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Do reports of consciousness during cardiac arrest hold the key to discovering the nature of consciousness?

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Summary Perhaps the biggest challenge facing neuroscience at the dawn of the 21st century is understanding the relationship between mind, consciousness and the brain. Editorials in recent years have highlighted the difficulties faced by cognitive neuroscience in attempting to answer questions regarding the nature, as well as the mechanism by which subjective experiences and our sense of consciousness may arise through neuronal processes. Current scientific views regarding the origin of consciousness vary widely and range from an 'epiphenomenon' arising from neuronal networks, to neuronal quantum processes, to a separate undiscovered scientific entity. Although there has been a lack of experimental studies to test these theories, recent studies have indicated that the study of the human mind during cardiac arrest may hold the key to solving the mystery of consciousness. Four published prospective studies of cardiac arrest survivors have demonstrated that paradoxically human mind and consciousness may continue to function during cardiac arrest. This is despite the well demonstrated finding that cerebral functioning as measured by electrical activity of the brain ceases during cardiac arrest, thus raising the possibility that human mind and consciousness may continue to function in the absence of brain function. In this article the broad theories for the causation of consciousness are reviewed as well as a novel method to study consciousness during cardiac arrest. This may provide a unique experimental method to determine the nature of human mind and consciousness as well as its relationship with the brain.

Introduction

One of the most profound questions facing science today is understanding the nature of consciousness and the mind, as well as their relationship with the brain. The basic scientific problem is simple to describe but difficult to answer: how does our sense of self-awareness together with all our subjective thoughts, feelings, and emotions arise from the brain? [1].

Unfortunately despite obvious interest in this area nobody has yet been able to propose a plausible biological mechanism to account for how the brain may give rise to the mind or consciousness [1,3]. A number of wide-ranging and eloquent mod-

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els as well as theories have been proposed as starting points for the study of consciousness, however as yet there has been a distinct lack of experimental models to test any proposed theories. A novel and innovative method that has arisen in the last few years for testing any theory of consciousness is the study of the state of the human mind and consciousness during cardiac arrest [2].

Despite the lack of plausible biological mechanisms to account for the development of the subjective sense of consciousness [1,3,4], many researchers of all backgrounds, including neuroscientists, psychologists, physicists, mathematicians, and philosophers have expressed views and theories regarding the mechanism of consciousness. When examining the literature, the proposed theories can broadly be divided into two groups: (a) conventional neurobiological theories and (b) alternative non conventional theories.

Broadly speaking, the conventional neurobiological theories propose that the subjective sense of consciousness and the human mind are products of the brain, even though, it is accepted that no one yet knows 'how' cerebral activity may give rise to consciousness and the mind. The theories proposed are currently largely concerned with identifying areas of the brain that may mediate conscious awareness. An outline of the major views are that (1) consciousness arises through the activities of neuronal networks [4], (2) synchronous neuronal network oscillations in the brain temporally bind information [1,5], (3) consciousness emerges as a novel property of computational complexity among neurons [6,7], (4) consciousness arises from the interaction of two evolutionary distinct areas of the brain [8], (5) The NMDA receptor plays a pivotal role in conscious processes [9—11] and (6) consciousness arises from the cerebral electromagnetic field [12]. It is further argued that neurones and their chemical synapses are the fundamental units of information in the brain, and that conscious experience emerges when a critical level of complexity is reached in the brain's neural networks.

Evidence to back up the conventional theories above come from the clinical observation that specific changes in function such as personality or memory are associated with specific cerebral lesions such as those that occur after head injury. This is further supported by the results of cerebral localisation studies using functional MRI and PET scanning, in which specific areas of the brain have been shown to become metabolically active in response to a thought or feeling [13]. However, the above studies, although providing evidence for the role of neuronal networks as an intermediary for the manifestation of thoughts, do not necessarily imply that those cells also produce the thoughts [14].

