill should coalesce with a profound knowledge of the structures and process of the central nervous system (Star, 1989; Moreira, 2000). Instead of allowing his hands to be directed by the neurologist, the surgeon became responsible for the diagnosis, localization and treatment of brain lesions (Cushing, 1925: 137). One of the consequences of this vision was the development of research programmes that were intimately connected with the possibilities offered by neurosurgical interventions. In this context, Cushing's own

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research on the surgical significance of instrumental blood pressure measurement in the operating room can be seen as a central component in the consolidation of neurosurgical practice and its association with the value of precision.[6]

A simple historical exploration of the link between the values of precision in medicine, the instrumental measurement of blood pressure and the practice of neurosurgery would lead us to expect the neurosurgeon to hold the means of producing precise numerical measurements at all times. Interestingly, in the operating room, the values of precision in the measurement of blood pressure seem to be held by the anaesthetist. Both historicist and constructivist histories of blood pressure measurement would lead us to expect the anaesthetist's precise measurement to override the surgeon's vague one. In the historicist version, the rational quality of instrumental measurements – their consistency with the physiological process of blood circulation – would justify such overriding (Booth, 1977). In the constructivist version, this would be seen as an effect of the outcome of the controversy between clinically minded physicians and scientifically driven doctors.

In neurosurgery, however, it is not the case that the sphygmomanometer supplants the finger at all times. During operations, the surgeon's tactile assessment and the anaesthetist's measurement of the patient's blood pressure stand on equal grounds. During my fieldwork, I experienced this parity as exceptional, because, for once, surgeon and anaesthetist collaborated as equals. Other studies consistently report divergences and/or tensions between anaesthetists' and surgeons' perspectives on the patient's health (Fox, 1994; Katz, 1999). The conventional asymmetry between surgeons' and anaesthetists' definitions of the patient's health might lead us to expect the surgeon to control the determination of blood pressure and thus the course of the operation itself. My ethnographic observations lead me to believe that *in the operating room, in relation to blood pressure*, surgical and anaesthesiological blood pressure measurements work to facilitate collaborative work *within* this professional asymmetry. This collaborative dimension was noted right from the first days of my ethnography:

Excerpt 2 (Operating Room 1 – Day 3)

> After the cranial bone was trepanned and given to the nurse, everything seemed much bloodier than I had seen before in cranial surgery, which tends to be cleaner than spine or other forms of surgery. It was an operation to a tumour of the meninge that was heavily vascularized and had started bleeding. The surgeon Dr Pinto and Dr Amaro talked a lot about the patient's blood pressure and drug intake. During the targeting of the tumour, Dr Pinto said a few times that they were 'almost in control', which prompted Dr Amaro to check monitors and adjust drug pumps' contents. Once Dr Pinto had the tumour exposed, he asked Dr Amaro to keep the blood pressure low for a few minutes. He clipped the two main arteries that were supplying the tumour's growth, after which he proceeded to detach the tumour from the clipped arteries. He then slid three fingers under the tumour and pulled it out whole, opening the sight

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> of an indented cortex. He finished coagulating the arteries. Finally, he asked Dr Amaro to bring the pressure up to check on the coagulation of the arteries he had just done. No blood. He proceeded to close up.

In another operation the blood pressure was conspicuous by its absence:

> Excerpt 3 (Operating Room 1 – Day 116)
>
> Dr Soares was opening up for one of Dr Almeida's cranial nerve tumour patients. The team had problems positioning the patient, an obese woman who had presented with visual hallucinations a few weeks before. When Dr Soares cut the first incision, he commented that there was more bleeding that he would expect. He asked the anaesthetist, Dr Marques, about the patient's blood pressure. Dr Marques, who had just minutes before replaced Dr Rosendo, the anaesthetist responsible for the patient on the table, because of a personal emergency, searched the patient's record for blood pressure measurements done before to compare with the measurement shown by the sphyg. 'It does not say in here, but she must be hypertensive', said Dr Marques. 'What! Am I operating on someone who we don't know what's her blood pressure', shouted Dr Soares. The operation came to a halt, and Dr Marques sent the circulating nurse downstairs to the wards, to enquire about this absence. She soon returned with a piece of paper in her hand: 'Someone just recorded them here for some reason and forgot to transfer to the proper record.' 'It must have been Dr Rosendo. He thought he was going to do it later but then that (the personal emergency) happened', Dr Marques added. With the paper in hand, he confirmed the patient was hypertensive and proceeded to adjust the drug quantities with that in mind.

Both of these episodes indicate the central, organizing role played by blood pressure in neurosurgical interventions. From examining them, it is possible to appreciate how blood pressure figures in the coordination between the activities of the surgeon and anaesthetist. Such coordination results from a negotiated process, in which surgeon and anaesthetist confer before the operation about the management of the patient's blood pressure. This conversation seemed crucial in determining how the surgeon's and anaesthetist's actions, although dealing with independent matters, were almost synchronized during the course of the intervention. Rather than the surgeon controlling the structure and timing of the anaesthetist's actions, there is a mutual adjustment: the surgeon structures the timing of operative tasks (opening up, clipping, closing up, and so forth) in close relation with the timing of the tasks performed by the anaesthetist. The anaesthetist's monitoring, lowering and raising of the patient's blood pressure allows the surgeon in turn to approach the tumour, to remove it and to coagulate its vascular supply. Their parallel trajectories of action adjust to each other through their different assessments of blood pressure.

In the second episode (Excerpt 3), the absence of recorded instrumental measurements makes this mutual adjustment impossible. The absent record prevents the surgeon from constructing his own assessment of blood pressure and operating according to the plan he negotiated with the anaesthetist. The anaesthetist, in turn, is also lacking a major element

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to carry out his/her work, and is unable to compare the patient's usual blood pressure with the values shown in the monitor of the sphygmomanometer. This is particularly relevant for the planning, execution and evaluation of the drugs' sequence and its effects on blood pressure, and eventually it could have required the operation to stop. This is because the absence breaches a central rule of exchange of the neurosurgical operating room (Garfinkel, 1984), in which the measurements offered by the anaesthetist are informed by and inform the tactile assessments made by the neurosurgeon, and vice versa.

This exchange depends upon the autonomy of and the parity between the different ways of assessing blood pressure. The autonomy of each form of blood pressure assessment is not solely derived from the fact that they use different indirect measures, but most importantly by the way in which these measurements are immersed in separate collections of skills, artefacts, and representational and non-representational procedures through which surgeons and anaesthetists generate different knowledges about the patient in order to manage the trajectory of the operation. It is thus not a question of whether or not one is using a precise diagnostic technology, but of how the different methods are embedded in two different sets of epistemic resources. But there is more to be addressed. In neurosurgery, for blood pressure measurement to rest – to use Charles Goodwin's (1995: 268) words – 'upon an infrastructure of historically sedimented practice which is mobilized as a situated, temporally unfolding process in order to accomplish the work at hand', means that such measurement is characterized by multiplicity and symmetry. How can multiple enactments of the same object sustain the coordination of activities that are characteristic of surgical teams? How are we to think about the role of multiple, equally important knowledge practices within a local coordinated activity?

