Multiplicity and ontological instability in nonhuman hearts

Multiplicidade e instabilidade ontológica nos corações não-humanos

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Abstract

This paper reflects on the relationship between biological bodies and technological artifacts, based on ethnographic research on the development of circulatory assist technologies, known as artificial hearts. To understand the embodiment that such mechanical devices help to produce, we aim to characterize two types of bodies enacted from medical practices and biotechnologies designed for patients with advanced heart failure. The immunological bodies, produced from heart transplantation, will be contrasted with the bionic bodies, composed of the assembly with artificial hearts. We propose that it is necessary to consider each of these technologies as co-produced with different natures, supported by specific materialities, practices, moralities and assumptions. The attention given to practices and materiality will allow to highlight the various material-semiotic intertwinings. Tracing the development trajectory of this field will allow exploring the imagination from which such interventions emerge and the transformations that have occurred, emphasizing the link to the body-machine woven in the biomedical scope.

Keywords: Body Constitution; Biotechnology; Heart Transplantation; Heart Failure; Artificial heart.

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Resumo

O artigo reflete sobre as relações entre corpos biológicos e artefatos tecnológicos, a partir da pesquisa etnográfica sobre o desenvolvimento de tecnologias de assistência circulatória, conhecidas como corações artificiais. Para compreender as corporeidades que tais dispositivos mecânicos ajudam a produzir, buscamos aqui caracterizar dois tipos de corpos instituídos a partir de práticas médicas e biotecnologias projetadas para pacientes com insuficiência cardíaca avançada. Os corpos imunológicos, produzidos a partir dos transplantes de coração, serão contrastados aos corpos biônicos, compostos pelo arranjo com corações artificiais. Propomos que é preciso considerar que cada uma dessas tecnologias se coproduz com distintas naturezas, sustentadas em materialidades, práticas, moralidades e pressupostos específicos. A atenção dada às práticas e à materialidade permitirá destacar os diversos entrelaçamentos materiais-semióticos. Resgatar a trajetória de desenvolvimento desse campo nos permitirá explorar o imaginário a partir do qual tais intervenções emergem, assim como as transformações ocorridas, ressaltando o vínculo ao corpo-máquina tecido no âmbito biomédico.

Palavras-chave: Constituição corporal; Biotecnologia; Transplante de Coração; Insuficiência Cardíaca; Coração Artificial.

Introduction

The present paper will approach the production of bodies and medical technologies, based on an ethnographic study of the so-called artificial hearts. Such artifacts aim to replace cardiac function in the face of exhaustion of what in cardiology is called the 'native organ' - which is better described not as the "natural", physiologically ideal heart, but as the biological organ originally integrated into a circulatory system, belonging to a human organism. The inability to properly pump blood and distribute fluids for oxygenation of the body's cells is called heart failure, a highly debilitating condition that, in its advanced stage, poses a high risk of death. Central station of chemical and mechanical communication, vital for the organism, the heart has become a fatigued organ worn out by the conditions of survival in a system that dispossess the subjects of their health, their vitality and even the physiological rhythm and pulsatility[1] instituted evolutionarily. The high rates of heart failure in contemporary times - which greatly exceed the supply of organs available for transplantation - are exacerbated by the forecast of a significant expansion of cases in industrialized and developing countries.

Data suggest an increase in the impact of cardiovascular diseases of around 120-137% in developing countries, compared to an increase of 30-60% in developed countries (Leme, 2015). Among the causes mentioned in the specialized literature that contribute to the increase in cardiovascular diseases and allow the projection of future statistics are: physical inactivity, obesity and smoking. Such factors are related to eating habits and lifestyles, but the brutal difference in the increase in developing and developed countries leads us to think that there are bodies that are more exploited than others, lives that have been more eroded by a productive system that exposes subjects' health unequally. It goes without saying that just like the devastated

1 We refer here to pulsatility as the ability to have a pulsation, pulsatile movement of blood, in contrast to bodies whose pulsation is extinguished, silenced with the establishment of a continuous, unvarying blood circulation. In the medical literature the term is used to refer to the flows and movement of different substances, such as hormones secretion. There are normality parameters for these speeds and movements that are fixed by means of indices (Aires, 1999). Further on, we will provide detailed explanations about blood circulation and how the pulsatile flow is established, whose measurement is given with reference to atmospheric pressure.

lands, rivers and forests extensively exploited in the global south – the so-called natural resources largely violated and consumed by the center of world capitalism –, there are bodies and lives more exploited on the fringes of capitalism in its financialized fold, and heart disease can be thought of as a symptom of this exploitation.

Technologies for replacing native hearts with artificial organs are an experimental and unstable field, which means that there are still no standardized and routine medical protocols (Marini, 2018). Mechanical devices are justified by their advocates as alternatives to heart transplantation (Anand; Singh; Antoun; Cohn et al., 2015), which presents an unavoidable technological barrier related to tissue compatibility and limited graft availability. There are other lines of investigation and experimentation, such as xenotransplantation, which recently gained renewed interest, despite having been discouraged at another time in history (Sharp, 2014), as well as bio-printed organs and tissues, related to the bet of creating vascularized tissues, which are expected to allow the production of artificial organs.[2] The task here will be to specifically explore "hard" mechanical devices, albeit designed to ideally perform the organicity of physiological functioning in a simplified way. These are technologies linked to the trajectory of imagining alternatives for "artificial" ventilation and mechanical maintenance of circulation, heir to the modern Frankensteinian imaginary of electrical and mechanically constituted chimeras. These can be seen as old-fashioned devices when compared to bioprinting initiatives, being composed of tubes, mechanisms, motors and paraphernalia whose appearance resembles "a piece of plumbing that might attach somehow under my sink" (Sharp, 2014, p. 105).

