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Be still, my beating heart: reading pulselessness from Shakespeare to the artificial heart

Abstract

Today, heart failure patients can be kept alive by an artificial heart while they await a heart transplant. These modern artificial hearts, or left ventricular assist devices (LVADs), remove the patient's discernible pulse whilst still maintaining life. This technology contradicts physiological, historical and sociocultural understandings of the pulse as central to human life. In this essay, we consider the ramifications of this contrast between the historical and cultural importance placed on the pulse (especially in relation to our sense of self) and living with a pulseless LVAD. We argue that the pulse's relationship to individual identity can be rescripted by examining its representation in formative cultural texts like the works of William Shakespeare. Through an integration of historical, literary and biomedical engineering perspectives on the pulse, this paper expands interpretations of pulselessness and advocates for the importance of cultural – as well as biomedical – knowledge to support LVAD patients and those around them. In reconsidering figurative and literal representations of the heartbeat in the context of technology which removes the need for a pulse, this essay argues that narrative and metaphor can be used to reconceptualise the relationship between the heartbeat and identity.

Keywords: pulse, biomedical engineering, artificial hearts, LVAD, Shakespeare, metaphor, *Romeo and Juliet*

Patient involvement

Patients were not involved in this research.

Introduction

Cardiovascular disease is one of the biggest killers in the developed world. The ideal treatment for someone suffering from end-stage heart failure is a heart transplant, however the demand for donor hearts greatly outweighs supply, leaving thousands of patients at risk of dying on the waitlist.¹ These patients can benefit from the implantation of a cardiac assist device, commonly referred to as an artificial heart, in order to keep these patients alive whilst they await a heart transplantation. Left ventricular assist devices (LVADs), the most common form of artificial heart, have functionally evolved over the last 50 years into small, easily implantable devices that can provide suitable pressures and flow rates to blood. However, there is a catch: due to the operational mode of these LVADs, implanted patients no longer have a discernible pulse.

For those directly experiencing pulselessness as well as for those around them (from the engineers designing the LVADs to surgeons who implant them, to family and social networks, support services, and so on), the phenomenon of life without a heartbeat contradicts powerful, centuries-old understandings of the criticality of the pulse. Not only is the heart and the heartbeat a foundational sign of life in medicine, but the heart and its pulse are dominant symbols in cultural, religious, spiritual, psychological, and literary contexts. As Fay Bound Alberti writes, ‘emotions, the heart and the “self” (however defined) have been linked in medical and popular consciousness for many centuries.’² The heart is central to human ontology. Both a vital organ and a pervasive metaphor, the heart has for centuries been fundamental to conceptualisations of humanity. It pervades language and colloquialisms: our hearts ‘pound’ when we are excited or afraid; our ‘pulse races’ when we feel fear or desire; we are ‘heartbroken’ when we suffer loss and ‘heartless’ when we are callous. We retain these ‘emotional expressions’ as ‘linguistic habits’, hangovers from the ‘very real system of humoral medicine’.³ The heart and its ‘diverse languages’⁴ are a central

means of defining our physiological and emotional responses, and thus in the image of the heart we collapse the literal and the figurative, the physical and the metaphorical. We have ‘ended up with two hearts’: ‘the heart-as-pump found in science, and the heart-as-emotion rhetoric that survives in popular culture’, a divergence which Bound Alberti argues ‘has seldom been explored.’⁵ William E. Slights puts this slightly differently, describing the heart in two ways, as a complex ‘material and poetic subject/object’ and an ‘ideologically fraught body part’.⁶ Thus, while our heartbeat is a universally recognisable sign of life and the heart itself is ‘an organ demonstrably essential to physical human life’, the heart ‘is also felt to be essential to a human’s “inner self”’.⁷ The heart and its pulse comprise a fundamental image of physiological, emotional and even moral health, and integral to our sense of self.

This article seeks to better understand the experience of pulselessness through an interdisciplinary approach that combines biomedical engineering and literary studies. We will investigate the physiological and cultural meanings of pulselessness through a parallel investigation of the development of LVADs (which are themselves described as ‘metaphorically rich’⁸) and representations of pulselessness in the works of an author who ‘writes the modern culture in which we think we live’: William Shakespeare.⁹ While we can trace representations of the heart as a symbol of the ‘inner self’ from Aristotle to contemporary clinical practice, ‘one of the richest sources of the heart-related idioms we use today is Shakespeare’s canon’.¹⁰ Shakespeare’s discourse pervades our modern language and influences the way in which we conceive of and articulate ourselves, our bodies and others. Through examining representations of the literal and metaphorical pulse and pulselessness in Shakespeare’s canon, we can begin to interrogate the development of our own understandings of the heartbeat in contemporary medicine and culture, and ramifications for this at a time when the pulse is no longer always necessary for life.