Heterogeneity and Coordination: Mutual Parasitism

The relationship between different forms of knowledge, different domains of practice, and different scientific languages has been a persistent concern of the social studies of science, technology and medicine. It has become common to say that there is no single representation, language, cognitive model or cultural form unifying science, technology or biomedicine (Galison & Stump, 1996; Berg & Mol, 1998). It is indisputable that both technoscientific and biomedical practices require coordination between types of expertise, different local contexts, forms of knowledge, humans and non-humans, and so forth. The process through which coordination and heterogeneity are articulated in practice has been described by a variety of concepts that are central to the field of the social studies of science, technology and medicine, ranging from networks of translation to, more recently, partial connections (Law, 2002). The concept of boundary object immediately springs to mind as suitable for identifying the phenomena analysed in this paper.

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The concept of boundary object was devised to counteract the rigid and centralized assumptions about the nature of coordination contained in the translation model by highlighting the process of 'developing and maintaining coherence across intersecting social worlds through the shared use of plastic, yet locally structured objects' (Star & Griesemer, 1989: 393). Accordingly, blood pressure – the assessment of which is necessary for the coordination between surgeons' and anaesthetists' actions – can be considered a plastic enough object to afford both technically mediated measurement and embodied assessment. While capturing the ontological diversity of blood pressure, the concept of boundary object is better suited to investigate collaboration across local sites, rather than to understand how a heterogeneous object can be mobilized in a situated, temporally unfolding process of inter-professional collaboration. For this reason, intra-operative blood pressure cannot be understood as a boundary object. The concept of boundary object renders the relationship between knowledge practices analytically in a way that abstracts from the local practices in which the object is embedded. This abstraction, while satisfactory when trying to understand the social organization of scientific theories or classification systems, cannot capture the situated, dynamic character of the relation discussed here. It cannot account for the way in which *multiplicity can both structure and be maintained by local coordinated activities.*

Instead of working with a dichotomy between difference and coordination, I suggest that difference can be the very foundation of coordination and that coordination might generate difference. In what follows, I reveal how, in neurosurgery, surgeons and anaesthetists derive their understandings of blood pressure from collections of epistemic resources through which they independently generate separate knowledges about the patient. My argument is: (1) that this difference is fundamental to the achievement of coordination of surgeons' and anaesthetist' activities in the operating room; and (2) that the difference is itself sustained by the local, unfolding mutual orientation towards each other's assessments of blood pressure. To do this, I draw on Michel Serres' (1980) figure of the parasite. I do this despite the possible associations between the metaphor of the parasite and the derogatory terms used to describe the practice of medicine, such as leechcraft, because Serres' figure beautifully encapsulates how dichotomous terms such as signal and noise, order and disorder or coordination and difference are mutually dependent on each other, and because it has been a consistent source of inspiration for social studies of science, technology and medicine (see Berg & Timmermans, 2000: 37; Brown, 2002).

In *Le Parasite*, Serres' main argument is that a fundamental characteristic of communication is the noise against which the message is assembled (Brown, 2002). He constructs the figure of the parasite in an attempt to rethink the character of exchange relations, arguing that they are logically and practically preceded by unidirectional, asymmetric transactions. The parasite is the uninvited guest that eats alongside the host, and does not offer anything in exchange. It eats without interest in where the food came

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from. It eats, and because it was not invited, it has no obligations. In this, it 'simplifies' the host to its own aims. Serres further describes the 'parasite' as both inside and outside the relations of exchange, the 'parasite' is both relational and non-relational. This is because the parasite does not establish a relation with any element of the system; instead, it creates a relation with their relations (Serres, 1980: 97–103). The 'parasite' is thus a mediator of relations in the way it continuously creates a default in their mutuality and thus becomes their foundation. This default is a source of innovation, movement and change. However, to remain both relation and non-relation, the parasite has to remain at the boundary of the exchange, always outside to be inside. If it is brought in, it is enrolled in the logic of exchange. If it is permanently expelled, it will cease to generate difference within the system: the flows within the system of exchange will tend towards equilibrium and eventually the cessation of systemic activity.

Operationalizations of the figure of the parasite have been drawn to the parasitic relation as producing cascading chains of appropriations. Most notably in the notion of translation network is embodied the idea that meaning, representation, action and power are outcomes of chains of appropriation – black-boxing – where different domains of practice are made to correspond. In Michel Callon's (1980) classic formulation, translation is an appropriation of significations, interests or concerns that, in creating a convergence between actors, also makes those actors possible. The appeal and success of this conceptualization of knowledge generative processes has relied upon its focus on the hybrid character of techno-science, its embeddedness in and effect on society and culture. One of the important criticisms of this approach has been, however, that the very idea of hybridity relies upon a vision of translation as hubris, as an affront to previously set boundaries between domains (Bensaude-Vincent, 1998).

By accentuating the creation of equivalences, actor-network theory can be said to neglect how differences between domains are generated in the same process. ANT's interests in heterogeneity is confined to the limits of the network within which the research at hand is concerned (Lee & Brown, 1994). For this reason, much research in the past 10 years has been concerned with how ambiguity, alterity, multi-centredness and multiplicity are deployed in structuring the value and usability of facts, artefacts and techniques (Berg & Mol, 1998; Law & Mol, 2002). Among these, Annemarie Mol's (2002) research on the ontology of disease is pivotal in the reformulation I am proposing here.

Mol suggests that diseases, such as arteriosclerosis or anaemia, are enactive effects of the medical practices of diagnosing, visualizing, studying and treating them. This idea represents an alternative to the way diseases are normally described in medical textbooks. In typical textbooks, different practices – such as surgery and anaesthetics – are said to refer to the same entities. Such practices, however, produce distinct diseases, as they engage with very different materials, bring about diverse modes of practical reasoning, and differently outline the patient's body. Despite such differences, the different practices can be made to collaborate. A possible

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collaborative relation is what Mol calls *inclusion*, an operation through which different objects relating to the same disease are generated by being simultaneously incorporated in and enveloping one another. In drafting this notion, Mol specifically draws on the notion of interference, and on the work of Serres. Mutual inclusion, Mol (2002: 149) argues, is a relation in which objects are 'both parasitic on and contain as parasites what [is performed] elsewhere'.

Mol's emphasis on the spatial distribution of mutual inclusion – objects are parasites on what is performed elsewhere – is what distinguishes her concept from mutual parasitism. Mutual parasitism focuses the analysis on how the difference between each way of doing blood pressure depends upon the local, unfolding coordination between surgeons and anaesthetists. To draw attention fully to the looping process by which two knowledge practices might be interrelated, it is necessary to emphasise the temporal rather than the spatial dimensions of the parasitic relation.[7] In the management of blood pressure in the operating room, for example, surgeons and anaesthetist *translate* – appropriate, misunderstand, etc. – each other's measurement of blood pressure, and in doing so construct it as mediator for their action. This appropriation is continuous and reciprocal. Mutual parasitism corresponds thus to a looping process through which different knowledge practices progressively generate their own epistemic resources by translating each other's. In appropriating each other's resources, these knowledges create a composite. This composite, however, is never truly harmonized as it depends upon the asymmetries and heterogeneities these knowledges can create between them. In this way, these practices simultaneously produce their collaborative relations and generate their differences.