The research problem that resulted in Marini's doctoral thesis on artificial hearts, from which our elaborations start, was established from one of these circulatory assist devices, developed in an institution in São Paulo that had public repercussions. It was from the disclosure in Brazilian newspapers that we arrived at the auxiliary artificial heart, its developers and the network they were part of. Announced as the first artificial heart in Brazil, the news carried hopes that such device could manage the occurrence of deaths from advanced heart failure, offering an alternative to patients who were on the waiting list for a heart transplant. Also, the purpose was to manufacture it to be distributed in the Brazilian National Health System (SUS), since the bioengineering laboratory in which this technology was developed was part of a public hospital specialized in cardiology, dedicated exclusively to the diagnosis and treatment of cardiovascular diseases. From this device it was possible to weave a network of relationships, follow the development of other technologies and the debates promoted around them.[3]

The effort to investigate the hypothesis that such technologies transformed understandings and divisions between natural and artificial; human

2 In Brazil, the pioneering bioprinting startup TissueLabs has stood out, led by an ideal poster boy, Gabriel Liguori, a cardiologist motivated by his own experience with a congenital heart disease. The researcher and entrepreneur, who in 2020 joined the list of young innovators at MIT, publicly highlights that his research interest is crossed by his personal history, insofar as his heart disease led him to be operated on at the age of two, which makes him to this day a patient at InCor, an institution where he took part of his training as a cardiologist. In addition to bringing technology in line with innovations in the field of bioprinting, tissue engineering, regenerative medicine with stem cells, the entrepreneur brings a new academic research model aligned with the modernization interests pursued by some Brazilian institutions. TissueLabs is a young company that received support from Fapesp through the Pipe program (*Pesquisa inovativa em pequenas empresas*).

3 Each project has a longer time frame than a doctoral thesis to go through all the steps needed to develop and validate a medical device. When the ethnographic research was initiated, the "Brazilian heart" was already in the final phase, of clinical evaluation, approved by ANVISA to be implemented in humans. Throughout the research, however, we were able to follow the bench or *in vitro* tests of other technologies under development and that were part of the same research network, as well as the subsequent *in vivo* tests with the participation of pigs and calves. The ethnographic research carried out in the bioengineering laboratory and in the cardiology hospital of which he was a part, following the interlocutors in their research activities that extrapolated these premises, began in 2013. In addition to monitoring the *in vitro* tests carried out in the period from 2013 to 2017, and between 2014 and 2015, the laboratory was visited at different times, where one can freely interact with the researchers. In addition, between 2016 and 2017 formal interviews were carried out with some of the interlocutors.

and non-human; life and death; took Marini to the bioengineering lab benches where cardiac devices were designed and tested. The *in vitro* research through which the prototypes were born was the beginning of a (non-linear) chain of procedures. There were many steps needed to transform prototypes into a device approved for use in humans, perhaps making it a marketable product. In the São Paulo institution where part of the ethnographic research was carried out, the bioengineering laboratory was configured as a kind of bridge from the clinic to the operating room. The medical demand found in the hospital, given the limitations of the techniques available to mitigate the occurrence of deaths, led to the imagination of alternative solutions that could return to the hospital and contribute to the management of lives and deaths. As it is a field of invasive surgical tradition, the solutions imagined involved devices to be surgically implanted in open heart procedures, although there were questions and the search for less invasive procedures was a trend in the Brazilian scenario, in dialogue with the international community (Marini, 2018).

The purpose of this article is to investigate the different bodies produced in the arrangements with the various devices and technological solutions proposed by bioengineering researchers, in partnership with cardiologists and validated by surgeons and medical teams. In order to construct an interpretation of this assemblage between "native" bodies and "artificial" hearts, we took heart transplants as a contrast, whose implications for the bodies that emerge are radically different. In this way, we investigated the multiple bodies that emerge from sociotechnical processes that aim to replace "failing" hearts, thus seeking to interpret how each intertwining between heterogeneous entities produces ontologically distinct bodies. We seek to interpret such multiplicity as a product of divergent practices that, each in its own way, produces particular imbrications, with very divergent consequences for health, body, heart and immunity.

We have not sought to define a gradient of naturalness/artificiality here, categorizing different technologies and their embodiment as more or less natural. We are inspired by the proposition of an ethics oriented not in terms of degrees of 'naturalness' of biological bodies, but as something ontologically separated from an 'artificiality' of technological artifacts.[4] We think in terms of different embodiments and lived integrity (Derksen; Horstman, 2008), taking into account the different scenarios of management of bodies and deaths.. Thus, we understand that embodiment can be seen not as fixed, immanent, but as an emerging process, the result of dialogic and relational practices and processes. Such processes involve biology; technical artifacts; medical and scientific knowledge; and the very experience of patients who carry such hearts.

From an ethnography of the practices of development of artificial hearts, we intend to investigate ways of thinking and instituting the materiality of bodies, the ontological multiplicity that emerged in the material/semiotic intertwining of practices that disorganize, reorganize, unravel and weave new carnalities and embodiments, new flows and instabilities on the boundary between life and death. The contrast suggested here between an **immunological body**, identified as a unit that composes an identity, a physiological signature, in an immunological dispute with what is not part of

4 When analyzing tissue engineering and its ability to build body parts that can supposedly be fully integrated by the recipient organism, specifically starting from the case of heart valves, Derksen and Horstman (2008) argue that they should not be taken as superior to mechanical valves solely because they are composed of "flesh". If, on the one hand, they can be morally good, for being "copies of Nature", on the other hand, they are morally reprehensible for defying it. Therefore, they suggest: "Instead of stressing the differences between bionic technologies and Tissue Engineneering, and making either type of technology more innocent or more dangerous, a phenomenological analysis demonstrates that TE is no special, and can be analyzed in terms similar to those used in other technologies" (Derksen; Horstman, p.270). The understanding of a good embodiment for the evaluation of technologies is based on the notion of "lived integrity", which seeks to advance the debate on the "transparency" of the body. Thinking critically about its development in phenomenology, and the way it takes the perception of the sick body experience negatively, they argue: "for a notion of 'lived integrity' that does justice to experiences of being this hurting or changing body, which are often central during illness. 'Lived integrity' refers to the achievement of living illness, body change and technological additions as oneself" (Derksen; Horstman, p. 270)

that system; and a **bionic body**[5] allows the analysis of the different materialities and intertwinings inherent to organ transplants and the implantation of mechanical artifacts.

