The Demise of Brain Death

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ABSTRACT

Fifty years have passed since brain death was first proposed as a criterion of death. Its advocates believe that with the destruction of the brain, integrated functioning ceases irreversibly, somatic unity dissolves, and the organism turns into a corpse. In this article, I put forward two objections against this assertion. First, I draw parallels between brain death and other pathological conditions and argue that whenever one regards the absence or the artificial replacement of a certain function in these pathological conditions as compatible with organismic unity, then one equally ought to tolerate that function's loss or replacement in brain death. Second, I show that the neurological criterion faces an additional problem that is only coming to light as life-supporting technology improves: the growing sophistication of the latter gives rise to a dangerous decoupling of the actual performance of a vital function from the retention of neurological control over it. Half a century after its introduction, the neurological criterion is facing the same fate as its cardiopulmonary predecessor.

1 Introduction

A widely shared conviction is that an organism is alive when its organs function in an integrated way; and that, consequently, death occurs when this somatic unity is lost (President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research [1981], p. 33; Bernat [2001], pp. 175f.).[1] In most cases, this point is reached after heartbeat and breathing have stopped and have failed to resume spontaneously. For

[1] In order to avoid circular reasoning, I will speak of the 'body' when I want to withhold judgement as to whether the entity in question is still a living organism. Whenever I use the term 'organism', this is meant to imply that the whole entity, rather than solely some of its organs, is alive in the biological sense and constitutes a unified whole.

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hundreds of years, this so-called cardiopulmonary criterion was the standard for determining death, until in the middle of the twentieth century three developments in intensive-care medicine called it into question: the advent of positive pressure ventilation, the promotion of cardiopulmonary resuscitation, and the first successful heart transplantation. What had previously been deemed permanent, suddenly became reversible. Not only could doctors replace a defective heart with a functioning transplant; a body could also be kept oxygenated in the total absence of spontaneous diaphragmatic function. The traditional boundaries between life and death became blurred. In 1968, an *ad hoc* committee of the Harvard Medical School ([1968]) ultimately argued that the cardiopulmonary criterion was no longer applicable under these circumstances and suggested that neurological criteria be used instead.[2] This proposal proved to be very influential, and most legal systems around the world adopted brain death as the new standard (Wikler [1993], p. 239). In the fifty years that have passed since then, there has been a huge increase in medical knowledge accompanied by rapid advancements in intensive-care technology. It is now time to re-evaluate the neurological criterion. Is brain death the death of an organism?

Identifying the destruction of a single organ with the death of the organism as a whole requires an exceptionally well-founded justification. I shall present two reasons why such a justification cannot be given in the case of the brain. In the first part of the article, I will compare brain death with conditions that are universally accepted as constituting living organisms—the persistent vegetative state and anencephaly—to show that cognitive capacities are not essential to organismic functioning and that, hence, only brainstem-mediated functions can be relevant to biological definitions of death (Section 2). With cognitive capacities excluded, five major differences remain between a brain-dead body and a body in a persistent vegetative state, whose respective significance to integrated functioning I shall evaluate by contrasting them with high cervical spine transection, locked-in syndrome, bilateral vagotomy, and panhypopituitarism (Section 3). I will conclude that the dissimilarities between bodies in these conditions and brain-dead bodies on life support do not warrant considering the former alive but the latter dead.

In the second part of the article, I shall take these physiological considerations to a more abstract level (Section 4). I will introduce a classification of the different ways that vital functions can cease to be performed and show why it is highly problematic to base one's judgement of whether a biological entity is dead or alive on the status of the neurological control mechanism of a function, rather than on the execution of the task itself.

[2] See also (Mollaret and Goulon [1959]; Wertheimer *et al.* [1959]).

2 Death of the Brain or Death of the Brainstem?

An organism comprises many interrelated subsystems that operate in concert. By way of this integrated functioning, the organism is able to perform higher-order functions that can only be brought about through the collaborative, internally coordinated work of mutually dependent organs or organ systems, rather than by one organ or tissue in isolation. The detoxification and recycling of cellular wastes throughout the body, for instance, does not only require the participation of those organs that carry out the actual purification processes; it also presupposes an intact circulation that transports the toxins from wherever they accumulate to the target organs, supplies the latter with oxygen, and removes carbon dioxide that is produced in the process.

Determining the criterion of an organism's death, therefore, means identifying a change in status of an organ or any other physiological subsystem that is indicative of the irreversible cessation of these higher-order functions, thereby marking the transition from the organism's constituting an integrated whole to being a mere collection of isolated organs. According to the neurological criterion of death, it is the destruction of the brain that is to be identified with this transition. The brain executes, or enables the execution of, certain functions that are indispensable to an organism's persistence. When it stops carrying out these tasks, so the assumption goes, somatic unity dissolves.[3]

Roughly speaking, the functions to which the brain gives rise fall in two categories: cognitive and vegetative. Should both play a role in biological definitions of death? At least at present, we cannot artificially replace cognitive brain functions. If the justification given for equating brain death with our death is psychological, the destruction of the brain (or of certain parts of it) is consequently a sufficient condition of a person's ceasing to exist. A growing number of authors support definitions along these lines.[4] However, if the underlying rationale is a biological one—that is, if it is concerned with the death of the organism—then the absence of cognitive capacities must be irrelevant (McMahan [2006], pp. 45f.).[5]

[3] See, for example, (Korein [1978], p. 26; President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research [1981], pp. 32f.; Lamb [1985], p. 37; Bernat [1998], pp. 19f.), and the work of most other authors who endorse biological justifications of brain death.