It is my claim that mutual parasitism is a distinct form of coordination through heterogeneity. Mutual parasitism suggests that different knowledges can be dynamically interlinked by a relationship of appropriative externality. The concept of mutual parasitism aims to capture the temporal, dynamic, reciprocally exploitative dimension of relationships between knowledge practices. It highlights the *simultaneous, multiple doings of the 'same object' in one local collaborative situation*.

Professional Touch

In Excerpt 1 discussed in the first section of this paper, it was apparent that, despite working together, Dr Carvalhosa and Dr Amaro had two different 'definitions' of blood pressure. For the surgeon, blood pressure corresponded to the tension endured by blood vessel walls, while for Dr Amaro it coincided with a measurement shown on a monitor. For the surgeon, blood pressure was mostly a matter of touch. His 'measurement' of blood pressure was done through his touching of the patient's cortex with his gloved hand. Touch is a fundamental perceptive ability enabling surgeons also to diagnose conditions and plan interventions. Surgeons rely on this kind of sensorial experience to guide their actions within the

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operation. The expertise of surgery can be defined partly by the surgical hand's sensitivity to the structure of the operative field (Adams, 1998).

The importance of touch for the craft of surgery, although fully realized by practitioners, is not sufficiently recognized in social research. It is recognized in phenomenology: from Husserl onwards we can find the first attempts to recover touch as a primary sense for experiencing the world (Husserl, 1996: 136–60). Associated with its underlying critique of the modernist foundation of human reasoning, phenomenologists treat touch as the means through which the subject, by representing the tactile feature of an object, experiences the body as a sensitive object in itself (Merleau-Ponty, 1945). This primacy of touch is also driving the experimental investigations of David Katz, who emphasized the active characteristics of tactile perception (Gibson, 1962; Katz, 1989). With the recent development of virtual reality and robotic application for remote manipulation, haptics has consolidated as a research field (Lederman, 1991). Research in that field has, however, continued to dwell on the same assumptions that have sequestered the investigations of touch in psychology and phenomenology, fascinated as they were by its primacy in human perception.

The assumption of psychological research is that the perceptual information gathered by touch can be analysed separately from the socio-technical relations and cultural setting within which such information is generated. In the perspective of sensorial psychology touch is analysed as a naked, generalized form of perception. Naked because its archetypical analytical unit is the body, and, more significantly, the hand in direct contact with the world, relegating culture and technology to the place of 'special cases' of tactile mediation (Katz, 1989: Ch. 4); and generalized because, in this paradigm, touch is imagined to have universal characteristics that are insensitive to the situations and professional practices within which it is deployed. My 2 years of ethnographic fieldwork with neurosurgeons suggests otherwise. It suggests that, in neurosurgery, touch is immersed within a complex form of professional expertise (Goodwin, 1994; also see Sudnow, 2001).

Surgical touch is, in fact, many different forms of touch, situated within the various technically intricate situations in surgeons' routine working lives. Surgeons use their skin as a differentiating apparatus in diverse practical contexts. There is, for example, the 'diagnostic touch', through which the surgeon identifies by manipulation structural problems in a patient's anatomy (for example, bone fractures) or physiology (for example, reflexes). This form of touch is more easily comparable with other clinical practices. There is also the 'empathic touch' which surgeons, known for their cold approach to clinical practice, are increasingly encouraged to engage with by talking to patients in a proximal manner, transmitting security and trust through touch. Touch is, furthermore, used to identify anatomical structures to which the surgeon has no direct visual access when operating. Cerebral vessels, malformations and other structures are sometimes perceived only by the 'feeling' of their contours.

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Surgeons also ordinarily ‘feel’ their way in an operative field to which they have visual access, generating further knowledge of its saliencies and problems by comparing the resistance and the texture felt by the pressing of the hand or finger on the brain, muscle or bone. Such ‘feeling’ is guided by the knowledge of cerebral structure held by the surgeon, but it is also a means through which surgeons gain knowledge of the relative positions of certain ‘markers’, such as important arteries or brain regions.

This relationship between anatomical knowledge and haptic skills organizes the actions of the surgeons, as shown in the following excerpt from field notes collected during an operation on a male patient with a temporal lobe brain tumour:

> Excerpt 4 (Operating Room 2 – Day 94)
>
> After having exposed Mr Antunes’ cerebral cortex, Dr Lopes moved towards the operating area, looked more closely at what could be seen of the tumour at the surface of the brain and felt the cortex with two of his fingers. Looking at Dr Carvalhosa he said:
>
> ‘So, where do you think we should stop [the excision]?’
>
> They both walked over to the MRIs [magnetic resonance images] of the patient attached to the lamp. In their conversation, which I overheard, it became obvious that their concern was with the ‘Wernicke’s area’. They wouldn’t want to do any damage to that area, as it would involve increasing the difficulties Mr Antunes had in understanding language. On the other hand, they would like to remove the greatest amount of the highly malignant tumour from the patient’s brain. As the tumour was visibly lodged in the end of the temporal lobe, they decided to follow a ‘wise rule’ and limit the excision at about 6 centimetres from the end of the lobe. That way they wouldn’t touch the ‘Wernicke’s area’ and would be able to remove the tumour and the cortical matter around it, which could be infiltrated with isolated cancer cells.
>
> Dr Lopes re-started the operation by carefully feeling the end of the temporal lobe of the patient’s brain, after which he marked the cortex by carving the excision limit with the electric scalpel. Dr Carvalhosa took over the main position and repeated the same ‘feeling’ of the cortex so as to confirm Dr Lopes’ assessment. He then opened a small incision in the cortex and inserted the suction apparatus in it. He extended the incision and repeated the suction. Next, he paused, and opening the wound he looked and touched inside with the bipolar pincers. He then ‘coagulated’ the wound.
>
> After this, he and Dr Lopes stopped, looked at and touched inside the wound again with their pincers. With this they identified the limits of the tumour, and showed them to each other by pointing with pincers to visible patches of cancerous tissue. Dr Lopes walked again towards the MRIs and confirmed the limits chosen by them by putting his thumb between his indicator and middle finger, demonstrating thus how big the tumour should be.

In this operation, the surgeons’ main objective was to find the best balance between removing the greatest amount of tumour tissue and doing the

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smallest damage to the patient's already impaired speech. For this purpose they needed to determine the specific contours of the 'Wernicke's area'. This is a cortical area associated with the comprehension of language. Patients suffering from what neurologists call 'Wernicke's dysphasia' normally produce a fluent yet nonsensical speech with neologisms, non-existing words or half-right words (Lindsay & Bone, 1997: 119). In order to determine the contours of the region in this particular patient, the surgeons merge a variety of procedures and forms of knowledge. In this merger, touch both generates its own epistemic field and plays a fundamental mediating role between other forms of knowledge.