What we can say about the imagined and performed embodiment in the bionic body, compared to the immunological body of transplants, are the mechanical transformations promoted by the arrangement between native physiology and the artificial heart, which in general concern the "silencing" of the organ and emergence of new "noises". This refers not only to sounds, but also to movements and flows, as is the case of continuous flow that does not produce pressure variations, which has several implications, as we will argue in this study. Although designed for temporary use, the transformations carried out in the bionic body are inexorable, producing material effects on the organism even after the dismantling of the arrangement with the artificial heart. These effects may persist over time, although the artifacts may allow considerable "recovery" to the native organ.

Imagination and projection of circulatory assist devices

Since the first devices used in open heart surgical procedures in the 1950s, these artifacts have allowed the maintenance and extension of patients' lives. They also enabled a reformulation of the concept of death, no longer associated with cardiorespiratory functioning, but defined by brain function (Lock, 2002). In the Lazarus Era, in which cardiopulmonary resuscitation became possible, the technologies used to replace the cardiac function made it possible to transform death conceptions not only in terms of its legal definition, but also its meaning, its senses and its material "manipulation".

Although artificial hearts are currently designed as alternatives to transplantation, they are logically and historically prior (Anand; Singh; Antoun; Cohn et al., 2015). For this reason, we suggest that their existence and development was what allowed the imagination of heart transplants. If it is possible to keep a body alive with mechanical circulation, is it possible to transfer an organ from a healthy body to a diseased body? This is the type of speculation that we imagine having been raised from the 1950s, in the wake of the questioning made by the French physiologist Le Gallois, credited with the first attempt to apply a circulatory support, in 1812. He wondered if it would be possible to keep any part of an organism alive, indefinitely, which allowed him to imagine and try to respond to the challenge of replacing the heart with a form of artificial pumping. The potential for (re)construction of blood circulation mechanisms that germinated since the early 19th century bears new fruit with the emergence of the first mechanical devices and, subsequently, of heart transplants.

The surgery performed by Gibbon in 1953 using a heart-lung machine of his own is recounted as the first major event associated with the history of circulatory support. Akutsu and Kolff are described as the first surgeons who implanted an artificial heart in a dog, in 1958; Liotta, in 1963, reported having implanted an artificial ventricle in a patient with cardiogenic shock, raising the hope that such systems could be used to treat heart failure as well (Anand; Singh; Antoun; Cohn et al. , 2015).

We bring up these historical events to argue that mechanical devices were on the horizon for treating heart failure in the 1950s. However, with the advent of heart transplants in the 1960s, the scenario changed. Initially, the focus on mechanical circulatory support is maintained, as tissue rejection caused by organ transplants was characterized as an insurmountable challenge. The advent of immunosuppressants in the 1980s, however, relegates and at the same time allows the clinical use of artificial hearts as a "bridge to transplantation", that is, a temporary use that offers survival while waiting for a transplant.

Heart transplantation still offers a longer life expectancy than mechanical devices, despite

5 It is worth noting that there are variations between the different bionic bodies produced from different technologies, such as continuous flow devices, which will be investigated here, but also the mechanisms that mimic the physiological nature of the organ, and that stabilize other embodiments, in addition to the Brazilian technology, whose originality is a hybrid proposal that relies on the native heart and replicates it. However, it is not within the scope of this article to work exhaustively on these differences.

improvement efforts by bioengineers dedicated to finding new solutions to the limitations posed. Although they still present themselves as clinically better options, transplants have high costs, including ecological ones, since they require the use of helicopters and complex logistics, and a rush so that the organ removed from an organism can be transplanted without suffering degradation, that is, without cells being damaged, which may compromise the quality of the graft and the success of embodiment into the recipient body.

Narciso,[6] a cardiologist dedicated to postoperative care and case follow-up of transplanted and implanted patients, one of the interlocutors of the ethnographic research, stated:

> *The logistics of heart transplantation is extremely complex, much more complex than VAD implantation. In the case of the device, you have the machine, so you program the procedure and implant. For heart transplantation, the logistics are infinitely greater, it is a fact, it is an event.* (Cardiologist Narciso)

Currently, both heart transplantation and artificial heart implantation require the performance of a complex surgical procedure, seen as highly invasive. For both, it is necessary to perform an "open chest" surgery, using an extracorporeal circulation machine so that the native organ can be paralyzed and manipulated, which implies greater postoperative risks, such as the occurrence of a cerebrovascular accident.

Despite appearing as the most stabilized option, organ transplants are still not a definitive solution. Briefly retrieving the trajectory of technological development of solutions for heart failure allows us to speculate on the imaginary of pumping possibilities, and what the different strategies in the attempt to find an adequate way to circulate and move a failed system reveal about the understandings of the body in the biomedical field.

Multinaturalism and ontological multiplicity

In order to interpret embodiments as processes and as multiples; but not as a unified nature, we seek inspiration in ethnographies and research in the field of science and technology studies (STS) (Barad, 2003; Lock, 1993; Mccallum; Rohden, 2015; Mol, 2002; Strathern, 1996). The anthropological training of part of the authors of this paper led us also to see similarities in the writings of Americanists (Lima, 1996; Seeger; da Matta; de Castro, 1979; Viveiros de Castro, 2002a) in parallel to the biopolitical and feminist issues, both with theoretical-methodological reverberations relevant to the present reflection.[7]

Amerindian perspectivism and the proposition of multinaturalism (Viveiros de Castro, 2002b, Lima, 2002) lead us to reinstate the place of the body, and reconsider its naturalization, which implies the recognition of other possible worlds. Aiming to bring together and contrast such diverse bodies, it can be considered that, in Amerindian multinaturalism, the materiality of bodies, as well as their relational constitution, marks differences between the beings/people. Schematically, if the soul is what differentiates humans from other species in the modern naturalist understanding, in Amerindian perspectivism the difference operates in bodies.[8]

The discussion gains an exemplary expression in the anecdote presented by Eduardo Viveiros de Castro in *O nativo relativo* (2002a), in which a Piro woman claims that, among her own people,

6 The pseudonyms adopted here are inspired by the names of heroes and characters from Greek mythology, except for patients, following the logic of Marini's doctoral thesis.