[4] They include Green and Wikler ([1980]), Youngner and Bartlett ([1983]), Gervais ([1986]), Zaner ([1988]), Veatch ([1993]), Kurthen and Linke ([1995]), McMahan ([1995], [2006]) and Lizza ([2018]). Recently, Bernat ([2018]) has also expressed sympathies for the psychological rationale.

[5] Requiring that cognitive capacities be absent is intuitively very appealing. Lizza ([2004], p. 52) speculates that the relatively high acceptance of brain death in society stems from this very fact rather than from its official justification as marking the cessation of integrated functioning and organismic unity.

One can infer this from two medical conditions. The first is anencephaly. Infants suffering from this disorder are born without a cerebrum but usually possess an intact brainstem. An anencephalic infant 'can breathe spontaneously, swallow, and grimace in response to painful stimuli. Its eyes are open. The heart can beat normally for many weeks' (Pallis and Harley [1996], p. 5). Thus, it is undeniably a functioning organism. But it is never going to be conscious or develop any cognitive capacities.[6] The other medical condition is the persistent vegetative state. The difference between anencephalic infants and patients in a persistent vegetative state is that the former, lacking a cerebrum, can never acquire cognitive capacities, whereas the latter have lost them owing to the destruction of the upper brain. In the following section, I will discuss the persistent vegetative state in greater depth.

There is another argument. To the best of our knowledge, the vast majority of creatures do not develop the capacities for complex cognitive processes, yet we consider these animals to be fully functioning organisms. One could, of course, legitimately hold that the persistence conditions of human and non-human organisms need not be congruent. The universal applicability of their account, however, is what proponents of biological definitions of death generally see as one of its major advantages over the psychological rival (Bernat [2001], p. 177).

If anencephalic infants and patients in a persistent vegetative state are functioning organisms despite their lack of an intact cerebrum, and if many creatures that we consider organisms do not possess any cognitive capacities to begin with, then these capacities cannot be necessary conditions for organisms to retain their integrative unity. On a definition of death that is rooted in a biological framework, the only consistent position is therefore that, in Becker's ([1975], p. 353) words, the 'loss of consciousness is not death any more than is the loss of a limb'. Thus, if one chooses to endorse a neurological criterion of death based on a biological (rather than psychological) understanding of human life, then its anatomical locus must not include the upper brain but focus solely on the brainstem as the supposed apex of integrated functioning.

[6] Merker ([2007]) and Shewmon *et al.* ([1999]) provide evidence for the possibility of consciousness without an intact cerebral cortex in hydranencephalic infants, arguing that the latter are awake and display emotional and orienting reactions in response to their environment; see also (Miller and Truog [2016], pp. 88–95; Fuchs [2018], pp. 113f.). The question is to what degree this 'primary consciousness' (Merker [2007], p. 80) is equivalent to the ordinary clinical notion of awareness. Several authors—for example, Coenen ([2007]), Collerton and Perry ([2007]), Doesburg and Lawrence ([2007]), and Morin ([2007])—maintain that it is anatomically impossible that the structures remaining in hydranencephaly can give rise to what is often described as 'phenomenal consciousness', 'qualia', or 'subjective experience'.

From this it follows that the so-called whole-brain criterion, which is employed in nearly all countries that endorse neurological criteria, is inappropriate (Law Reform Commission of Canada [1981], p. 29; Schweizerische Akademie der Medizinischen Wissenschaften [2011], p. 4; Bundesärztekammer [2015], p. 2). The conceptual error can, of course, be avoided if the status of the cerebrum is merely utilized as a confirmatory criterion, as initially suggested by the Havard Committee ([1968], p. 338).[7] In this case, no claim is made as to the mandatory participation in integrated functioning of the upper brain.

If the capacity for cognition is not a prerequisite for organisms to function in an integrated way, our evaluation of the neurological criterion of death must not compare, as has often been suggested, brain-dead bodies with healthy ones, but with bodies in a persistent vegetative state (or in a similar condition in which cognitive capacities are irreversibly absent while vegetative functions are preserved). We must consequently ask: is the discrepancy in integrated functioning between brain-dead bodies on life support and bodies in a persistent vegetative state large enough to license the conclusion that the latter are living organisms while the former are not? This is the focus of the following section.

3 The Functional Loss in Brain Death Compared with Related Conditions

In a persistent vegetative state, most higher-brain functions are irreversibly absent. Hence, there is no awareness of self or environment. Purposeful behaviour cannot be detected, but sleep–wake cycles persist, as do other brainstem-mediated autonomic functions. Spontaneous breathing is retained and cardiovascular and gastrointestinal functions continue nearly unimpaired. The body is in a state of homeostasis and homeothermia (Multi-Society Task Force on PVS [1994], pp. 1500f.).[8]

[7] The United Kingdom is one of the few countries that does not subscribe to the whole-brain criterion but focuses exclusively on the brainstem (Academy of Medical Royal Colleges [2008], p. 11). This approach, while conceptually sound, can lead to diagnostic difficulties if not combined with any confirmatory test carried out on the cerebrum because perfusion of the upper brain can in some rare cases persist in spite of the brainstem being nearly entirely destroyed (Kosteljanetz *et al.* [1988]; Zwarts *et al.* [2001]).

[8] Functional magnetic resonance imaging (fMRI) revealed conscious awareness in some patients who met the behavioural criteria for the vegetative state in clinical assessment (Owen *et al.* [2006]; Monti *et al.* [2010]). While interpreting these findings is difficult (Miller and Truog [2016], pp. 91–5), they seem to show that there are cases in which a profound dissociation between the observable motor output and the actual level of residual cognitive function can occur, which may necessitate a revision of the standardized test procedures for the vegetative state (Shewmon [1997], pp. 58–60). Since this is predominantly a diagnostic problem—albeit an important one—I shall not pursue it further, however.