This essay offers a health humanities investigation into cultural and biomedical perceptions of the pulse and pulselessness as it pertains to sense of self. First, we will consider the representation of the pulse in Shakespeare's early modern context to better understand the development of its metaphorical roles and the cultural value placed on the heartbeat - specifically, the link between identity and the pulse. Second, we will discuss how modern artificial heart technology can provide circulatory support without reliance on a pulse. Third, the paper will reconceptualise the meaning of pulselessness and sense of self through a focus on one of 'Shakespeare's best loved works': *Romeo and Juliet*.¹¹ In so doing, we will argue that narrative and metaphor offer a means to reimagine pulselessness and to interrogate the relationship between the heartbeat and sense of self.

Windows to the heart: utilising narrative and metaphor to reconceptualise the pulse

The increasing use of LVADs and the associated rise in pulseless patients necessitates a shift in the rhetoric used to conceptualise the heart and the heartbeat, not only in the realms of cardiovascular medicine and engineering, but in our broader cultural discourse. One means of achieving this shift is to explore interdisciplinary approaches to the heart. As Slights points out, 'we always view the heart through the window of our own theoretical assumptions. Our particular angle of inquiry determines what we see through that window.'¹² To understand the ramifications of pulseless living, we must understand the problem through multiple 'windows'.

Narrative provides a shared space in which we may gain this multiperspectival view of the role of the pulse. The value of storytelling and metaphor in the health humanities is well-established. Narrative medicine is founded on the role of stories as a means of fortifying healthcare.¹³ Rita Charon describes narrative medicine as 'a new frame for health care', as

‘medicine practiced with these narrative skills of recognizing, absorbing, interpreting, and being moved by the stories of illness.’¹⁴ She draws on a specific skill essential to narrative medicine: narrative knowledge, which is defined as ‘what we use to make sense’ of stories.¹⁵ Narrative knowledge encompasses our ability to respond to narratives, which are ‘stories that have a teller, a listener, a time course, a plot, and a point’.¹⁶ To reconfigure our understanding of the role of the heart through narrative knowledge, we can use one of the key tools of narrative: metaphor. This literary device is one of the central ways by which humans articulate and understand their experiences:

Over the last three decades, scholars of the humanities and social sciences have argued that metaphor and narrative are the principle tools with which human beings make sense of their experiences.¹⁷

Metaphor is a primary vehicle for human communication and for conceptualising our own experiences – including those understood to be physiological. As Jay Parini writes,

metaphors are more than merely decorative. [...] Rather, metaphor is the fiber of language itself. As such, analogical thinking is central to the human enterprise of making sense. It actually organizes our experience in subtle ways. Without metaphor, there is no thinking at all.¹⁸

The medical humanities and narrative medicine have similarly recognised the potency of metaphor. Lynne Angus and Jeffrey Scott attest that ‘without metaphor it is difficult to adequately render the emotional richness and complexity of our lived experiences as told stories’.¹⁹ They argue that ‘it is through *emotionally focused metaphor phrases*’ that patients are available to ‘most evocatively express’ their bodily felt experiences.²⁰ Further, this expression is correlated with ‘positive treatment outcomes.’²¹ Oldfield and Jones reinforce the importance of metaphor, arguing that ‘metaphor and storytelling are important tools for

meaning-making' in medicine and across disciplines and discourses.²² Narrative and metaphor are therefore essential to reconfiguring phenomena such as the pulse in twenty-first century culture. As Bound Alberti articulates, 'the language in which the mind-body-brain relationship has been addressed throughout history' is largely bound up in the 'available metaphors' over time.²³ Metaphors not only help us to 'articulate difference' but they are also integrally related to 'broader cultural shifts in social and economic life'.²⁴ A pulseless, living heart necessitates a shift in the metaphors utilised to understand the physiological and cultural functions of the heartbeat.

Both literary studies and biomedicine share this view of the importance of metaphor. The experience of destination LVAD therapy (i.e. permanent LVAD implantation) has been reported as 'profoundly metaphoric'.²⁵ Oldfield and Jones reiterate the importance of metaphor for biomedicine:

Because of the limited ability of the biomedical narrative to convey the meanings of disease and treatments, doctors and patients need to communicate through the rich possibilities of metaphor.²⁶

Braus and Mueller assert that 'metaphors are central to how we make sense of illness, and that by mystifying heart failure even as it supports circulation, a destination LVAD may multiply metaphors rather than simplifying them'.²⁷ This suggests that the development of LVADs increases the quantity and complexity of associated metaphors, necessitating an investigation into the ways in which metaphorical meaning making can enhance our understanding of pulselessness.