Prior to the operation, the surgeon responsible for Mr Antunes' treatment either had performed or had ordered, interpreted and discussed a variety of tests on the patient. These normally include, besides the usual clinical assessment: a neurological examination; MRIs, computerized tomographies (CTs), 'normal radiographies'; and, sometimes, formal neuropsychological assessments. In Mr Antunes' case, the neurological examination would have displayed his difficulties in understanding ordinary questions and requests, and the MRIs that he brought to the room would have provided an anatomical two-dimensional mapping of the lesion. This knowledge is essential in the surgeon's evaluation of how to plan the intervention and where to set the limit of the excision; and it also informs his discussions with the patient about whether or not to operate.

This information would have determined the 'operative approach' – the direction and angle from which the surgeon will move towards the lesion. Such determination will, in turn, present the surgeon with a range of salient anatomical and structural items, such as facial skin, muscle constitution, bone and arterial formations, which need to be taken into account when operating on the patient. The surgeon's actual manipulation of these structures is only possible after the patient's body has been prepared by the anaesthetist for sedation, muscular relaxation and monitoring (Hirschauer, 1991). The surgeon's first contact with the patient-as-body initially takes place on the operating table. In setting a position for the patient's head, a fundamental preparation in neurosurgery, the surgeon takes into consideration three factors: the operative approach as planned before the operation; the relation between the height of the table and the surgeon's own height; and the tactile impression of the patient's head.

In the 'opening up' section of the operation, the surgeon's actions deploy the way in which the relation between these factors is embodied in the position of the head of the patient. This relation is used as a platform for gaining further knowledge of the patient's body. As the surgeon cuts through skin, muscle and, finally, bone, the specificities of the patient's anatomy are progressively exposed materially, perceptually and discursively (Mondada et al., 2000). The exposure of the cortex is, in this context, fundamental for the establishment of relationships between what was planned, what is seen and what is felt. At this moment, surgeons usually stop and reassess their plan in light of what can be seen and felt at the surface of the brain. What the cortex feels like is a fundamental part of

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the intra-operative assessment made by neurosurgeons. For example, a 'tenseness' of the cortex can indicate either existence of pressure exerted on the brain by intracranial masses such as tumour or arterial malformations, or by an excess of cerebrospinal fluid, or by the pressure endured by blood vessels as a result of the mass itself or derived from co-morbid conditions (Lindsay & Bone, 1997: 75–76). In all these situation blood pressure is involved, either as a cause of consequence.

To address this question, at this point the surgeon can ask the anaesthetist for a measurement of blood pressure and compare it with what he or she can feel on the brain with the fingers through their gloves. This knowledge is essential in the surgeon's evaluation of the brain as operable matter, as it provides clues to the causes underlying the 'feel' of the cortex and to the probable anatomical textures to be encountered. In this distinction, a comparison between overall 'tenseness' of the cortex and that felt in blood vessels is paired with the anaesthetist's assessment of the patient's 'normal blood pressure'. Determining whether the patient suffers from essential hypertension is central in assessing whether the tension felt by the fingers is related to a structural problem or to a systemic, long-term condition. Such information allows the surgeon to adjust his/her evaluation of the practical consequences associated with different sources of 'tension': how to operate, how to time the incisions and what to expect from cut blood vessels. By establishing a relation of equivalence – a sort of exchange rate – between the values given by the anaesthetist and the surgeon's own evaluation, the anaesthetist's measurement can be effectively and recursively converted into a resource for surgical action during the rest of the operation.

This moment also represents the first time the surgeon has direct access to the texture of the tumour, and can thus consider how best to handle its excision. The surgeon also can visually appraise the tumour's incorporation in the cortical matter. This additional knowledge demands a re-assessment of the adequacy of the operative plan, as it was devised through interpretations of MRIs and neurological tests. It also can entail considering how such re-assessment can be put in practice, given the other anatomical and physiological details of this case. Thus, in the surgeons' conversation about Mr Antunes' MRIs, the main dilemmas of the patient's case are re-articulated.

By observing the variable colouration of cortical tissue at the surface of the brain and feeling with his two fingers a corresponding textural salience, the surgeon in the above excerpt constructs an embodied impression of the tumour's contours. His re-interpretation of the MRIs aims to evaluate how his tactile impression matches the visual image.[8] This triggers a discussion about the clinical objectives of the operation: a complete excision of cancerous matter would substantially reduce the likelihood of re-growth, but also might damage the Wernicke's area. The surgeons collaboratively respond to this dilemma by discursively positioning the core of the tumour at the end of the temporal lobe. This decision, in turn, orientates their attention to a specific anatomical marker: the material boundary of the

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cortex as delimited by the dura mater. From this position, the 6-cm-wide rule provides another relevant resource. Such rules of thumb are fundamental in surgery, as their transportability and constancy sustain surgeons' judgments in real time (Moreira, 2004b: 53–69).

As they re-start the operation, Dr Lopes' first aim was to re-check the assumption that the core of the tumour was at the end of the temporal lobe. This is also an opportunity to make a tactile estimate of the outline of the temporal lobe and thus assess, with eyes and hands, where the 6 cm mark would be set. The clue to the way in which this estimation is completed comes later in the excerpt: surgeons use a memorized relation between 6 cm and the length of their thumbs in setting the excision limit. They also compare each other's estimation before actually cutting the cortex.

The first incision represents another crucial moment in the trajectory of the operation. In Excerpt 1 presented early in this paper, this was the moment when the surgeon realized that there might be raised blood pressure by observing the flow of blood running from the artery. In that example, this became the moment where the establishment of the 'exchange rate' was attempted and failed. But it also tells us about the role of instruments in the surgeon's assessment of blood pressure. Neurosurgeons, especially those specializing in intracranial surgery, realize their expertise through a combination of neurological knowledge about cortical structures and surgical knowledge about how those structures appear to the eye, feel to the hand and interact with instruments. The instruments used by neurosurgeons – scalpel, bipolar pincers, micro-suction, and so forth – become more central to the task at hand as they often replace the hand or fingers as haptic tools. This is because, in a large proportion of neurosurgical interventions, the incision opening is too small to access the interior of the wound with the fingers properly. The bipolar pincers, in particular, become a multifarious object used for cutting, coagulating, placing and picking up various materials, and for pointing at and touching the surface and interior of the cortex.