If one compares this functional profile to that of a brain-dead body, five major differences become apparent: (1) brain-dead bodies are irreversibly comatose, while those in a persistent vegetative state exhibit sleep–wake cycles; (2) somatomotor function is abolished in brain-dead bodies, while it is intact in the persistent vegetative state (albeit not under voluntary control); (3) all functions mediated by cranial nerves are absent in brain death but usually present in the persistent vegetative state; (4) autonomic nervous system function is heavily depressed in brain death but unaffected in the persistent vegetative state; (5) endocrine system function is often altered in brain death but normal in the persistent vegetative state. How are we to interpret these differences?

(1) As concerns the preservation of sleep–wake cycles, the case is clear: wakefulness is brought about by the ascending reticular activating system in the brainstem. But devoid of a functional cerebrum, which is responsible for the awareness-component of consciousness, episodes of arousal have no experiential content.[9] The persistent vegetative state is therefore very appropriately described as 'wakeful unawareness'. Lacking a target organ that the ascending reticular activating system could activate, its functioning does not contribute to organismic unity. Thus, the absence of sleep–wake cycles cannot be what makes the difference between life and death of an organism.

(2) Without consciousness, voluntary movements are not possible, yet patients in a persistent vegetative state are not immobile. They may move their limbs or trunk in meaningless ways (Multi-Society Task Force on PVS [1994], p. 1500). Are these non-purposeful movements, which are absent in brain-dead bodies, essential to organismic unity? One can best establish the significance of these subcortically coordinated motions by considering C1-quadriplegia, a condition in which a lesion at the level of the neck has damaged the spinal cord and prevents motor signals that originate from the brain from reaching their target muscles. Limbs and torso are completely paralysed. Hence, the spontaneous movements characteristic of the vegetative state cannot occur. In spite of this fact, we regard quadriplegic bodies as living organisms. Given that the lesion is located at the very same level at which the functional spinal cord ends in brain death, namely, at the foramen magnum, quadriplegia and brain death are exactly

[9] For an analysis of the relation between the destruction of brain regions and the persistence of mental characteristics, see (Meier [2020]).

on a par as far as the extracephalic somatomotor deficit is concerned. And, correspondingly, spinal reflexes are preserved in both conditions since they operate independently of cerebral input (Walker *et al.* [1977], p. 985; Pallis and Harley [1996], p. 9; Han *et al.* [2006], p. 588; Gordon and McKinlay [2012], p. 228). If quadriplegic bodies are functioning organisms despite their lack of voluntary movements below the neck, the same criterion should apply to brain-dead bodies.[10]

Quadriplegic patients often lead fulfilling lives, and there can be no question regarding their status as persons and full members of society. In contrast, brain-dead bodies and those in a persistent vegetative state do not possess any mental characteristics and thus they are devoid of what is probably the most defining feature of our existence. As we have seen, however, psychological capacities are irrelevant to the question of organismic integration, and therefore to those justifications of the neurological criterion that are rooted in a biological framework. When a quadriplegic patient lapses into a coma from which he or she is never going to emerge, the organism does not thereby disintegrate and die. Rather, the death of the organism is a separate event that may take place months or even years later (Wikler [1993], p. 243).

(3) For conscious subjects, all functions mediated by cranial nerves are of utmost importance, as they enable them to see, hear, or smell, to move their eyes and to speak. In a persistent vegetative state, some of these functions are usually retained, so that eye-opening, grimacing, shedding tears, or occasional vocalizations may occur (Multi-Society Task Force on PVS [1994], p. 1500). Conversely, in a brain-dead body, all functions mediated by cranial nerves—sensory, motor, and parasympathetic—are absent. *Prima facie,* this difference appears extensive. When all cognitive activity is irreversibly absent, however, the status of nerves I to VIII, XI, and XII may well be of great diagnostic importance as it permits doctors to test the integrity of the brainstem and thus to distinguish the persistent vegetative state from brain death[11]; but

[10] A critic might point out that the fact that in the former case, but not in the latter, motor instructions are generated by the brain presents a relevant disanalogy—despite their ineffectiveness. This objection is blocked by the discussion in Section 4.

[11] Cranial nerves IX and X participate in extracephalic autonomic nervous system function, are therefore potentially relevant to integrated functioning, and are consequently covered under (4).

none of the functions that these nerves mediate have any bearing on somatic unity.[12]

That we can regard a body as a living organism despite the paralysis of cranial nerves is also exemplified by another condition: locked-in syndrome. Resulting from damage to the base of the pons, the transmission of practically all motor signals from the brain to the target organs, both outside of and within the head, is blocked in affected patients. Only voluntary blinking is usually possible. Consciousness is preserved (Bauer *et al.* [1979], p. 78). Since most reflex tests will be negative and thus mimic brain death, diagnostic difficulties may occur. However, the fact that consciousness is maintained in locked-in patients is best evidence that brainstem function can only be partly absent since an entirely defective brainstem would entail a destroyed ascending reticular activating system, which in turn would inevitably preclude any cognitive activity regardless of the status of the cerebrum (Schlake and Roosen [2001], pp. 70f.). Locked-in syndrome can therefore not serve as a counter-argument to the neurological criterion of death. What it does show, however, is that cranial (motor) nerve function is inessential to the basic level of integrated functioning that we require for regarding a body as a living organism. Locked-in patients sometimes survive for many years (Bernat [2001], p. 131).