Many have argued that these theories cannot fully explain the observed features of consciousness. The most obvious limitation of such theories is that they do not provide a plausible mechanism that may account for the development of consciousness from neuronal activity. Amongst other things, they also do not account for how brain activities that are distributed within multiple areas of the brain bind into a unitary sense, such as occurs with vision, or the development of a coherent sense of self, or 'oneness'. Nor do they account for how a pre-conscious event becomes conscious, other than to simply say that it 'somehow' occurs at a critical point. They also cannot account for how we have a sense of free will.

These and other limitations with the conventional views have led some scientists to seek alternative explanations for consciousness. It has been proposed that the fundamental cerebral level where consciousness arises may be at the sub-atomic quantum level [15]. Others have also argued that mind and consciousness may in fact be an irreducible scientific entity in its own right [3,16,17]. Some have argued that this entity is a product of the brain, whereas others have argued that it is an entirely separate entity that is not produced by the brain [18—20] and that although there is a separation of the mind and the brain, nevertheless the mind is not immaterial [16,17]. Rather, it is composed of a very subtle type of matter that, although still undiscovered, is similar in concept to electromagnetic waves that are capable of carrying sound and picture, and are also governed by precise laws, axioms and theorems [16,17]. Therefore everything to do with this entity should be regarded as a separate undiscovered scientific discipline and studied in the same objective manner as the other scientific disciplines [16,17].

Cardiac arrest as a model to study consciousness

Although broadly speaking the theories regarding consciousness can be divided into two categories: (1) those that propose consciousness is a product of cerebral activity and (2) those that propose consciousness to be a separate scientific entity irreducible in terms of currently understood brain processes, until recently there had been little opportunity to test these theories experimentally. However, in recent years a number of independent studies have raised the possibility of testing these two categories of theories by studying the human mind during cardiac arrest.

Many critically ill patients have recalled lucid, well-structured thought processes together with reasoning and memory formation as well as consciousness from their period of cardiac arrest resuscitation. These vary from images of bright lights and tunnels to the very interesting recollection of actual verified events from their period of resuscitation in which people describe a feeling of separation from their bodies and being able to 'watch' themselves, as if from a vantage point above (out of body experience). Although initially largely anecdotal, recently four studies in cardiac arrest survivors have been carried out which have confirmed that 11—20% of cardiac arrest survivors report these experiences [21—24]. Out of body experiences have been reported in approximately 25% of patients who report mental states from during their period of cardiac arrest [22]. These experiences do not appear to be due to changes in serum electrolytes, PaO_2 and $PaCO_2$ [21,22]. The consensus of opinion raised by the authors of these studies has been that the occurrence of lucid well-structured thought processes together with reasoning and memory formation as well as an ability to recall detailed accounts of events from the period of resuscitation is a scientific paradox [21—24]. This is due to the fact that the studies of cerebral physiology during cardiac arrest have indicated that cerebral blood flow and cerebral function are severely impaired and therefore consciousness would be expected to be lost.