This touching of the wound with the pincers is more delicate and considerate than the kind of touching deployed either on skin and muscle or on the unopened cortex. This form of haptic grasping is also less differentiated from the other actions the surgeon does at the same time, and it becomes embedded in the performance of the coagulation or incision. Surgeons identify cancerous tissue not by looking at it *and* touching it, but by looking *while* touching–coagulating. For Dr Lopes and Dr Carvalhosa it was important, when they identified the cancerous tissue, to observe also how the tumour visibly bubbled when they turned the power to the pincers on and to assess the resistance that it offered to the coagulation action. The identification of the tumour is further developed through the changes that Dr Carvalhosa produced on the aspect and material consistency of the tumour. But this is not the end of the story. Having produced this new set of resources, they then examine the MRI and reiterate the applicability of the rule of thumb to the case at hand.

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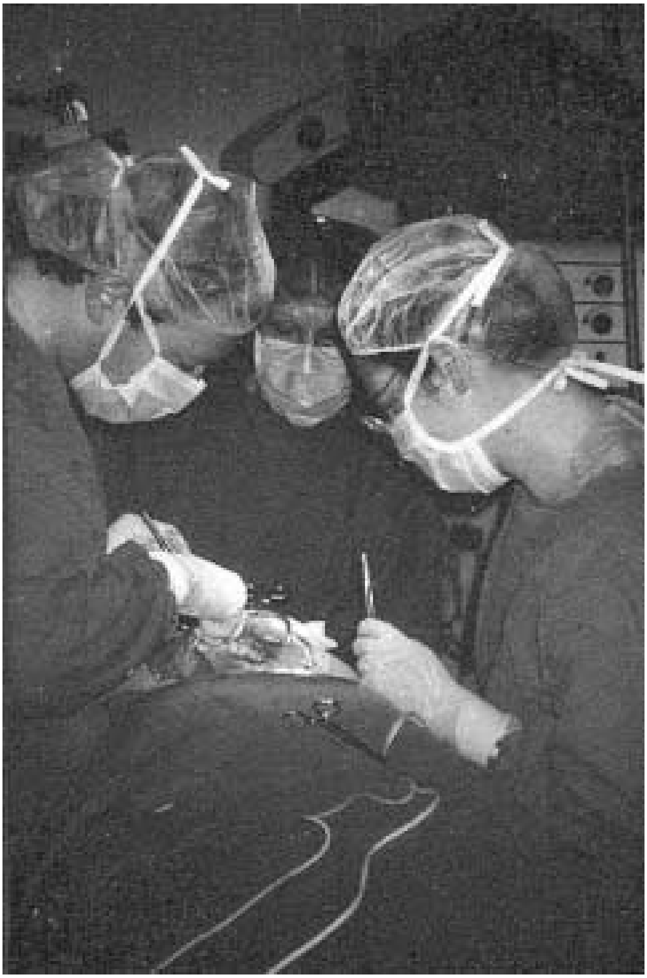
FIGURE 1
Neurosurgeons operating with instruments (author's own records).



The trajectory of action, encapsulated in Excerpt 4, is structured by a dynamic adjustment between epistemic resources of various kinds: texts, anatomical images, MRIs, their rules of interpretation, and the visual and haptic knowledge generated in the operation itself. The trajectory unfolds through a continuous moment-by-moment re-construction of the case at hand. In this process, perception and action mutually constitute each other: the surgeon works on the body of the patient *with* and *through* the resources present in the operating room (MRIs, CTs, microscopes, surgical instruments, and so on). In order to see what s/he needs to operate on, the surgeon cuts through and manipulates skin, bone, muscle and brain, attempting to establish what Hirschauer (1991: 312) called the 'reflexivity of similitude' between the body of the patient and anatomical representations. The cross-referential relation between the body of the patient and

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representational elements in the operating room is sustained through an embodied engagement in which the senses are themselves mutually relevant to each other. The surgeon's actions are reflexively immersed in the different sensorial effects that he himself/she herself is creating.

Surgical touch cannot thus be taken as a distinctive perceptual system. It is situated within a professional practice and a technical culture; it is mediated by various forms of knowledge and by technological artefacts; it is furthermore immersed within a socio-technical apparatus – the surgical team, instruments and life-support system – through which knowledge of the patient's specific anatomy is constructed. *Part of the socio/technical apparatus of surgical touch is the measurement offered by the anaesthetist based on his/her reading of the sphygmomanometer.* In order to appreciate the tension that his/her hand feels at the surface of the brain, the surgeon must have access to the anaesthetist's assessment of the patient's blood pressure. Such appreciation depends upon an *attempt to convert*, or *translate* the numerical values given by the anaesthetist into a usable resource for the dynamic unfolding of his/her actions; in other words, a resource that will help him/her decide whether or not to start the intervention and how to approach it, and which continues to assist him/her throughout the operation in the construction and manipulation of the intra-operative field.

Neuro-Anaesthetic Inscriptions

The measurements offered by the anaesthetists to the surgeon also derive from a complex set of practices and epistemic resources. The construction of such measurements begins in the wards. On the first encounter with the patient, the anaesthetist deploys a variety of tests, the results of which she will use for structuring the timing of surgical interventions. In this process, she uses measurements made previously by nurses and other health workers, some of which she performs herself with the help of devices such as sphygmomanometer. By establishing a normal, individual range of blood pressure, the anaesthetist establishes narrow criteria from which she can evaluate whether measurements shown in the operating room monitor are above or below the expected value for a specific time. In this process, blood pressure becomes attached to a variety of other measurements.[9]

Another excerpt from Mr Antunes' case (the patient discussed in the previous section) shows how the patient's normal individual range of blood pressure and its epistemic apparatus is established:

> Excerpt 5 (Surgical Ward – Day 92)
>
> About mid morning, the anaesthetist, Dr Amaro, came into the ward. She picked up Mr Antunes' record and went into his room. In the room, she directed the questions at Mrs Antunes. The questions focused on the patient's previous operations, the medications he was taking at the time, and the allergies from which he suffered. She tested the patient's respiration and cardiac rhythm. She confirmed the blood pressure values written on the patient's record by measuring them herself. She also checked on

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> his liver and renal conditions, as well as his blood tests. She was, however, not satisfied with the blood test results and ordered another set.
>
> *
>
> The new blood collection was done by nurse Paulo while Dr Amaro was still in the patient's room. 'With his age (Mr Antunes was 73), it is better to know what we are in for, I do not want any surprises in the operating theatre.' Mrs Antunes seemed worried to hear these comments and asked if there was anything wrong. 'No, just that we do not want any surprises.'
>
> While writing her observations and measurements in Mr Antunes' record, she informed nurse Paulo that she was prescribing some sleeping pills because his blood pressure indicated some stress: 'He may not understand what we say but he knows where he is and he knows it's not good.' The rest of the prescription was 'the same as any other tumour patient', she added.

Dr Amaro's visit to Mr Antunes' room marks the beginning of a new clinical relation for the patient. After his case has been considered by the surgeon to evaluate the importance and feasibility of surgery, he is put through another set of assessments. Mr Antunes' interaction with the anaesthetist, mediated by his wife due to his language impairment, took the form of an overall evaluation of his fitness to endure surgery, and covered such matters as previous sedations, physiological function and cardiac robustness. In this process, the anaesthetist's aim might be seen to contradict the scenario elaborated by surgeons for specific patients: it is as if the anaesthetist is trying to establish the 'patient's interests', interests which have been overlooked in the surgical consultation room. This gathering of information about the patient is thus enveloped in what is known as the protective role of anaesthetics in surgery.