(4) The task of the autonomic nervous system is to control many of the automatic functions that an organism has to perform and to adapt the activity of its organs to the requirements of different situations. The autonomic nervous system can be subdivided into the sympathetic, the parasympathetic, and the enteric system. Roughly speaking, the sympathetic branch increases the activity of organs, while the parasympathetic branch decreases it. The enteric nervous system governs digestion. As the autonomic nervous system operates without conscious direction, the absence of higher-brain function in the persistent vegetative state does not terminate its activities. In brain death, however, where not only the cerebrum but also the brainstem is destroyed, this system is deprived of its primary controller.[13]

[12] As Veatch ([1993], p. 21) notes, considering brainstem reflexes as constitutive of bodily integration, while denying spinal reflexes—which persist after brain death—the same status, would be arbitrary.

[13] There are two exceptions: the enteric nervous system can operate largely independently of central nervous system input, and the heart depolarises without external influence as its rhythm is generated by the sinoatrial node (Shewmon [2012], pp. 444f.).

Of the five major functional differences between brain-dead bodies and those in a persistent vegetative state that I have identified, the disabling of large parts of the autonomic nervous system in the former is, with regard to somatic unity, undoubtedly the most crucial one. Does a body whose organs have ceased to be connected by this overarching network turn into a mere collection of organs, that is, into a corpse? This can best be assessed when we return to a condition that resembles brain death in important aspects of autonomic nervous system function and with which we have already dealt: quadriplegia.

As quadriplegia results from a transection of the spinal cord, not only are somatosensory and somatomotor pathways severed, as detailed in (2), but so, too, are all fibres of the autonomic nervous system that travel through the spine—namely, the entirety of the sympathetic pathways as well as the sacral branch of the parasympathetic pathways. When these fibres are disconnected from cerebral input, a multitude of visceral functions is affected. Quadriplegic patients with lesions above the third cervical segment are dependent on a ventilator for breathing, exhibit imbalances in cardiovascular- and thermoregulation, and suffer from a loss of bladder and bowel control (Karlsson [2006], pp. 2–5).[14] Brain-dead bodies display precisely the same symptoms (Wijdicks and Atkinson [2001], p. 35; Gordon and McKinlay [2012], p. 225). This is to be expected, given that from the perspective of all body parts below the neck, there is, neurologically speaking, no difference between a transected spinal cord above which the brainstem is functional (quadriplegia) and a destroyed brainstem with an intact spinal cord (brain death), since in both cases no impulses are transmitted between body and brain via the spinal route. Brain death is 'from the cord's perspective, a transection at the cervico-medullary junction' (Shewmon [1999], p. 316).[15] In the second part of the article, I will show that this peculiarity poses a problem for the neurological criterion of death. In summary, as concerns the extent of neurological integration mediated by somatosensory-, somatomotor-, and sympathetic autonomic function relayed by the spinal cord, quadriplegic and brain-dead bodies are exactly on a par.

[14] It is worth noting that even devoid of rostral input, cardiac activity remains under the influence of the sympathetic centres of the spinal cord (Ouaknine [1978], p. 254).

[15] The non-endocrinologic characteristics of spinal shock after high cord transection are so similar to those of brain death that Shewmon ([1999]) devoted a whole article to comparing the two conditions.

There are, however, also differences in the preservation of neurological unity between quadriplegic and brain-dead bodies. Since the non-sacral parasympathetic fibres travel through the extraspinal vagus (X) and glossopharyngeal (IX) nerves, they are unaffected by transections of the cord and continue to transmit impulses between brain and viscera.[16] This parasympathetic influence is now unopposed, which is why quadriplegic patients often suffer from severe bradycardia, hyperthermia, and bladder flaccidity (Grundy and Swain [1993], p. 13). The symptoms are especially pronounced in the acute phase of spinal shock, that is, in the months directly following the injury, but may improve later (Karlsson [2006], pp. 3, 7f.; Gordon and McKinlay [2012], p. 227).

This imbalance in autonomic nervous system activity in quadriplegic individuals leads Shewmon ([1999], p. 321) to conclude that brain-dead bodies could in fact be viewed as being even better somatically integrated than the former. One may reply that whether a certain function is physiologically advantageous and whether it contributes to unifying a collection of organs into an organism are two related but inherently distinct issues. Although unbalanced parasympathetic influence is usually a physiological disadvantage, its presence still means that a higher degree of communication and control exists among the body's constituents.[17]

[16] The nervus vagus (X) is the longest nerve of the autonomic nervous system. It is responsible for the parasympathetic control of several organs, in most of which its influence leads to a decrease in activity. The glossopharyngeal nerve (IX) is involved in detecting changes in blood pressure (baroreception) and in the composition of arterial blood (chemoreception). It also carries out other functions, which are not relevant to the present investigation. Technically, cranial nerves III and VII also belong to the parasympathetic system, but they do not contribute to somatic unity.

[17] Insisting that the preservation of the vagal parasympathetic branch was essential to organismic life would not help the advocate of the neurological criterion, however. The side effect of an operation helps to see this: bilateral truncal vagotomy is the surgical transection of the two main trunks of the abdominal vagus nerve, which is sometimes performed to treat peptic ulcer disease. The procedure causes a decrease in peristalsis, and patients who underwent it usually report minor digestive inconveniences (Clark *et al.* [1964], pp. 902f.; Martin [2015], p. 3088). Governed by the enteric nervous system, digestion continues even in the absence of parasympathetic input. One might object that in a truncal vagotomy, the nervus vagus is not transected at the neck but where it enters the abdomen, so that the operation—while denervating the stomach, intestines, pancreas, and the liver—leaves intact the connections to those structures that lie above the point of separation. To be equivalent to the non-sacral parasympathetic visceral denervation that occurs in brain death, the vagus would instead have to be severed at the skull base. In this case, sensation in the supraglottis is also lost and the pharyngeal musculature as well as the vocal cords become paralysed. Due to dysphagia, tube feeding may be necessary (Montgomery *et al.* [2009], p. 515). These are configurations that also occur in many other intensive-care patients, however (Bernat [2001], p. 126). Finally, a complete vagotomy would additionally denervate the heart, thereby impairing heart rate adjustment. All recipients of cardiac transplants live with denervated hearts, and while the loss of vagal input profoundly disturbs the smooth functioning of many