7 The body emerged as a central issue in lowland ethnographies in the analysis of Americanist anthropologists. Such works highlighted questions that Melanesian and Africanist theories were unable to answer. The attentive look at the fabrication of bodies by Brazilian ethnologists represented a turning point in thinking, especially its aspect not addressed by Clastres and Levi-Strauss, who highlighted, respectively, the inscription of social conditions in the body as a torture device and as a surface for creation of art, fleeting works attached to bodies (Seeger et al., 1979).

8 We would like to thank Professor Marina Vanzolini Figueiredo for reading the article and helping us to think about this approximation between ontological multiplicity and multinaturalism, a theme that is familiar to her.

it is boiled water that causes diarrhea, and not the other way around, as the white missionary tried to convince her. The argument does not refer to an alternative biological theory, that is, it is not a world endowed with another physics or biology, but a non-biological idea of the body – an idea that makes such issues as child diarrhea not to be treated as the object of these theories. With that, the Piro woman claimed to live and have a distinct body, while the white missionary's effort to convince was based on the understanding of the universality of the body, reducing the understanding of another culture to mere superstition.

The recognition and claim that it is up to the social sciences to deal with the materiality of bodies – which ends up revealing their multiplicity – has an enormous impact on the reorientation of anthropological reflection,[9] and it also has reverberations in the thought of contemporary STS (Woolgar; Lezaun, 2015). The so-called ontological turn and contemporary anthropology, whether from S&T or not, has been exploring the consequences of these theories to think about bodies, experiences and intertwinings with specific technologies, thus enriching the field of possible questions for both fields of research (Pickering, 2017; Sismondo, 2015; van Heur; Leydesdorff; Wyatt, 2013).

The proposition of bodies composed of heterogeneous arrangements is also part of feminist reflection, in an ontological perspective that criticizes the understanding of the body as a stable material support for representation (Mol, 2002). Authors such as Mol are thus reflecting on the differences not only within the same epistemological regime but considering the very encounter and negotiation between different ontologies. This opens the modern linearity and what is included as inherent to body production.

Having these understandings and perspectives on the horizon, we propose to think that the body is not a given and ready object, but a material-semiotic bundle (Haraway, 1991) that is instituted in the relationship with the world and with other beings. Specifically considering the arrangement with mechanical assist circulatory devices in the biomedical scope, which inaugurate unusual relationships, we approach the opening of the body informed not only by the critical perspective of preconceived dualisms in the scope of theories focused on modernity and their criticism (Callon; Law, 1997; Latour, 1994), but also attentive to the relational character of the constitution of bodies in the face of distinct, conflicting epistemologies and ontologies that arrange, form and deform.

In both perspectivism and the debate on ontological multiplicity, what is at stake is the recognition of differences as material and practical realities, and not as mere representations of a universal reality. It is no longer new to attend to the limits of modern divisions, which are unable to organize the world and bodies and distinguish them into absolutely separate realms, domains of output divided and purified. By shifting attention to practices, it is revealed that there is no nature outside or prior to the laboratory (Latour, 1994; Mol, 2002). What is understood as a natural body is a construct based on knowledge and practices, so that there is no reason to claim its universality, despite the (always limited) effectiveness of biomedical strategies based on generalization strategies.

The Cartesian rupture (Descartes, 1998) enabled the emergence of a "biotechnological body", by making matter ontologically different from spirit (Donatelli, 2000). And the biotechnological body turned against the body/spirit duality, making it obsolete with the emergence of "digital bodies", post-humans and cyborgs (Tadeu, 2000). In other words, what instituted modern science and medicine is also what unfolds in its exhaustion and crisis.

Such changes in the way of understanding bodies are positioned within reconfigurations of technoscience and multinational capitalism, a "new world order" (Haraway, 1997) and a new type of post-human subjectivity (Hogle, 2005). In this sense, the question of why our bodies must end in the skin, why the limits of the subjects must have

9 These movements resonate with political and analytical propositions that actively claim the recognition not only of other epistemologies, but of an ontological multiplicity that implies a proliferation of worlds, as expressed in the pluriverse proposition (Cadena; Blaser, 2018) and in the critique of the problem of the "one-world world" (Law, 2015).

the skin or the organism as a limit, as Haraway asks, is increasingly relevant today, in which body boundaries increasingly challenge not only the normative performances of the subjects, but also the very understanding of what is considered human (Shildrick, 2015).

With Americanist ethnology (Lima, 1996; 2002) we learn to question the universalism of the biological, natural body, and that such divisions are specific to a modern ontology, marked by Euro-American science, impossible to be universalized for all human experiences. This opens the possibility, together with Mol (2002), of rethinking the oneness of this ontology, even in worlds marked by this science, in environments where biomedical technology is fundamental, as in the case of contemporary medicine. The Americanists' elaborations opened new perspectives to anthropological thought, leading it to face material and relational realities, assuming that we are not always talking about the same body when we analyze practices of production of embodiments.

In the Amerindian worlds described by the Americanists, to be a subject is to enter bundles of relationships that involve the most diverse bodies, including non-human ones. The universe in these cosmologies is populated by different subjects or subjective agencies, which are related to capacities to see, fundamental for the institution of a perspective. These are epistemologies that locate the difference in the referent (Viveiros de Castro, 2004). It is not about a plurality of worldviews, but a single vision of different worlds, differences that derive from bodies and their affectations/affections. It is the body that stands as an instrument of ontological differentiation. It is worth considering that these are cosmologies in which the many beings that populate the earth see themselves as people. Everyone is people, but occupying different perspectives, that is, inhabiting bodies manufactured in specific ways. The image often used to explain how these perspectives operate is the description that what is beer for some is blood for others. If there is recognition among Amerindians, for example, that pigs are human, by that they mean that the beings also drink beer. Yet what is beer for the pigs is blood for the Amerindians. The affirmation of the humanity of pigs is a statement that reveals the Amerindian concept of sociality, which includes pigs (Viveiros de Castro, 2004).