The question they are asking seems to be: is Mr Antunes going to survive the anaesthesia? So for example, when Dr Amaro and Mrs Antunes recapitulated Mr Antunes' surgical history, they were able to relate his history to standard recommendations, appropriately memorized by Dr Amaro, regarding the correct level of sedation used in any specific patient according to measurements such as weight and blood pressure. The picture was completed with the results of cardiac tests that Dr Amaro had in her hand. These elements, and especially the patient's age, placed Mr Antunes' case favourably towards the constraints of anaesthesia.

In reaching this point, which does not happen with every patient,[10] the aims of anaesthetics shift. This shift can be observed in the above Excerpt. In the first episode, Dr Amaro was mainly interested in gathering information about the patient and evaluating how the patient would endure sedation; in the second episode she is more interested in creating a condition for the management of the patient's body in the operating room. She focused her attention on the fact that the patient's results of blood tests – coagulation time, oxygen saturation and so on – seemed inconsistent in

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light of the patient's age, and she took the patient's age as an indication of his body's fragility and weakened self-regulating mechanisms. Her explanation of the reasoning behind her request for new blood tests caused Mrs Antunes to worry. Dr Amaro's reply took into consideration the patient's and relatives' emotional responses to the prospect of surgery.

Instead of being experienced as a protective practice, the anaesthetists' activities in the second section of Excerpt 5 became embedded in another set of concerns, those of setting the parameters to 'work with' someone's body. To 'work with' someone's body in anaesthetics means that particular material states in the patient's body in the operating room can be brought about by the 'use' that some organs give to particular drugs. By establishing parameters of interaction between organs and functions, and managing the emotional orientation of the patients before the operation, the anaesthetist constructs a bounded set interrelated variables – variables that she uses as facilitators for her actions when she is 'working with' the patient's body in the operating room, and as resources for her practical control of the surgeon's action.

Establishing the patient's normal range of blood pressure through repeated measurements is a central concern in this. The parameters of blood pressure enable evaluations of when the patient blood pressure can be considered normal or abnormal. The management of blood pressure with drugs is required during different phases of the operation. In brain tumour surgery, blood pressure needs to be lower when 'opening up' or 'cutting', and higher when 'closing up'. Such manoeuvres can be performed only when the patient's blood pressure history is assembled, and their safety depends heavily on that history, as does the anaesthetist's ability to cite blood pressure measurements as a legitimate reason to stop surgery.

This history produces blood pressure as a function of a variety of other vascular and non-vascular elements, such as age, gender, diet and so forth. As the anaesthetist listens to the patient's answers and reads his/her record, she adds an interpretative layer by relating various measurements to each other in the face of the surgeon's planned intervention. In this, the anaesthetist's notes are essential, as they inscribe blood pressure and its associated measurements in one single space: they are registered in the anaesthetist's own patient record, a document in which blood pressure measurements are visible at a glance next to their associated variables. This record is further summarized in the 'intra-operative anaesthesia record' (see Figure 2), a table in which the evolution of blood pressure – and other variables such as O_2 and CO_2 saturation, for example – before, during and after the operation, is traced on a special diagram by the markings ('arrow heads') drawn on the paper.

These markings enable Dr Amaro to ascertain the evolution of the patient's blood pressure, as possibly influenced by a particular drug when, for example, she says in the field note given in the beginning of the paper: 'He's been lowering for the past ten minutes, the [drug] is doing its thing.'

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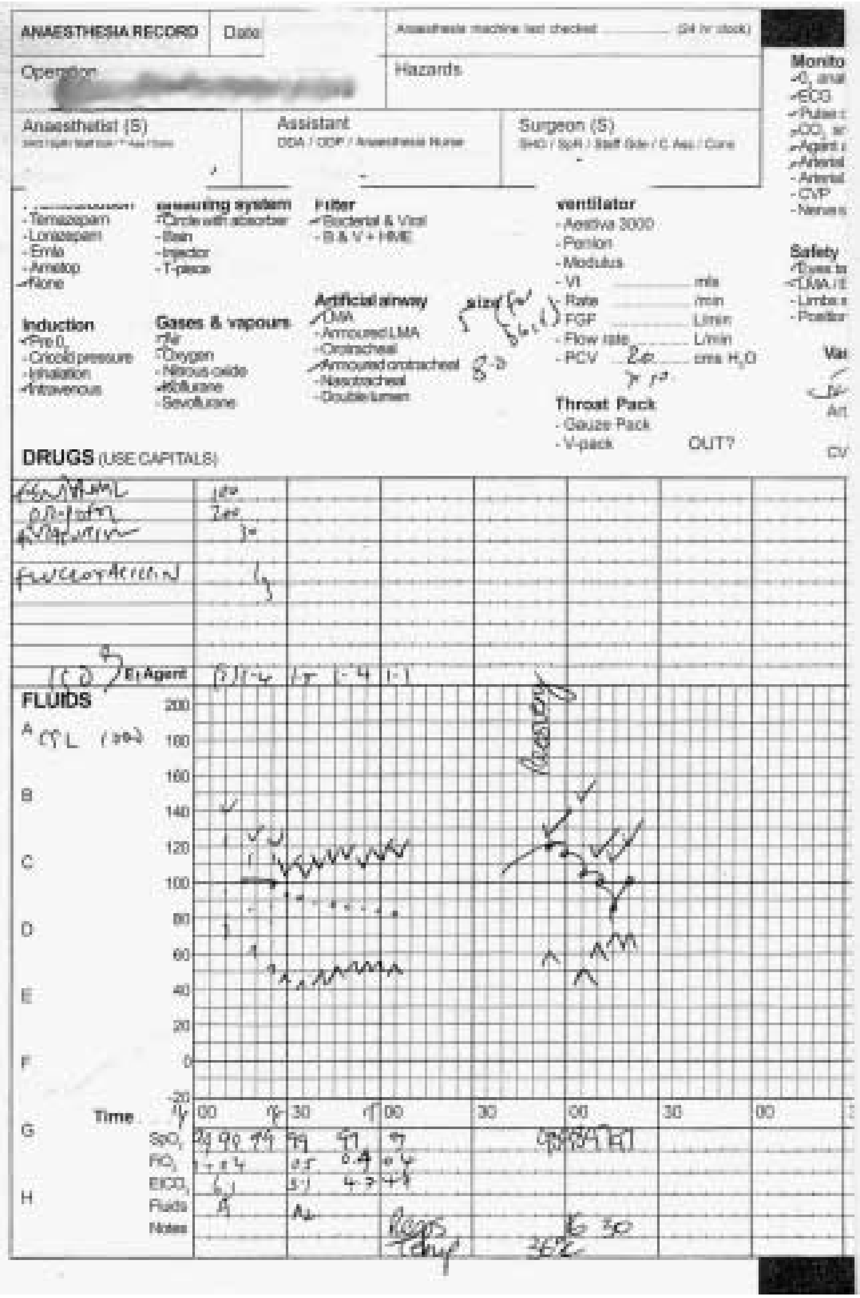
FIGURE 2
Anaesthesia record (kindly provided by Dr Andrew Smith, Royal Lancaster Infirmary).