It is therefore safe to assume that quadriplegic bodies indeed manifest a greater level of neurological integration than brain-dead ones. However, as the foregoing considerations show, this difference is not profound enough to mark the line between the presence and the absence of somatic unity. To reiterate, as regards cognitive capacities, the contrast could not be starker; but we are here concerned only with those physiological characteristics that form the basis of the current justification of the neurological criterion.

(5) There is another potentially unity-conferring network with the brain at its apex that is preserved in all conditions reviewed so far, but affected in brain death: the endocrine system. This chemical messenger system is complex, and I shall here focus only on what is absolutely necessary for answering the question at issue. Just like the nervous system, the endocrine system integrates signals from different parts of the body. While the nervous system elicits immediate responses, endocrine activity is mostly geared towards long-term effects. The primary controller of large parts of this system is the hypothalamus—a brain structure that synthesizes releasing hormones, which in turn prompt the secretion of hormones from the pituitary gland.[18] Most of the hormones that the pituitary gland secretes subsequently act on effector hormone glands in the body, thereby regulating physiological processes at their respective target organs. How does brain death impact on this delicate system?

Hypothalamic-pituitary function can be altered in brain death, but it is not normally completely abolished. Presumably, this is due to the fact that the inferior hypophysial artery, which perfuses parts of the pituitary gland and of the hypothalamus, arises from extradural branches of the internal carotid arteries. The blood supply of these structures is therefore less vulnerable to increases in intracranial pressure and the subsequent stoppage of circulation (Schlake and Roosen [2001], p. 23; Wijdicks and Atkinson [2001], p. 30).

Hence, brain death does not necessarily lead to endocrine failure. Anterior pituitary hormone release seems to be preserved 'on a functional level sufficient to maintain circulating hormones at

organs, none of the listed consequences is life-threatening given the provision of adequate support. In addition to surgical transection, vagus nerve function can also be suppressed pharmacologically, for example, by administering atropine.

18 There are also non-brain-regulated types of hormones, which are secreted independently of the hypothalamic-pituitary axis (Silbernagl and Despopoulos [2009], p. 270).

> least in the lower reference range even for prolonged periods' (Gramm *et al.* [1992], p. 856). Posterior pituitary function is usually more seriously affected, which is why the majority of brain-dead bodies develop diabetes insipidus (Emery and Robertson [2001], p. 204; Shewmon [2012], pp. 459f.). Diabetes can easily be treated by introducing antidiuretic agents, however (Wijdicks and Atkinson [2001], p. 32). Even if the pituitary gland were entirely dysfunctional, so that all types of hormones that it normally produces stopped being secreted, doctors could still substitute the products of the effector glands, as they do in the case of neurologically unimpaired patients who suffer from panhypopituitarism (Moskopp [2015], p. 33).
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> Since the hypothalamus is part of the brain, preserved hypothalamic activity is, strictly speaking, inconsistent with the notion of whole-brain death (Potts [2001], p. 482; Shewmon [2007], p. 376). Some authors tried to circumvent this problem by labelling hypothalamic neurosecretion a non-critical function (Bernat [1998], p. 17). In the light of other functions that they do class as critical, however, this categorization seems *ad hoc* (Miller and Truog [2016], p. 61; Nair-Collins and Miller [2017], p. 751; Shewmon [2018], p. S23).

In summary, the functional profile of brain death resembles in several important aspects that of other conditions in which the brain is functional or partly functional, but in which the exchange of information with the rest of the body is hindered. In high-level quadriplegia and locked-in syndrome, brain and body cannot communicate via the spinal cord; after a vagotomy, in which the major parasympathetic nerve is severed, a whole branch of the autonomic nervous system ceases to function; and in panhypopituitarism, endocrine signalling from brain to body is entirely disrupted. All of these maladies are survivable given appropriate treatment.

It should be emphasized, however, that in each of the conditions that I contrasted with brain death, a multitude of other bodily functions are retained that would be absent if the brain was destroyed. The aim of this section was therefore not to argue that the number of functions lost after brain death would be surpassed by any other disorder, but to demonstrate that there is no single type of vital function whose modification or absence following the breakdown of neurological control in brain death is incompatible with the survival of the organism. I also hope to have shown that although the extent of functional loss in brain-dead bodies is greater than in the conditions used for comparison, this discrepancy is not large enough to warrant regarding the latter as living organisms and the former as corpses. I shall return to this issue in Section 5.

4 The Decoupling of the Performance of a Function from the Retention of Neurological Control

Let us now take these physiological considerations to a more abstract level. Diagnoses of brain death establish the status of the brain's capacity to direct a certain task instead of determining whether the task itself is being executed.[19] 'When an individual's breathing and circulation lack neurologic integration, he or she is dead', submits the President's Commission ([1981], p. 33) in its report on the determination of death, for instance. This approach makes sense since the introduction of the neurological criterion was motivated by the desire to be able to make a diagnosis in the presence of a ventilator. The traditional cardiopulmonary criterion, which focuses directly on the performance of heartbeat and breathing, did not permit this. Hence, when doctors carry out an apnoea test as part of the brain-death diagnosis routine, they do not test whether the body is being oxygenated. One would establish this by checking the oxygen saturation monitor. Rather, what they determine is whether the organism retains the neurological capacity to breathe, that is, whether it would in principle—in principle because a positive result does not necessarily entail that the respective target organ, in this case the diaphragm, is working effectively too—be capable of breathing.