To investigate the relationship between metaphorical meaning making and the heartbeat, we can turn to the works of William Shakespeare, which offer a prime example of the complexity and density of metaphor. As Simon Palfrey writes, metaphors in Shakespeare

‘do far more than dress an already apparent world. Without them, there is no world.’²⁸

Turning to Shakespeare’s literal and figurative references to the heart and its beat enables us to investigate the way language shapes our ‘two hearts’: scientific and cultural.

Shakespeare’s metaphors, alongside his vocabulary, ideas, characters and tropes, permeate our discourse. He is a formative and continuing influence on contemporary cultural life. Marjorie Garber writes that ‘Shakespeare makes modern culture and modern culture makes Shakespeare’.²⁹ His works are embedded in our language and cultures, to the point that Shakespeare ‘has become a lingua franca of modern cultural exchange’.³⁰ Garber adds that

Shakespeare has scripted many of the ideas that we think of as ‘naturally’ our own and even as ‘naturally’ true: ideas about human character, about individuality and selfhood, about government, about men and women, youth and age, about the qualities that make a strong leader. Such ideas are not necessarily first encountered today in the realm of literature – or even of drama and theater. Psychology, sociology, political theory, business, medicine, and law have all welcomed and recognised Shakespeare as the founder, authorizer, and forerunner of important categories and practices in their fields.³¹

The symbol of the heart is one of these naturalised ‘ideas’. The role of the heart – in terms of physiological function in the human body, its figurative manifestations in our discourse, and its spiritual and philosophical meanings – is in part scripted by Shakespeare and naturalised into discourse that continues into the twenty-first century. This is, of course, not to credit Shakespeare with the creation of these associations, but rather with their articulation and exploration in dramatic literature which continues to play a potent role in the formation and sustenance of our public spheres, discourses, contemporary arts and culture. If a critical

understanding of the heart's history is central to 'modern debates about emotions, the brain, and the mind-body relation' and therefore the self,³² then we cannot overlook Shakespeare's role in influencing our understanding of the heart and its pulse.

The heart in Shakespeare's England

The role of the heart (and the heartbeat) was fundamental to Shakespeare's early modern culture and its understandings of physiology. The heart 'was at the centre of the emotional and physical worlds for seventeenth-century men and women, and directly related to the physiological processes that took place under humoralism.'³³ The heart was 'crucial' to the period's interpretation of the humoral system.³⁴ Importantly, at this time the body was thought to contain 'a heart whose blood did not yet circulate'.³⁵ In this system,

As generator of heat and distributor of refined fluids and *spiritus* to the rest of the body, the heart kept the body alive and well regulated. Its initial beating signalled the start of life, and its cessation marked the moment of death. Though it could not ordinarily be seen or touched and still be able to perform its vital functions, it was the wellspring of life and health.³⁶

For Shakespeare and early modern English culture, the beating of the heart bookended the beginning and end of human life. While the heart encompassed critical 'physiological and spiritual functions' in early modernity drawn from ancient philosophy and the Bible, its palpable presence through the rhythm of the pulse made tangible an organ that, in English culture, was not only physical but spiritual and metaphorical.³⁷

While twenty-first century conceptualisations of the literal and figurative heart indicate our tendency to separate 'mental and physical states of self-awareness', early modern understandings of 'human interiority' allow for the 'fusion' of these states.³⁸ In the early modern period, the passions and the physical world were inseparable. Early moderns did not

divide between ‘inner’ and ‘outer’ in the way that twenty-first century western culture does. Gail Kern Paster calls this relation between inner and outer ‘a premodern ecology of the passions.’³⁹ For Shakespeare’s early modern culture, ‘there was no way conceptually or discursively to separate the psychological from the physiological.’⁴⁰ And the site at which the emotions and the physiological were understood to co-locate was the heart. The heart was ‘the organ most in charge of the emotions’, and changes to the heart could ‘create significant emotional changes’.⁴¹ Shakespeare’s contemporaries linked the emotions to the heart not only metaphorically, but literally.⁴²

The early modern body’s internal organs differ profoundly from our own, in epistemic as well as in phenomenological terms, because...they are assigned psychological functions and thus a crucial role in conscious experience—as it was then articulable— of bodily pleasures and pains.⁴³

Beyond the individual bodily experience of the heart, Shakespeare’s culture registered a profound interest in the heart. Slight, following Michel Foucault, detects the development of heart-related cultural codes in the period, codes which define both ‘the historical moment’ and its later reconstructions.