How to look at the more-than-human socialities in the context of the production of subjects in contemporary biomedicine and technoscience? What do these relationships tell us about the understanding of the body and its manipulation? How to think about the argument of one of the interlocutors, an engineering researcher, who in his practice claims the productivity of the development of different devices, insofar as each one could prove to be more suitable for specific cases or situations? Putting it into question: Why bet on a single line, if there are different bodies/pathologies? With a multiplicity of devices, it would be possible to attend to a diversity of pathological conditions and anatomical characteristics, resisting the universalizing and homogenizing scales of technoscientific production. There is no better device by definition. There is a naturalization that is more compatible with a particular clinical picture. But it is a thought that conflicts with capitalist and technoscientific logic. Either because it is extremely expensive and complicated to validate developed devices, or because it is commercially unfeasible to produce and distribute a variety of products.

It is not new that efforts to universalize bodies and diseases in the field of biomedicine are provisional and limited. There is no need to contrast different cosmologies, such as the Piros' understanding of the ineffectiveness of boiled water in preventing diarrhea. At least when it comes to the management of heart failure, biomedical understanding itself predicts that disease manifestation and organ anatomy are not always the same, so there is no reason to believe that a single device could always provide better responses, other than an economic convenience. The choice of more stabilized solutions is based on evidence that is not absolute, but capable of bringing together a greater level of effectiveness. There is also no way to support the understanding that mitigating the occurrence of deaths with transplants or implantation of devices is the same thing. But, with this contrast, we illuminate the contemporary biomedical problems with other colors.

What happens if we project Amerindian multinaturalist problems onto artificial hearts? Could it be that the different bodies performed in and by different biomedical practices, the arrangements between different physiologies and artifacts, are also born from different capacities of looking? Bioengineers, cardiologists, nurses and medical teams, in general, develop skills to see/conceive/institute distinct bodies. If the temporary intertwining that is established is admittedly different and new, as compared to the physiological system temporarily instituted in the (co)evolutionary process, with specific implications, it is also necessary to consider that what is seen when manipulating a graft for transplantation, a continuous-flow device or an artificial heart of another type is also different. Other indices are sought, other physiologies seen, other manipulation techniques, other rhythms instituted, different natures performed. Each system is articulated by instituting its own nature, operating within a logic that allows relationships to develop, even at the risk of failures and noise.

This projection, however, does not lend itself to diminishing or increasing the differences between so-called modern and Amerindian cosmologies, a generalization that is in itself complicated. When we approach analytical contributions produced from different ethnographies and cosmologies, we risk readjusting the device of alterity. If the denaturalization of the universalization of nature is potentiated by the evidence and analyses undertaken from the Amerindian worlds, it should not be deduced from this that the constitution of subjects and bodies from biomedical intervention makes us more equal or different than people living in Amerindian cosmologies. It is not about reducing the differences, or even making them bigger. Nor is it because "their" bodies are relations that are not given and fixed *a priori* that we will have to be so here as well.

With these approximations, we do not intend to promote immediate translatabilities, which are not even possible, much less suggest an ontological continuity. What interests us is also multiplying the naturalistic nature, cannibalizing it, illuminating the differences between bodies. In addition, it is a matter of highlighting certain coincidences between arguments from such diverse worlds, experiencing possible limits between dualist divisions, both in Amerindian multinaturalism and in the emerging ontological multiplicity, from the interventions, practices and biomedical and scientific knowledge. Given that Amerindian perspectivism is an analytical fiction that sustains a multinaturalism precisely in sharp contrast to modern multiculturalism, what happens when we turn this scheme back to the critique promoted by the perspective of ontological multiplicity?

Debating ontological multiplicity (Mol, 2002), as well as the issue of ontological politics that comes in tow; and the demand for the fabulation of alternative narratives (Haraway, 2016), new natures and possible worlds; inspires us to fable about emerging embodiments. To suggest a multiplicity of bodies and natures is to attend to differences that matter, to multiply natures and to recognize their (un)naturalness.

The still uncomfortable embodiment of heart transplantation

The differences between organ transplantation and mechanical device implantation are not limited to logistics and the surgical procedure. They are also present in care and corporeality, in the process of maintaining heterogeneous arrangements. In heart transplants, the senses and "governments" implied by this organ imply not only the difficulty of material adaptation, but also "moral readjustments" to the recipient organism. Everything happens as if each transplanted subject experiences a "transitory displacement" of their psychosomatic organization, as if the heart conveys the (supposed) personality of the donor, thus demanding some time to be personalized, a re-elaboration of the image that each person makes of himself and his body (Vaysse, 2005). These readjustments go through the psychic and somatic spheres referring to the introduction of a new organ and an imaginary heart, which carries the "spirit" of another subject, causing a "restructuring of the self". This would explain the expressed preference of a patient reported by Vaysse (2005) for an artificial heart over a human one, which would be, in her reading, associated with the primacy

of the machinic and composite view of the body in the contemporary medical world.[10]

In terms of incorporation, the cardiologist Narciso highlights that the patients are totally different: in general, the patient with an artificial heart needs anticoagulation and specific care with the battery and with the wound that forms around the cable that crosses the body - the driveline, the wire through which electrical energy reaches the heart, connecting the controller and battery on the outside of the body to the VAD implanted inside the body. The transplant patient, on the other hand, is immunosuppressed, which means that his risk of infection is of another order, involving the entire system, and not just around the opening crossed by the cable. Other aspects of the difficulty of incorporation formulated by Nancy will be presented below, from which we will sew the immunological body.

Performing the immunological body

The concept of immunological body serves us here to account for a set of material-semiotic relationships involving biological hearts transplanted to patients with heart problems. We use the idea of 'immunological' in order to highlight the preponderance of the management of immunity in the emerging materiality of these interventions. In this body that emerges with the transplant, a process of problematic coexistence with a native organ of another person begins, in which the immunological processes are inexorably altered, requiring constant management.

Jean-Luc Nancy's (2000; 2008) phenomenological analysis of his own heart transplant process is inspiring to think about the immunological body that emerges from the implantation of a foreign body in a coherent and semi-closed system. In transplant medicine, the body is a semi-closed or semi-open system, composed of controlled openings and "barriers" that guarantee communication and protection. More than establishing an interior as opposed to an exterior, the body is a system with controlled communications and protections against intrusions that can cause the organism to collapse.