Prima facie, this difference seems trivial. But it is not. The more comprehensive life-supporting machinery becomes, the less closely does the status of the brain correspond to the functions that are in fact being carried out in the body. The diagnosis of the absence or the retention of mere neurological capacities then overrides the much more important question of whether the associated functions are actually being performed. To see this more clearly, consider the classification in Table 1 of the different ways in which a certain function, understood as the interplay between the neurological controller and its target organ, can break down. There are four possible types of malfunctioning, and I shall illustrate each of them with an actual medical condition. An example of the first type is Duchenne muscular dystrophy, a condition that leads to progressive skeletal muscle degeneration. When it finally affects the diaphragm, the patient requires external ventilation (Lo Mauro and Aliverti [2016], pp. 324f.). Although the function itself—breathing—cannot be executed any longer, the brainstem retains the

[19] This would obviously not apply to the capacity for consciousness since it is a function that the brain itself executes. We have already determined, however, that the status of cognitive capacities must not figure in definitions of death that are rooted in a biological framework.

Table 1. Types of malfunctioning in the interplay between neurological controller and its target organ

Type 1	Damage to the target organ, while the brainstem retains the capacity for directing its function (for example, Duchenne muscular dystrophy)
Type 2	Disruption of the pathway between brainstem and target organ, while both the brainstem as well as the organ are intact (for example, cervical spine transection)
Type 3	Destruction of the brainstem, while the target organ remains undamaged (for example, respiratory centre failure)
Type 4	Loss of function in both the brainstem and the target organ

capacity to direct it. Respiratory arrest, if irreversible, would have constituted one of the two clinical signs of death on the traditional criterion (the other being asystole), since it was only decisive whether or not a function was actually being carried out. On the neurological criterion, the converse is true: it only takes into consideration whether a function could be controlled by the brainstem, that is, whether the stem retains the respective capacity, but not whether it is in practice being executed. Absent function of Type 1 does therefore not constitute death on this definition. Hence, the organism counts as alive although not its brainstem but a ventilator is responsible for controlling the oxygenation of the body.

The same goes for Type 2, where the communication between controller and target is disrupted. Despite both organs being intact, the respective function must be provided externally. When cervical spine transection occurs at cord segment C1, the patient is not only quadriplegic but the pathways connecting the brainstem to the phrenic nerves, which supply the diaphragm and exit the cord at C3 to C5, are also severed. Hence, the brainstem cannot communicate with this main muscle of respiration, and the patient is unable to breathe. Since the brainstem is intact, however, the body is regarded as alive according to the neurological criterion.

An example of what I have labelled a Type-3 condition is respiratory centre failure. When this area of the brainstem is damaged, for example due to haemorrhage or trauma, breathing stops even though the diaphragm and the intercostal muscles are not affected by the injury. This is a case of a defective controller with an intact target organ.

Let us assume that the three disorders are irreversible. As concerns the demand for the provision of life support, the conditions are exactly on a par: in all three cases, the brainstem de facto does not control the function, which means that a ventilator is required. That external ventilation is sufficient to provide the lost function in all scenarios shows that the presence of an intact brainstem is redundant in this regard. The sole dissimilarity between the situations is that while in the first two the brainstem could in principle act as the controller, although, in fact, it does not, it cannot—not even in principle—do so in the third scenario. Is this a crucial difference?

According to the neurological criterion, those patients who suffer from conditions of the first and second types would be classified as alive, while the third patient would be regarded as dead. However, there are no physiological dissimilarities between these cases that warrant such attributions. A patient who suffers from respiratory centre failure does not differ in her ability to breathe from another patient whose diaphragm is paralysed as a result of Duchenne muscular dystrophy, since the respective function is absent in both cases. The former must be a living organism if the latter is.

This also goes for Type 4. Whether, in addition to a dysfunctional diaphragm, the respiratory centre is defective or not has no bearing on whether the function in question is in fact being carried out. All four scenarios yield exactly the same result: the organism is unable to oxygenate itself. That on the neurological criterion Types 3 and 4 would constitute death, while Types 1 and 2 would not, is arbitrary—especially in the light of the fact that the mechanical stand-in for the lost function in the first two cases is not under the control of the brainstem either. Beside the de facto controller of ventilation (which does not need to be inorganic—it could also be a nurse operating a bag valve mask), there exists an additional control centre, the brainstem, which is idle. Its presence is not physiologically required, as a comparison between Types 1 and 3 shows.

The reason why patients survive the described conditions is not that the brain is still intact and only unable to communicate, but rather that adequate external support substitutes for a vital function that the brainstem would otherwise direct. If this were not the case, these patients would die of anoxia within a few minutes. Hence, basing the diagnosis of death on the status of the brainstem is completely arbitrary.

Obviously, the brainstem directs many functions in addition to ventilation, and a patient is, of course, only declared dead when all its controlling capacities have irreversibly ceased. As long as the potential for neurological control over other bodily functions is retained, the brainstem is taken to integrate the different organs into a unified whole, and the organism is regarded as alive. I have, as an example, confined my considerations to ventilation, yet the point of the classification that I introduced is a more general one. When there are no grounds to require an intact respiratory centre in the case of external ventilation, then, by parity of reasoning, one cannot insist on an unimpaired neurological control mechanism of other replaceable functions.