The ecclesiastical politics of the period, along with developments in the natural sciences, helped to shape the underlying cultural codes that over time simultaneously bolstered and disguised such common practices as worshipping the heart, monitoring its rhythmic pulse, and expanding its symbolic meanings in religious and artistic contexts.⁴⁴

Both science and religion played a formative role in the development of the heart’s symbolism in cultural codes that retain their significance over time, from the sixteenth century to today. This, however, is not to suggest that the heart was always a stable image in

Shakespeare's culture. Slight describes what he terms 'stress fractures' in medieval and classical bodies of thought which led to 'conflicting cultural responses to the human body and spirit'.⁴⁵ Part of these responses involved

the reformers' reconfiguration of the penitent Catholic heart, the renewed anatomical study of the heart's motions, and the reshaping of heart symbolism from late medieval and early Renaissance love poetry into the theatrical site of villainy, anguish, and repentance.⁴⁶

Representations of the heart in religion, anatomy, literature and drama were thus contested and shifting in the early modern period. They were also interrelated. Jonathan Miller points to the interdependence of medical and metaphorical interpretations of the heart in his argument that a 'lack of satisfactory metaphors' delayed the development of the anatomy and physiology of the heart.⁴⁷ The extension of the heart's importance beyond theology and anatomy is also exemplified in James Harrington's *Commonwealth of Oceana* (1656), which combined politics with the anatomy of the heart, using William Harvey's model of the heart and movement of the blood to model 'a two-chambered legislature' and 'the circulation of political offices and powers'.⁴⁸ These different spheres in which the heart featured were also mutually-informing:

Just as the anatomist and physician created an exacting language of psychophysiology that could be appropriated for the embodiment of dramatic characters, the drama provided concepts of power through spectatorship that could explain the hierarchy of the organs in the body. This kind of interchange continued undiminished throughout the age of Shakespeare.⁴⁹

Slights here points to an exchange of metaphorical ideas around the heart across medicine and early modern drama. The ‘psychophysiology’ of the heart helped to generate understandings of dramatic character in the period. As the organ in charge of the emotions, early modern understandings of the scientific heart were integral to developing representations of character and identity.

This is not to obfuscate the complexity of interpreting identity and character in the early modern period or our own. Stephen Greenblatt’s seminal work observes an ‘increased self-consciousness about the fashioning of human identity as a manipulable, artful process’ in the sixteenth century.⁵⁰ As Greenblatt reminds us, ‘there is no such thing as a single “history of the self” in the sixteenth century, except as the product of our need to reduce the intricacies of complex and creative beings to safe and controllable order.’⁵¹ Care must also be taken when approaching the notion of character; as Stephen Orgel argues, ‘character is no more stable than texts, and like texts, depends utterly on interpretation.’⁵² While a deeper analysis of the nuances of identity and character is beyond the scope of this essay, we argue that the early modern heart and its pulse are integral to developing understandings of (physical and emotional) identity and selfhood in Shakespeare’s England.

The heart and heartbeat in Shakespeare’s canon

Shakespeare’s canon repeatedly utilises the image of the heart in its dual role as organ and seat of emotion.

In Shakespeare’s plays the word “heart” and its derivatives and compounds occur over 1,400 times, a third again as often as “hand” and more than twice as often as “head”, the next most prominent and active body parts in the corpus.⁵³

The heart is mentioned most often in *King Lear*, from the common trope of ‘heartbreak’ (‘this heart / shall break’; ‘Wilt break my heart?’) to the heart as a site of emotion too deep to be spoken (‘Unhappy that I am, I cannot heave / My heart into my mouth’).⁵⁴ Just as it is used today, the heart in Shakespeare appears in common phrases like ‘take heart’ (*Antony and Cleopatra*, 4.15.89), ‘with all my heart’ (*Hamlet* 3.1.24) and to ‘wear my heart upon my sleeve’ (*Othello* 1.1.63). It is a symbol of courage; Lady Macbeth tells her husband she would ‘shame / To wear a heart so white’ (2.2.63-4). It responds to fear: Macbeth’s encounter with the witches makes his ‘seated heart knock at my ribs’ (1.3.136). It is an often-concealed source of truth and character: the reluctant conspirator Brutus refers to ‘the secrets of my heart’ in *Julius Caesar* (2.1.305). In *Richard III*, Lady Anne says to the duplicitous and conniving Richard, Duke of Gloucester: ‘I would I knew thy heart’ (1.2.196). Shakespearean hearts not only feel but think: ‘what his heart thinks his tongue speaks’ (*Much Ado About Nothing*, 3.2.13). And it is also, of course, an organ integrally connected with romantic love: ‘your heart is in love with her’ (*Love’s Labour’s Lost*, 3.1.43). Much of this symbolism of the heart in Shakespeare’s late sixteenth and early seventeenth century drama is thus retained in early twenty-first century usage.⁵⁵