There are several intruders in the relationships inaugurated in a transplant, starting with the diseased, rusty organ itself, whose intrusion takes place through desertion, as suggested by Nancy (2000). Surgery also sets up a steady stream of oddities, such as medications. The first opening produced by the transplant is in the sternum bones, something that is materialized on radiographs. On the other hand, the entry of an organ belonging to another person is described as an event that disturbs intimacy. Despite initially restoring an integrity, the incorporation of the foreign organ resembles that of a secret, a complicity or ghostly intimacy between oneself and the other. Quickly the other appears as an immunological stranger. According to Nancy (2000, p. 167), there is a double strangeness in rejection, arising from the identification of the strange heart, which is attacked as another; in addition to the strangeness instituted by the medication to protect the graft, lowering the immunity so that the organism can tolerate the stranger, thus making it strange to itself.

With Nancy (2000), we could say, therefore, that it is not possible to be "immune" to the intruder, since the foreigner is the very "physiological signature" that makes the body a coherent and unitary system. However, as he shows, becoming a stranger to oneself does not bring one closer to the intruder with whom one establishes a network between life and death, making the incommunicable communicate.

In the process of controlling rejection of a foreign organ, established biomedical techniques - immunosuppressants - end up weakening the "immunological identity". There is a relationship between identity and immunity, signature and "closure". So, by reducing immunity, identity and

10 Moral readjustments can also be recognized in the medical team and among donor family members, although they are of a different nature. If today we have protocols duly instituted regarding the determination of the occurrence of death, this does not mean that the convention of brain death and the removal of organs from patients in this clinical condition do not produce moral dilemmas. The condition of "living corpses" (Lock, 2002) can produce confusion and discomfort, because brain-dead patients continue to have vital signs, continue to breathe and remain warm, challenging the perception that they are dead. In his ethnography, Lock shows that heart transplantation is a less stable option than is supposed and that it produces difficulties and maladjustments of different orders.

"physiological signature" are weakened, which implies that the process of managing an intruder makes the person susceptible to others.

Metaphors and immunological science have already yielded good analyses of the institution of borders and their relationship to biopolitics (Haraway, 1991; Martin, 1990; Sontag; Broun, 1977).[11] For Susan Sontag, the idea of immunity is related to the image of the body as a fortress, strongly associated with military metaphors, especially in the 20th century. The metaphors are constructed in a language of science fiction, referring to "the way particularly dread diseases are envisaged as an alien "other," as enemies are in modern war" (Sontag, 1990, p. 99).

In Martin's analysis of scientific and popular discussions, immunology refers to an understanding of the body as a "network of regulatory communications". It is a system imagined as an arsenal that works to stop foreigners from entering or destroy them - in case of failure to contain the "invasion". The body is portrayed as the scene of an all-out war between ruthless invaders and determined defenders. In this logic, immunological problems refer to failures in this regulation, in the recognition of oneself and of the world/others and in the protection of one's own borders.

The immunological body instituted with transplants both establishes and weakens a physiological signature that presents itself as a device for the production of borders and division between self and other, organism and world, reinforcing and questioning the imagined and performed body in the modern immune paradigm, argued by Emily Martin and others. It is possible to consider, therefore, that the immunological body of the transplant is a body against the immune paradigm, in a certain sense, since it disarms this body, normalizing the foreigners.

Nancy's (2000) report, as well as the discussions presented earlier by Lock (1993) and Vaysse (2005), tell us about the immunological body, the challenges of graft incorporation, the moral, ethical and technical dilemmas posed by the arrangement between body and transplanted heart from which the immunological body emerges. Such elaborations reverberate the experience of caring for transplanted patients presented by the research interlocutor, Narciso, regarding his practice as a cardiologist.

Performing the bionic body

Bodies intertwined with artificial hearts - composing what we call a "bionic body" - suggest an image of being composed as coherent systems, characterized as a whole, consisting of parts that can be detachable and replaceable. While this configuration partially resembles the immunological body, there are considerable differences in terms of what integrity and uniformity mean. The characterization of the body as a set of communicating elements, in the case of the arrangement with mechanical devices, does not imply a possible radical rejection of a foreign organ or device that does not belong to an identity. There is room for possible negotiations, despite being a body susceptible to complications and damage to its parts, especially to the blood - the fluid that makes the systematic character of the body explicit.

The blood system unites the body and the blood pumped by the heart and oxygenated by the lungs supplies its cells. The main challenge in the case of the bionic body refers to the effort to create a mechanism capable of composing a new harmonic, well-orchestrated and responsive entity. It is less a matter of disturbing an intimate (immunological) identity, and more of how to (re)choreograph the movements and flows of blood and its pumping. The risk in the immunological body, as we saw earlier, is the breakdown of the system as a consequence of rejection, due to the profound disturbance of identity. In the bionic body, the dangers are

11 Marini et al (2020) have further developed such narratives in which the immune system operates as a kind of border production machine between the body/self and the world. It is from this border that hostile strategies to what is not recognized as part of that world emerge. The discussion includes Roberto Esposito's proposition of an immune paradigm, which highlights the intimate connection between immunity and community, whose negative constitution makes reciprocity unfeasible. That is, immunity is a state of deprivation of community, which is made possible by the emergence of a modern sovereignty that allows the emergence of isolated individuals.

associated with the challenge of establishing good blood circulation, without "side effects" that can be fatal. Moving a living and extremely "inhabited" liquid, such as blood, implies a risk of clotting, potentiated by mechanical circulation. The clot resulting from a disharmonious distribution can be fatal if it reaches the brain.

An important principle of bioengineering in the production of artificial organs is the assumption that technologies can always be improved, modified and adapted. The first artificial hearts were based on the idea that physiology should be imitated. This was the assumption that supported the understanding of bioengineering interlocutors regarding the historical unfolding of improvement of the devices. Thus, the first generation had pulsatile flow, it was "total", which means that the native heart was totally replaced by the mechanical one.