In the previous Section, I compared brain death to other conditions. Quadriplegia, for instance, is a Type-2 case since it results from high spinal-cord transection: the brain and all target organs are intact, but they cannot communicate, except via the vagus nerve. If the neck injury that severed the spinal cord also damaged the vagus or if a quadriplegic patient underwent bilateral vagotomy, controller and target organs would be entirely neurologically separated.[20] The neurological criterion would nonetheless demand that the status of organismic unity be assessed by tests conducted on the brain. However, whether this isolated organ is intact or not would not make any difference at all to the functioning of the organism as a whole (while the cognitive differences, which are enormous, must not be taken into account).

In every condition that we have analysed in the foregoing section, there always remain some vital functions that the brainstem still controls, which means that, considered in isolation, none of them present a problem for the neurological criterion. Combined, however, they show that there is, in fact, no single vital brainstem-mediated function that one cannot, at least temporarily, artificially replace; for taken together they preclude all means by which the brainstem could control integrated functioning in the organism: neural—most notably via the spinal pathways and the vagus nerve—and endocrine, via the hypothalamic-pituitary axis.

As soon as all vital functions that the brainstem normally directs can be maintained with the help of external means, the status of this organ loses its justifiability as the sole indicator of an organism's death. Fifty years after the introduction of the neurological criterion, this point has already been reached. Intensive-care medicine can provide tailored oxygenation by constantly adjusting various ventilatory settings to live blood gas measurements; maintain haemodynamic stability through the automatic administering of vasoactive drugs; maintain normothermia using fluid warmers and heated ventilator circuits; manage diabetes insipidus by administering anti-diuretic agents; and regulate glucose homeostasis and electrolyte balance via targeted infusions of insulin and various other substances. These are just the more important of the technologically feasible interventions in a brain-dead body.[21]

None of these interventions achieve the regulatory perfection that an intact brainstem would have provided. They are only relatively crude substitutes for fine-grained physiological processes, which is why in many cases all measures that doctors take are unsuccessful and fail to prevent asystole. Often, however, they permit us to keep a brain-dead body functioning for a

[20] Both scenarios are relatively unlikely to occur, but represent sound theoretical possibilities.
[21] For a more detailed description, see (Emery and Robertson [2001], pp. 202–6).

considerable amount of time—sometimes even for years (Shewmon [1997], pp. 68f.; [2012], p. 456, [2018], p. S23; Nair-Collins and Miller [2017], p. 749).

It may be objected that even if a brain-dead body can be maintained for a while, eventual asystole is inevitable. In the vast majority of cases, brain death is indeed a precursor to total organ failure (Korein [1978], pp. 26f.; Green and Wikler [1980], p. 110; President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research [1981], p. 17; Pallis and Harley [1996], p. 30; Emery and Robertson [2001], p. 204; Wijdicks and Atkinson [2001], pp. 35, 39). Arguing this way, however, is confusing a diagnosis with a prognosis (Steigleder [2015], p. 108; Miller and Truog [2016], p. 110).[22] The neurological criterion of death purports to pinpoint the one event whose occurrence is identical with the ceasing to be of a living organism. Even if brain death did inevitably herald an organism's destruction, the two would still be separate events—regardless of how long the interval between these events is.

The new situation of the neurological criterion in current intensive-care settings is very similar to the one that the cardiopulmonary criterion was facing when heart and diaphragmatic function became replaceable. When a body's circulation is maintained by extracorporeal membrane oxygenation (ECMO), one may assess the status of heart and lungs, but this would not be an indication of whether or not the body is being perfused with oxygenated blood. As long as these organs are bypassed, no conclusions regarding the life or death of the organism as a whole can be drawn from their functional status. The same has now become true of the brainstem: while it is a necessary condition of organismic integration that tasks like ventilation or circulation are being carried out, it is not essential that they be neurologically directed by the brain. The relevant distinction is between the presence and the absence of a function, not between its being controlled internally or externally—provided that there remains a certain degree of coordination and regulation among the organs themselves to account for somatic unity. It is therefore no longer the case that 'when an individual's breathing and circulation lack neurologic integration, he or she is dead' (President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research [1981], p. 33).

When the brain-death criterion was introduced in the 1960s, the diagnostic decoupling of the neurological control mechanism from the actual performance of vital functions was a great advancement as it made possible diagnoses in the presence of ventilators. But the legitimacy of the criterion

[22] Lamb ([1985], p. 37) submits that following brain death, the continuing functioning of the various bodily subsystems only mimics integrated life.

began to shrink as the number of brainstem-directed functions that could be replaced was increasing. When the brainstem is found to be destroyed while none or only very little external assistance can be provided, it is obvious that the organism is dead already or at least in the process of dying since indispensible brainstem-mediated functions are bound to be absent. When, however, extensive life support successfully stands in lieu of all vital functions that the brainstem would otherwise direct, the status of the brainstem becomes immaterial to the organism's continued existence. A test carried out on a dysfunctional brainstem in a successfully maintained body will therefore yield a false positive, that is, the organism will be regarded as dead when it is in fact alive.[23]

5 Conclusion

Organisms are characterized by an internal cooperation and regulation of reciprocally dependent processes among their various parts. Advocates of the biological justification for the neurological criterion of death hold that this integrated functioning ceases irreversibly with the destruction of the brain. I put forward two objections against this assertion.