The blood pressure, for the anaesthetist, corresponds to an unfolding set of measurements, before the operation and in the operating room itself. Her

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assessment of blood pressure is thus both a reading of the sphygmomanometer and an interpretation – a projection – of the direction of evolution of the patient's blood pressure, even when it is stationary.

The surgeon's own operative plan plays a crucial part in the timing and structuring of the anaesthetist's intra-operative plan and management of blood pressure. The surgeon's plan was discussed with the anaesthetist at the beginning of the operation and is implied by his requests for measurements of blood pressure. This relation unfolds in time. First, the surgeon's plan furnishes the scenario against which the anaesthetist tests the resistance of the patient's body. In this evaluation, the establishment of a consistent blood pressure measurement is fundamental, as it determines if the patient is fit for intraoperative blood pressure management – what one neuro-anaesthetist called 'the pressure game' – and the vascular effects of sedation. Second, during the operation itself, blood pressure measurement is crucial for assessing the patient's general condition. Third, and more specifically, the anaesthetist's management of blood pressure depends upon the timing of the surgical intervention, reverberating, anticipating or delaying the surgeon's actions, as if from a different realm.

In this 'external' relation during the operation, the anaesthetist's measurement of blood pressure depends upon translating the surgeon's own assessments of blood pressure. The surgeon's reports of or request for a blood pressure reading tells the anaesthetist what the surgeon understands of the operative situation, what his next step may be, and what he may be uncertain about. She aims to establish a relation of equivalence between the surgeon's feeling of the brain surface and the measurements and the lines in front of her. Her interpretation of the state of the patient's blood pressure is thus partly achieved through the elaboration of this relation of equivalence. *The anaesthetist 'reads' blood pressure measurements through what the surgeon voices to be the feeling of the brain.* However, in translating his assessment, she converts his evaluation into a reference point from which to continue constructing and measuring the patient's blood pressure and, in so doing, transforms the meaning given by the surgeon to his own measurement.

Beyond Coordination and Heterogeneity?

The difference between the surgeon's and the anaesthetist's blood pressure readings is grounded in the different ways in which they accomplish the patient's blood vessels. However, it is not just a question of gloved hands and scalpels in direct contact with the cerebral cortex, on the one hand, versus repeated measurements logged in a chart, on the other. The different versions of blood pressure through which the surgeon and anaesthetist generate different knowledges about the patient involve different collections of skills, artefacts, and representational and non-representational procedures. These collections, or apparatuses as I have chosen to call them, are in a peculiar relation to each other. If on the one hand, they are

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constructed independently from each other, they also depend on one another.

The surgical and the anaesthetic apparatuses are external to each other insofar as their components are composed and gathered for autonomous practical purposes. Such autonomy may guarantee the safety of the patient by endowing the anaesthetist with the power to control the actions of the surgeon from an independent position, and the surgeon with the ability to work on a limited set of anatomical problems. Likewise, the surgeon's autonomous deliberating on what and how patients should be operated on is essential for determining a fit between the apparatus of surgery and the patient's condition. However, at the same time, they are also deeply interrelated. I argued that blood pressure plays a central part in the coordination of surgeon's and anaesthetist's activities, and this is partly achieved by a mutual orientation towards each other's assessments of blood pressure. To put this another way: just as the anaesthetist's reading of the chart of blood pressure measurements is part of the apparatus of surgical touch, so is what the surgeon voices to be the feeling of the brain part of how the anaesthetist reads blood pressure. How are we to think about this relationship of simultaneous externality and intersection of two knowledge practices?

I have suggested that Michel Serres' figure of the parasite is indispensable for thinking about the boundary relations between two knowledge practices or systems. The figure of the parasite appears time and again in social studies of science, technology and medicine: in the cascading chains of appropriation that characterize translation networks, in the more recent notion of translation as an ambiguous becoming of similarity and difference (Law, 1997), in Berg and Timmermans' (2000) research on the multiplicity on medical universalities, and in Mol's (2002) notion of inclusion. The common interest such investigations share in the notion of the parasite is the idea of the ambiguous relations in which dichotomies seem to be grounded. The parasite's attraction is that it remains at the boundary of the link between constitutive relations (of exchange, scale and meaning). By introducing the concept of mutual parasitism, I drew upon these conceptual resources to emphasize how a symmetrical, interdependent and temporally unfolding relationship between two local knowledge practices can generate differences between those practices.

The concept of mutual parasitism became pivotal for understanding how, in the operating room, the management of blood pressure is structured upon a *loop* through which the surgeon's doing of blood pressure contains, and is, in turn, contained by, the anaesthetist's reading of it. This loop is continuously enacted by both the neurosurgeon's and the anaesthetist's appropriation of each other's measurements. Such appropriation corresponds to an operation of *translation*, in which the externality of the two practices is locally achieved and maintained. Through these disengagements, each participant is able to constitute the other's apparatus as a mediator for his or her own paths of action. For this mediating function to take place, the apparatuses must be kept separate. However, the very

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attempt to create equivalence between the different blood pressures measurements creates and sustains the differences between practices.

In reworking a central tension in the social studies of science, technology and medicine, the concept of mutual parasitism offers various empirical and/or theoretical research possibilities. One possibility is to call attention to local inter-professional collaborations, allowing for a symmetrical exploration of each expertise involved. Within these situations, it may be possible to appreciate misunderstandings and 'silences' between perspectives as derived from locally coordinated dynamic relationships. Another important route would be to understand the extent to which differences between knowledge forms depend upon their mobilization in a 'situated, temporally unfolding process in order to accomplish the work at hand' (Goodwin, 1995: 268). Finally, it would be valuable to comprehend how the different scales of knowledge relate to each other when they are configured, included or changed by instances of mutual parasitism (Moreira, 2004b).

Finally, I want to suggest that the concept of mutual parasitism may be relevant not only to social studies of science, technology and medicine, but also to theories that underpin the organization of health care and medical education. Medical theory tends to order different forms of knowledge according to their consistency with ideals of science and scientific practice. In this, the sphygmomanometer has been taken since the 19th century as a symbol of the larger path of medicine towards becoming more a science and less of an art. By arguing that different knowledge practices can be peripheral to each other and yet intimately interdependent, I am suggesting that the relationship between different knowledges is neither hierarchical nor relativist. I believe that this complex form of interrelation should be relevant for how we think about relationship between different types of medical knowledge. I also believe that further work needs to be done to translate this complex form of interrelation into new ways of thinking and imagining the relationship between different types of biomedical and clinical knowledge in the practice of health care.