The proposal to challenge the inevitability of pulsatility, as it was known until then, led to the development of "simpler" miniaturized devices, in charge of replacing not the native organ, but the ventricular function. Given the organ's complexity, an imagined solution was to institute a mechanical way of pumping the blood without worrying about electrical adjustments relative to the pulse. Evidence found in the literature showed that the clinical results of non-pulsatile flow perfusion[12] were similar to those obtained with pulsatile pumps. Data suggested that "hemodynamic levels" were equivalent in the two groups tested (Anand; Singh; Antoun; et al., 2015), although their long-term effects were not yet known and controlled, and without taking into account the underlying risks.

The change from pulsatile devices to second and third generation, continuous flow pumps follows the change in their shape. While earlier devices emulated the function and shape of a biological heart, reproducing the appearance of a human heart, ventricular assist devices were designed as a set of tubes and mechanisms arranged to perform the function of the ventricle, a structure that in the native organ takes care of the heavy work of propelling blood.[13]

First generation total type pulsatile devices have mostly been discontinued or have not become approved products as second and third generation continuous flow devices proved viable. Because they are simpler mechanisms, they are less likely to fail. The development and improvement found, therefore, a simpler way and a way to act directly on the main need, since, in most cases of advanced heart failure, it is the left ventricle that needs to be "saved".

The great challenge associated with the incorporation of these continuous flow devices is the lack of pressure regulation, which implies a series of restrictions or adaptations to the body. A simple example that we observe in patients is the difficulty of getting up from a resting position with the same speed that people with pressure regulation measured against atmospheric pressure can have.

It should be noted that the measurement of blood pressure was evolutionarily established in reference to the Earth's atmospheric pressure. The pressure that blood exerts on the vascular walls depends on the volume of blood ejected by the heart and the resistance to its circulation (i.e., the space in the vessels). What propels blood along the cavities of blood vessels is the blood pressure gradient, given by the elevation of the aortic pressure (Aires, 1999). The pressure difference drives blood from the arteries to the veins through ventricular ejection, which raises the aortic pressure above atmospheric pressure (120 mmHg), while the pressure in the large veins is close to the atmospheric one. Blood pressure

12 Procedure for artificially circulating fluids in a body during surgical procedures, with the purpose of filtering and oxygenating the blood that is re-injected.

13 There is an artificial heart produced in Brazil that falls between these two classifications. It is a total device, with the appearance of a physiological, pulsating heart, which is designed to be implanted next to the native organ. The developer's argument was based on the security that the presence of the native organ offered, in case the device failed. Everything happens as if the performed nature presented itself as auxiliary but at the same time supported by the native physiology itself, trustable even when compromised, sick, failing. Each of these systems fails in different ways and for different reasons, and so they can support and complement each other. Although it has not been implanted in patients, it is projected that the pulsatility of the device intertwined with the native organ produces a second pulse, an echo. In terms of corporeality, we wonder if it would be too noisy compared to the silencing promoted by continuous flow devices. Noise and silence do not just refer to auditory experiences, but to broader sensations and challenges of incorporation that are not limited to the annoyance of hearing new noises or losing the ability to hear the organ itself.

is pulsatile because blood is ejected intermittently. Between successive ejections, blood pressure changes from 120mmHg to 80mmHg.

Blood pressure is expressed in millimeters of mercury because it is measured with reference to a column of mercury that establishes a zero-level scale defined by atmospheric pressure. The electrical impulses, producers of destabilization, institute a perpetually provisional equilibrium. An imbalance marked by the atmospheric scale, which produces a rhythm/flow of discontinuities and continuities. In the case of continuous flow devices, this variation is pacified, silenced. Blood is continuously pumped, circulating through the body without intervals of variation. Thus, "simple" adjustments, such as the pressure increase required by the system to accommodate rapid movement, are impossible in implanted patients.

The challenges are represented by the absence of pulsation.[14] Rogério, a patient who received an VAD from an American company in a philanthropy program at a private hospital in São Paulo, narrates in the film *Corpos Instáveis* (product of Marini's thesis) that his arrangement between the artificial heart and his native organ "revolves" continuously, without the typical noise of the pulsation given by the injection of blood into the ventricle. According to him, like Nona, another patient interviewed, the arrangement produced an odd, continuous, pulseless machine noise.[15]

There is an overlap of the mechanical pumping over the native one, so the native heart and pulse are silenced. The VAD becomes a guide, whose strength is responsible for the distribution of blood to help the weakened organ. The expectation is that the arrangement will be temporary, either because the patient will receive a transplant, or because he will be able to remove the device and continue with his rehabilitated native organ.

Rogério is an example of a patient who received a VAD implant, with which he lived for three years and a month. After that period, evidence that his heart had recovered led the medical team to the decision to extract the artificial heart, allowing the native organ to "work" on its own again. Almost two years after removing the VAD, Rogério underwent an ICD implant to stabilize the electrical signal of his organ, which was not in good condition. When we spoke, about four months after implanting the ICD, two years after removing the artificial heart, which silenced his organ for three years, Rogério still did not hear anything in his chest:

M: I was wondering today if Rogério's heart is back working again, if he feels his heart beating again?

A: And now that I've stopped to think about it. I don't feel it beating.

M: Nothing? And if you put your hand on your chest, do you feel anything?

A: No. I do not hear anything.

M: And do you feel anything? Any movement?

A: I already put my hand, I feel nothing. Yesterday I felt a tremor inside my chest, but nothing different.

M: How was that tremor? Scaring? Was it uncomfortable? What did you feel with this tremor?

A: Just shaking, normal.

M: Have you ever felt it before?

A: It was just this once.

(Patient Rogério)

More than two years after having the VAD removed, Rogério survived without the implant, but also without feeling his exhausted and anesthetized organ. Since his heart failure worsened Rogério no longer worked formally. He lived on a pension paid by the State, given his physical limitations. The imagery of a bionic superman contrasts with Rogério's fragile body, who moves with a certain slowness and has communication difficulties, either because he lacks air in his lungs or oxygenation in his thoughts. Speech is slow, thought is sometimes inarticulate. Anyway, Rogério was overcoming and surviving the statistics, with joy and thanking God.