In the first part of the article, I drew parallels between brain death and other pathological conditions that are comparable in relevant aspects. Whenever we regard as compatible with organismic unity the absence, or the artificial replacement, of function x in disorder y, then we also ought to tolerate the loss, or the artificial replacement, of function x in brain death. Combining the characteristics of high cervical spine transection, locked-in syndrome, bilateral vagotomy, and panhypopituitarism enables one to show that given adequate life support, there is not a single bodily function whose absence would be incompatible with somatic unity, even if all means by which the brain could exercise control, neural and endocrine, are lost.

What this comparative method fails to establish, however, is the exact threshold below which too many functions are either absent or executed by external means for the body to be a living organism rather than a mere collection of isolated organs and machines. The cardiopulmonary criterion regarded the irreversible cessation of breathing and circulation as clinical signs of death. Brain death, which was supposed to replace the former criterion in intensive-care settings, even narrows the possible loci down to a single organ whose status is deemed to be indicative of the state of the whole organism, thereby purporting to deliver a yet more precise cut-off

[23] This does not imply that we should continue life support for a brain-dead body—whether we should do so is a moral question, whereas I am here concerned with a strictly metaphysical one. One may, for instance, come to the conclusion that we are justified in letting die brain-dead organisms due to the fact that they have lost all cognitive capacities.

point. While this degree of precision may seem attractive for diagnostic purposes and facilitates the timely procurement of organs, matters may in reality not be so straightforward. Where exactly the threshold lies between life and death, or, put differently, at which point the organism vanishes and the corpse (or the machine) begins, is a question to which we cannot give a determinate answer. It seems that with what we are here confronted is a Sorites paradox.[24] While a body in a persistent vegetative state is clearly an organism, and a body in rigor mortis is clearly a corpse, we cannot point to a single event in the transition process between the two states that would mark the transformation from life to death—just as it is unclear at which point a heap of sand disappears when grains are taken away from it. Eventually, the heap will cease to exist, but it is impossible to attribute this change to the removal of a particular grain. Likewise, an organism persists as long as there exists a certain degree of internal coordination and regulation among its different organs, and when the functions that underlie these integrative processes are gradually terminating, or are being replaced externally, ultimately a point is reached at which there ceases to be a biological life present over and above organ level.

Is this vagueness linguistic or ontic, that is, is our concept of organism imprecise or are matters of biological life and death indeterminate in and of themselves? The answer to this question is contingent on one's deeper attitudes towards realism, which go far beyond the scope of this article. Suffice it, therefore, to say that if the linguistic view is correct, one could in principle eliminate this indeterminacy by making the concept of organism more precise, for example when additional physiological details come to light at a future time, whereas there is no such possibility if facts about the persistence of organisms are ontically vague.

Hence, to assess whether the destruction of the brain is a proper indicator of organismic death, the best we can presently do is locating brain-dead bodies on life support on a spectrum of organismic unity. I have been trying to achieve this by comparing the characteristic functional profile of brain-dead bodies to that of conditions that exemplify a smaller degree of organismic unity than the persistent vegetative state, while unanimously being regarded as belonging to the realm of life. I found the difference in integrated functioning between bodies afflicted with these conditions and brain-dead bodies to be relatively small—not great enough, in any case, to warrant classifying the former as organisms and the latter as corpses.

24 The original formulation of the paradox is attributed to Eubulides (Hyde and Raffman [2018]).

Conversely, on the other side of the spectrum, the difference in integrated functioning between brain-dead bodies on life support and bodies that begin to exhibit the classical signs of death is extensive. According to Shewmon's ([2001], pp. 467f.) canonical list, the former maintain homeostasis of mutually interacting chemicals, macromolecules, and physiological parameters; eliminate, detoxicate, and recycle cellular wastes; maintain energy balance and temperature regulation (to a certain degree); heal wounds; fight infections; display cardiovascular and hormonal stress responses; are able to gestate foetuses; and show sexual maturation and proportional growth (in children).[25]

The sheer number of items on this list is impressive. Even more relevant to the question at issue, however, is the fact that all of them, without exception, presuppose the coordinated participation of several organs or tissues. They involve interactions between systems as complex as the cardiovascular, the endocrine, the immune, or the lymphatic as well as of smaller components of the body, like blood cells or bone marrow. All these functions are realized without the brainstem (or any external mechanism) exerting centralized control, yet they achieve a high level of somatic integration through mutual interdependence. We can therefore conclude that if one leaves aside cognitive capacities, the functional profile of brain death is reasonably close to that of the pathological conditions that we have analysed, but very distant from that of a cold, stiff corpse.

In the second part of the article, I took these physiological considerations to a more abstract level and argued that the growing sophistication of life-support systems gave rise to a dangerous decoupling of the performance of a function from the retention of neurological control over it. I introduced a classification of ways in which a bodily function can break down, and demonstrated that two out of four permutations constitute death on the neurological criterion, despite the number of vital functions that the body actually performs, as well as the amount of external assistance that it requires, being identical in all cases.

Provided that the level of internal coordination between the different organs is still high enough to account for a sufficient degree of somatic unity, the existence of an organism is not conditional on the means by which a certain vital function is directed, but rather on its being performed or having ceased. In intensive-care settings, the status of the brain does therefore not reliably indicate whether an organism is dead or alive since the former need not correspond to the functions that are being carried out

[25] See also (Wikler [1984], p. 101, [1993], p. 241; Emery and Robertson [2001], p. 206; Miller and Truog [2009], p. 186; Jox [2014], p. 37; Sadovnikoff and Wikler [2014], pp. 39f.; Nair-Collins and Miller [2017], p. 750).

in the body—a discrepancy that can yield false positives. For these reasons, the brain is not a suitable locus for determining the death of an organism in the presence of extensive life support. Fifty years after its introduction, the neurological criterion is facing the same fate as its cardiopulmonary predecessor.

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