Immediately following the cardiac arrest, the mean arterial pressure (MAP) becomes immeasurable, however, properly performed chest compressions may raise the systolic values to 60—80 mmHg, but the diastolic values and hence the mean arterial pressure still remains inadequate. [25]. The use of vasopressors such as epinephrine has been shown to increase blood pressure, as well as cardiac and cerebral perfusion pressures [26], but since coronary and cerebral perfusion rely on adequate diastolic pressures the pressures generated during advanced life support, although better than no intervention, are still too low for adequate cerebral perfusion. In one study carried out in 10 humans with pre-hospital cardiac arrest it was shown that epinephrine led to an increase in systolic arterial blood pressure from 47 (±5) before its administration, to 69 (±7), 74 (±8) and 85 (±8) mmHg with increasing doses of 1, 3 and 5 mg. The diastolic pressure also increased from 18 (±2) mmHg to 27 (±3), 25 (±4) and 36 (±6), respectively, but still remained relatively low compared with pre-cardiac arrest levels [26]. It has also been shown that during a prolonged cardiac arrest, the intracranial pressure rises and hence a higher mean arterial pressure is needed to maintain cerebral perfusion [27]. These relatively low mean arterial blood pressures are maintained during advanced life support until the resumption of cardiac output [26,27]. In one study of cardiac arrest in cats treated using advanced life support, mean arterial pressure (MAP), intracranial pressure (ICP) and cerebral perfusion pressure (CPP) were measured. It was found that MAP fell from 107 ± 26 to 65 ± 18 after 4 minutes of resuscitation. At the same time, ICP increased from 4 ± 2 to 15 ± 6, while CPP reduced from 101 ± 26 to 31 ± 20 and cerebral blood flow reduced to 39% of baseline [27]. In another study in humans, it was concluded that during the cardiac arrest there was an average of 50% reduction in cerebral blood flow compared to control levels and in some areas of the brain this was reduced further to less than 20% [28]. The EEG is often used to assess cerebral ischaemia during procedures such as cardiac and neurosurgery. Concurrent EEG monitoring during a cardiac arrest has shown an initial slowing of the EEG waves which then progress to an isoelectric line within approximately 10—20 s and remain flat during the cardiac arrest until the resumption of cardiac output [27,30]. In cases of prolonged cardiac arrest, however EEG activity may not return for many tens of minutes after cardiac output has been returned. [29]. Therefore, during cardiac arrest impaired cerebral blood flow leads to a lack of electrophysiological activity in the cortex, which is made worse, as the time from the initial period of ischaemia to adequate resuscitation is increased. A reduction in cerebral blood flow in humans is associated with a deterioration in sustained attention [30].

Immediately after resuscitation there is a period of multifocal no-reflow, a phenomenon observed following recovery from cardiac arrest, in which, despite the restoration of adequate blood pressure multiple areas of the brain have been shown to develop perfusion defects that range from a pin hole, up to 95% of the brain [31]. This is thought to occur due to insufficient restoration of nutritive blood flow due to a combination of increased blood viscosity and perivascular oedema and is related to the initial period of ischaemia. This is followed by a period of transient global hyperaemia lasting 15—30 min, thereafter, cerebral blood flow becomes severely reduced while cerebral metabolic rate of oxygen gradually recovers. This is termed the delayed hypoperfusion phase and is thought to occur due to a disturbed coupling between brain function, metabolism and blood flow [31]. Clinically, these observations are supported by the loss of brainstem reflexes such as the gag reflex that indicate a loss of brainstem function, which normally activates the cortical areas via the thalamus.

Discovering the nature of human consciousness

The occurrence of lucid, well-structured thought processes together with reasoning, attention and memory recall of specific events during a cardiac arrest raise a number of interesting and perplexing questions regarding how such experiences could arise. As seen these experiences appear to be occurring at a time when global cerebral function can at best be described as severely impaired, and at worse non-functional. However, cerebral localisation studies have indicated that the thought processes are mediated through the activation of a number of different cortical areas, rather than single areas of the brain and therefore a globally disordered brain would not be expected to lead to lucid thought processes or the ability to 'see' and recall details. This consistent yet paradoxical observation needs to be considered in the search for understanding the relationship between mind, consciousness and the brain. In addition, from a clinical point of view any acute alteration in cerebral physiology such as occurs with a reduction in cerebral blood flow leads to impaired attention and impairment of higher cerebral function [30]. The experiences reported from cardiac arrest are clearly not confusional and in fact indicate heightened awareness, attention, thought processes and consciousness at a time when consciousness and memory formation are not expected to occur.