14 Little is known about the difficulties and specificities of incorporation and institution of bionic bodies. In Brazil, implanted patients are no more than a dozen. Access to them is not always easy and possible, since it is a private hospital, which has not published data on these implants. Even in the United States, the data found in the Intermacs database on the approximately twenty thousand implanted patients say little about corporeality, except for survival time and causes of death.

15 *Corpos Instáveis* (Unstable Bodies) is an audiovisual project that addresses the use of artificial hearts, the dilemmas and transformations produced by these technologies. Available on YouTube: < https://www.youtube.com/watch?v=RoL4AhYYYFo >. Access on 20 Apr. 2022

The continuous and pulseless bionic corporeality imposed a somewhat inert being in the world, an almost suspended life, silenced by vitality. And the transformations produced in its physiology by the arrangement with the VAD had apparently irreversible effects. The relationships in his organism had been transformed, to the point of sustaining the bionic "characteristics" even in the absence of the device. He was aware that he would possibly have died in the situation in which he received the VAD, but the instituted life had another rhythm, another flow, producing a certain suspension of death, keeping it, however, close. And that did not change after having the device taken out. In addition to the challenges with the batteries, the need to change them regularly, sleep plugged in, take care of the opening necessary for the passage of energy provided by the batteries, Rogério had been disconnected from his native organ. The phantom of the artificial heart prevailed even in the material absence of the mechanical apparatus.

It can be considered that the nature performed with first-generation artificial hearts, of the "total" type, which replaced the organ, seeking to effectively mimic both its form and functions, can be associated with an understanding of Nature's moral superiority – that is, the understanding that the evolutionary process found the best ways to distribute fluids in the human organism. Such perfection could be technically sought and reproduced, reinstating the Promethean place of technological production capable of finding solutions subject to constant improvement. Taking Nature as a model, the nature instituted by total artificial hearts proved to be flawed and ineffective, insofar as the complexity of physiology imposed difficulties that seemed irreproducible. It was very difficult to perform the pulsatile flow. The DAVs, in turn, seemed to suggest alternative solutions based on a simplified, simplistic nature, focused on the task of keeping bodies oxygenated, albeit somewhat inert. We can suggest that the moral assumption embedded in the materiality of the DAVs is related to a de-idealization of Nature, of physiology, which can be radically transformed by altering the pulsatile flow.

Final considerations

The distinction between phenomena of the order of nature or culture, natural or artificial, biological or technological enters into crisis when the modern project of purification of these ontological zones wears out (Latour, 1994). The purification machine gets caught in the face of the proliferation of translations and the creation of hybrids of nature and culture, promoted primarily by biomedical, technological and scientific developments. Such polarity becomes incommensurable. For a long time (or in certain debates), the social sciences were thought, or thought themselves, as destined to the second class of objects or to the denaturalization of what was considered natural, which has undergone transformations.

Looking at scientific production, techniques, technologies, knowledge, discourses and biomedical practices implies considering and seeking to understand the arrangements between different heterogeneous entities, so that the "technical" or "medical" character turns out to be inserted in a moral and political agenda. Illuminating the processes of emergence of technologies and new biomedical truths, and their procedural character, does not imply considering that materiality is an illusion, or that the intertwinings are sheer flux and becoming. Artifacts are important to maintain the solidity of societies, the nonhuman ones are conditions of possibility for the formation of human societies (Latour, 1994), and materiality becomes central to the understanding of phenomena (Mol, 2002).

The practices and materiality, as well as the policies, uses and incorporations of the subjects subjected to them, allow us to see the mixture of subjects and their co-production. The purpose of highlighting the materiality of events is precisely to bring to light the intertwining of beings. If, on the one hand, practices reinforce and highlight the pragmatism of certain divisions, which allow biomedicine and science to produce things, on the other hand, the attention given to them also allows us to highlight the limits of such divisions. The attentive look at materialities and the production of bodies in the biomedical, scientific and biotechnological scope

allows us to suspend and question the principles of isolation, fixation, autonomy and individuation, which supposedly characterize the modern ones.

If the surgical procedures required for the establishment of immunological and bionic bodies are similar in their complexity, the logistics for their preparation, as well as the challenges of maintaining them after the surgical transformation are quite different. The rush, transport costs, waiting line management and the dynamics of transferring an organ from one body to another is a more complex "event" than the implantation of a mechanical device. In terms of corporeality, the immunological body demands the naturalization of a foreign organ that threatens the physiological signature, in addition to implying dealing with the shadow of its "personality", if we consider the reports of difficulty of patients who are faced with changes that are bodily, psychic, emotional and related to the person that the received organ carries. The bionic body, in turn, establishes a dependence on an external energy source, in addition to implying challenges of slow and limited pressure adjustment, since the pressure variation and its automatic adjustments are silenced. Immunosuppressants on the one hand, anticoagulants on the other.

In the still unstable field of producing cardiac technologies designed to mitigate the high death rate resulting from heart failure, we believe that the different technical solutions proposed give rise to different bodies. It is not, however, a question of listing degrees of naturalness imbricated in the different solutions, but describing what such arrangements are made of and what kind of nature is instituted from them. There are distinct material-semiotic intertwinings in each of these technologies.

It is necessary to consider, however, that it is about a set of historically related technologies. There is a common repertoire of imagination in the ways of replacing failed hearts, and solutions can be associated, as in the case of its use as a "bridge to transplant". One does not replace the other in a linear evolution, but they emerge from associated medical/scientific practices and feedback as innovations and possibilities for solutions. In this way, as we sought to demonstrate, we cannot totally separate the bionic from the immunological body: they are not a binary opposition, but a close tangle of practices and techniques that, however, produce quite divergent embodiments, with different consequences for both medical teams and patients and for the medical practices to which they are intertwined.

Transplants are a long-term management of death, if the arrangement is well instituted and its maintenance successful; while device implantation is still taken as an emergency and experimental management of death. It is to enable patients to receive the hope of a transplant that mechanical devices have been used. Death is suspended so that another life may perhaps be offered.

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Contribution of the Authors

Marini, Monteiro and Slatman were in charge of analyzing and interpreting the data. Marini and Slatman structured the central argument of the research. Marini performed the data collection for the study. Monteiro contributed with the writing of the literature review.

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