Notes

This paper was first presented at the *Responsibility Under Uncertainty* – EASST Conference, University of York, 31 July – 3 August 2002, in a session I co-organized with Lorenza Mondada entitled 'Ordering Surgery in the Operating Room'. I thank her, Jon Hindmarsh and the session's participants for their generous comments and a lively discussion. The paper gained enormously from the constructive comments of João Arriscado Nunes, John Law, Jon Hindmarsh (again), Steve Brown, Tim Rapley and Simon Kitto. Three anonymous referees were generous in their reading of the paper and suggestions. Michael Lynch gave invaluable editorial guidance in the revisions of the paper. I thank the patients and staff of the Surgical Unit, who endured, for almost 2 years, my impertinent questions without asking anything in return. The research was funded by the Fundacão para a Ciência e Tecnologia, Lisboa, Portugal (BD13901/97). I thank Annemarie Mol for sustained intellectual companionship and inspiration. This paper is dedicated to her.

1. Extensive fieldwork was conducted during 1998 and 1999 in a neurosurgical clinic of national and international standing. Located in one of Portugal's main state-funded university hospitals, the clinic is directed by a prestigious neurosurgeon who did most

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of his surgical and scientific training in the USA. Most consultants or registrars have, at some point in their careers, undergone some kind of surgical training abroad (in the USA, the UK, France or Switzerland) and have academic responsibilities alongside their clinical work. Both because of the clinic's reputation and the national health care system's spatial organization, patients are referred to the clinic's surgical consultants by general practitioners and other consultants (neurologists, psychiatrists, orthopaedists) practising in an area radiating various miles around the city. The clinic's educational vocation is noticeable in the presence of medical students in the operating room and wards, a feature that facilitated my access and freedom of circulation in the unit as an ethnographer.

Fieldwork was divided into three periods, one preliminary (four weeks) and two others of 10 weeks each. During these periods I combined site-focused fieldwork with patient-focused fieldwork. In the patient-focused mode, I followed particular patients during their surgical treatment. The proportions of patients by types of surgical condition observed during fieldwork parallel those registered in the clinic's own statistics. In the site-focused mode, I observed the practices and routines in particular divisions of the clinic for a sustained period: the operating room and its immediate surrounds; the intensive care unit; the surgical wards; the neuropathology laboratory; and the outpatient clinic. In addition, I spent some days in the neuro-radiology department, and accompanied some neurosurgeons on their emergency shifts. I also regularly attended the clinic's weekly meeting and case conferences.

The analysis of the data was guided by the principles of analytic induction (Katz, 2001), an analytic method aiming to recursively adjust interpretations and hypotheses to the data gathered, and requiring these models to direct the process of data gathering. Analytical findings were validated through a short comparative ethnographic fieldwork in a similar clinical setting in the UK, and respondent validation, which was obtained during fieldwork and by formal commentary of written reports. The field notes presented in this paper are translations from the original notes in Portuguese.

The names of patients, their relatives, and of medical workers used in this paper are aliases.

2. Arterial blood pressure in the brain is a key mechanism in intracranial pressure and associated cortical stress, as the increase of the ratio of blood volume is intimately linked with the tension experienced in the brain as a whole, whether as cause or consequence of it. The determination of the relation between the two is a key concern of neurosurgical intra-operative assessment. See 'Professional Touch' section.
3. The 'gold standard' of measuring blood pressure is direct recording of intra-arterial pressure using a catheter. This is a highly invasive procedure and not practised in most health care settings. For these settings, the sphygmomanometer remains the standard when evaluating newer technologies in monitoring blood pressure – including wrist and finger cuffs with digital readouts, which are becoming more and more popular for home and clinic use. See Perloff et al. (1993).
4. See, for example, Segall (1975).
5. See Lawrence (1985).
6. Another was Cushing's own hypothesis that the localization and level of malignancy of gliomas were related to their cellular origin. See Moreira (2000).
7. See Deleuze (1990). I thank Thomas Scheffer for drawing my attention to this book.
8. Stefan Hirschauer (1991: 312) has called this the reflexivity of similitude between image and operative field. See also Moreira (2004a).
9. For a detailed analysis of anaesthetics work, see Hindmarsh & Pilnick (2002).
10. My field note relating to another patient, Mrs Gomes, reads as follows:

> Operating Room 2 – Day 86:
>
> Dr Amaro came into the nurses' working room and was told that the patient felt somehow she was not prepared for the operation. 'I think I know what it is . . .', she replied. She went to Mrs Gomes' room and introduced herself. Their conversation immediately focused on Mrs Gomes' heart condition. Dr

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> Amaro read the heart tests while talking to Mrs Gomes. She then listened to Mrs Gomes' heart carefully and thoroughly. She wrote some notes in Mrs Gomes' file and one could see she was concerned.
>
> Being asked about that, Dr Amaro said that she would like to speak to Dr Soares before they both talked with Mrs Gomes. Mrs Gomes and her daughter confirmed that they knew that Mrs Gomes' heart condition was problematic: 'Dr Soares said that you, doctor, were the one who was going to decide on this.' Dr Amaro told them not to worry and to wait until Dr Soares came.
>
> Dr Soares arrived a bit later from the surgeons' weekly meeting. Dr Amaro, who was waiting for him at the nurses' working room, charged at him right away: 'How could you have this patient scheduled for tomorrow?, this woman would never survive a general anaesthetic!, what am I supposed to do?' Dr Soares was a bit embarrassed by this invective. He listened to the reasons why the operation would be a failure: her irregular heartbeat would be affected by the drugs they needed to use; her heart could fail because of them; she could not '*work with* the heart' to produce the effects he needed in particular moments of the operation. 'I cannot take responsibility for taking her into the OR [operating room]', and waited for an answer from Dr Soares. Surprisingly, he did not apologise. Instead, he said that he had seen and been in operations where the patient's heart condition was even worse. He wanted to know her opinion as an anaesthetist and the only way to do that was to schedule her operation and have her in the wards for that reason. This seemed to calm Dr Amaro. They continued the conversation over the cardiac tests spread on the table with Dr Amaro explaining the detail of her opinion.

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Tiago Moreira is Research Associate in the Centre for Health Services Research, University of Newcastle-upon-Tyne. Most of his research has been concerned with the dynamics of diversity and coordination of knowledge practices in medicine, and in the clinical neurosciences in particular. He is currently investigating, within a multidisciplinary team, the changing relationship between biomedical, clinical, epidemiological, psychological and lay knowledge about cognitive ageing (<www.sci-soc.net/SciSoc/Projects/Identity>). Recent publications include 'Diversity in Clinical Guidelines' in *Social Science and Medicine* and 'Self, Agency and the Surgical Collective' in *Sociology of Health and Illness*.

Address: Health Technologies and Human Relations, Centre for Health Services Research, 21 Claremont Place, University of Newcastle-upon-Tyne, Newcastle NE2 4AA, UK; fax: +44 191 2226043; email: t.e.moreira@ncl.ac.uk

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