An alternative explanation is that the experiences reported from cardiac arrest, may actually be arising at a time when consciousness is either being lost, or regained, rather than from the actual cardiac arrest period itself. Any cerebral insult leads to a period of both anterograde and retrograde amnesia In fact memory is a very sensitive indicator of brain injury and the length of amnesia before and after unconsciousness is a way of determining the severity of the injury. Therefore, events that occur just prior to or just after the loss of consciousness would not be expected to be recalled. At any rate recovery following a cerebral insult is confusional and cerebral function as measured by EEG has in many cases been shown not to return until many tens of minutes or even a few hours after successful resuscitation. Despite these observations it can still be argued that the occurrence of some of the subjective recalled features such as seeing a bright light may potentially be occurring during the recovery phase, following a cardiac arrest, with the patient thinking that the experiences had occurred during the actual period itself. However the many anecdotal reports of patients being able to 'see' and recall detailed events that had occurred during the actual cardiac arrest, which have been verified by the hospital staff cannot be simply explained in this way, because in order for this memory to take place a form of consciousness would need to be present during the actual cardiac arrest itself.

The study of the human mind during cardiac arrest provides a unique opportunity to examine some of the proposed theories. If the generation of mind and consciousness is a product of the activity of neural networks or a consequence of electromagnetic processes within multiple areas of the brain as proposed by those in favour of the conventional theories detailed above, then one would expect there to be no activity of the mind and consciousness when there is a lack of brain function. However, if the occurrence of heightened consciousness and activity of the mind occurs during the actual period of cardiac arrest (rather than before or after), when there is a lack of cerebral perfusion and the brain has become non-functional then this would support the non-conventional views. The novel point for science is that for the first time these theories can be tested objectively through large studies. Such studies are currently possible, and a multi-centre trial has been designed to test the nature of consciousness and activity of the mind together with cerebral function during the cardiac arrest. In this trial, the patients who have a cardiac arrest will be attached to portable electroencephalogram (EEG) monitors to measure individual cerebral function. In order to test the claims of 'consciousness' and being able to 'hear' during the cardiac arrest, researchers will give patients' specific auditory stimuli and their ability to recall this information will be tested after recovery. In addition, in order to test the claims of visual consciousness (out of body experiences) from a vantage point above objectively, hidden targets with various pictures will be placed in the resuscitation areas. These will be placed strategically such that they are only visible from the ceiling above and not from the ground below. Thus, the claims of conscious awareness and out of body experiences will be tested independently. Patients recall of the images and auditory stimuli will be related to cerebral function as measured using portable EEG. The key to solving this mystery therefore lies in the accurate timing of the experiences. If it can be proven that this period of consciousness had indeed taken place during the cardiac arrest, rather than a period before or after, this will have huge implications for the scientific discovery of consciousness and will support the concept that human consciousness is a separate, yet undiscovered scientific entity as proposed by some researchers.

Today, the problems facing researchers into understanding the nature of consciousness are similar to the problems faced by physicists at the turn of the 20th century where it was discovered that classical physics cannot account for the observations made at the subatomic level. This thus led to the eventual discovery of quantum physics. In a similar way, current conventional neuroscientific models involving neuronal processing and plasticity cannot account for the observations being made as regards human consciousness. It would thus appear that a new science may be needed to account for the nature of consciousness and the planned large-scale studies of human consciousness during cardiac arrest may in fact provide the first key discovery as regards the nature of human consciousness and its relation with the brain. Should it be demonstrated that human consciousness can continue to function when there is a lack of brain activity, this would support the theory that human consciousness may be a subtle type of undiscovered matter that is similar to electromagnetic phenomena. Although, at first these suggestions may sound rather 'unconventional', however, the study of 'consciousness' has itself for many years been thought of as 'unconventional' area, but has now become a significant point of debate in neuroscience. Therefore a new way of thinking, may in fact be, what is needed to provide an insight into understanding this intriguing, yet largely undiscovered area of science.

References

[1] Crick F, Cock K. The hidden mind. scientific American 2002:10—7. special edition.
[2] Parnia S, Fenwick P. Near death experiences in cardiac arrest: visions of a dying brain or visions of a new science of consciousness. Resuscitation 2002;52(1):5—11.
[3] Chalmers DJ. The puzzle of conscious experience, mysteries of the mind. Scientific American 1997(special issue): 30—7.
[4] Greenfield S. Mind, brain and consciousness. Brit J Psychiat 2002;181:91—3.
[5] Crick F, Koch C. Consciousness and neuroscience. Cereb Cortex 1998;8(2):97—107.
[6] Dennett D. Are we explaining consciousness yet? Cognition 2001;79(1—2):221—37.
[7] Dennett D. Consciousness explained. Back Bay Books; 1992.
[8] Edelman G. Consciousness: the remembered present. Ann New York Acad Sci 2001;929:111—22.
[9] Flohr H. Sensations and brain processes. Behav Brain Res 1995;71(1-2):157—61.
[10] Flohr H. An information processing theory of anaesthesia. Neuropsychologia 1995;33(9):1169—80.
[11] Flohr H, Glade U, Motzko D. The role of the NMDA synapse in general anesthesia. Toxicol Lett 1998;100—101 (November 23):23—9.
[12] John ER. From synchronous neuronal discharges to subjective awareness? Prog Brain Res 2005;150:1—585.
[13] Frackowiak R, Friston K, Frith C, Dolan R, Mazziotta A. In: Human Brain Function. London: Academic Press; 1997. p. 329—65. 467—86.
[14] Freeman W. Consciousness, intentionality and causality. J Consciousness Stud 1999;6(11—12):143—72.
[15] Hameroff S, Nip A, Porter M, Tuszynski J. Conduction pathways in microtubules, biological quantum computation, and consciousness. Biosystems 2002;64(13):149—68.
[16] Elahi B. Spirituality is a science. Cornwall Books; 1999. p. 35—54.
[17] Elahi B. Medicine of the soul. Cornwall Books; 2001. p. 69—70.
[18] Eccles JC. Evolution of consciousness. Proc Natl Acad Sci USA 1992;89(16):7320—4.
[19] Eccles JC. Evolution of the brain: creation of the self. Routledge; 2001.
[20] Eccles JC, Popper K. The self and its brain. Routledge; 2003.
[21] Parnia S, Waller D, Yeates R, Fenwick P. A qualitative and quantitative study of the incidence, features and aetiology of near death experiences in cardiac arrest survivors. Resuscitation 2001;48:149—56.
[22] Van Lommel P, Wees Van R, Meyers V. Elfferich, — near-death experience in survivors of cardiac arrest: a prospective study in the Netherlands. Lancet 2001;358:2039—45.
[23] Greyson B. Incidence and correlates of Near Death Experiences in a cardiac care unit. Gen Hosp Psychiat 2003;25: 269—76.
[24] Schwaninger J. A prospective analysis of Near Death Experiences in cardiac arrest patients. J Near Death Experiences 2002;20(4).
[25] Paradis NA, Martin GB, Goetting MG. Simultaneous aortic jugular bulb, and right atrial pressures during cardiopulmonary resuscitation in humans: insights into mechanisms. Circulation 1989;80:361—8.
[26] Gonzalez ER, Ornato JP, Garnett AR. Dose dependent vasopressor response to epinephrine during CPR in human beings. Ann Emerg Med 1991;18:920—6.
[27] Fischer M, Hossman KA. Volume expansion during cardiopulmonary resuscitation reduces cerebral no-reflow. Resuscitation 1996;32:227—40.
[28] Christensen SF, Stadeager C, Siemkowicz E. Estimation of cerebral blood flow during cardiopulmonary resuscitation in humans. Resuscitation 1990;19:115—23.
[29] Mayer J, Marx T. The pathogenesis of EEG changes during cerebral anoxia. In: Van Der Drift J, editor. Cardiac and vascular diseases handbook of electroencephalography and clinicial neurophysiology, Amsterdam, vol. 14; 1972. p. 5—11.
[30] Marshall RS, Lazar RM, Spellman JP, et al. Recovery of brain function during induced cerebral hypoperfusion. Brain 2001;124:1208—17.
[31] Buunk G, Van der Hoeven JG, Meinders AE. Cerebral blood flow after cardiac arrest. The Netherlands J Med 2000;57:106—12.