Less common in Shakespeare, though, is reference to the pulse (or pulses), which is found around 11 times in his works.⁵⁶ There are several references to variants of a ‘throbbing heart’ (*Venus and Adonis* 1186), which indicates that the Shakespearean heartbeat could be interpreted as an emotional expression of desire or sorrow. For Macbeth, the throbbing of the heart is a sign of desire: he tells the witches that ‘my heart / Throbs to know one thing’ (4.1.100-1). Conversely, in *Titus Andronicus*, at the telling of the tragic events that have unfolded, the public is promised that ‘Your hearts will throb and weep to hear him speak’ (5.3.94, Folio only). In *Henry VI Part 2*, a symptom of the Queen’s grief is her ‘throbbing breast’ (4.4.5).

In place of ‘pulse’ or a heart ‘throb’, Shakespeare also references the heart ‘beat’. While the word overwhelmingly appears in non-heart related usages (over 100 references), beat and its variants are used several times in reference to the pulse.⁵⁷ These usages are predominantly literal references to the heartbeat as a physiological symptom. For example, in Shakespeare’s poem *Venus and Adonis*, the pulse is invoked as a sign of life. When the mortal Adonis offends the goddess Venus, she falls, emulating death and lying ‘as she were slain’ (473). ‘The silly boy, believing she is dead, / Claps her pale cheek, till clapping makes it red’ (467-8), and as part of his emergency assessment of Venus,

He wrings her nose, he strikes her on the cheeks,

He bends her fingers, holds her pulses hard,

He chafes her lips; a thousand ways he seeks

To mend the hurt that his unkindness marr’d.

(*Venus and Adonis* 475-78)

Checking Venus’ pulse here becomes a means by which to assess her physiological state and bring the goddess back to consciousness. The pulse is also referenced in *Henry IV Part 2*, when the Hostess Mistress Quickly says to the intoxicated Doll Tearsheet:

I’faith, sweetheart, methinks now you are in an excellent good temperality.

Your pulside beats as extraordinarily as heart would desire, and your colour I warrant you is as red as any rose, in good truth, la! But i’faith you have drunk too much canaries, and that’s a marvelous searching wine, and it perfumes the blood ere one can say, “What’s this?” (2.4.21-7)

Mistress Quickly blends the literal and the figurative senses of the heart in her comment that Doll’s pulse beats as ordinarily as ‘heart would desire’. Doll’s pulse is a sign of her good

temperality (temper) and physical health (her colour is a healthy 'red'), but Doll's circulatory system has also been affected by the level of canary wine she has imbibed, which has 'perfumed' her blood.

In *The Comedy of Errors*, the pulse is used as a means of diagnosing madness and even identifying the possibility of demonic possession. In assessing the patient, the schoolmaster Doctor Pinch says, 'Give me your hand and let me feel your pulse' (4.4.54). Later, the patient describes the experience: 'And gazing in mine eyes, feeling my pulse, / [...] Cries out, I was possess'd' (5.1.244-46). This connection between the pulse and mental health is reiterated in *Hamlet*:

My pulse as yours doth temperately keep time,
And makes as healthful music. It is not madness
That I have utter'd.
(3.4.142-3)

Hamlet reinforces that the steady, regular beat of his heart is indicative of his physiological and mental health; that as his pulse does 'temperately keep time' the words he speaks must therefore not be 'madness'. The pulse here is aligned with both the passage of time and music. The connection between the pulse and time is reiterated in *The Tempest*: the spirit Ariel tells his master, Prospero, that he will 'return / Or ere your pulse twice beat' (5.1.102-3). The musicality and rhythm of the heartbeat is something that is still recognised in relation to Shakespearean poetic metre; iambic pentameter is sometimes described as emulating the rhythm of the heartbeat.⁵⁸

Not only does the pulse provide a means of ascertaining a character's physical and mental health, it is also used to confirm their very humanity, delineating the mortal from the

supernatural: ‘But are you flesh and blood? / Have you a working pulse? And are no fairy?’ (*Pericles* 5.1.153-55) Similarly, in *The Tempest*, the pulse is an indicator of humanity, used to help detect whether Prospero is a man ‘of flesh and blood’ (5.1.114) or ‘some enchanted trifle’ (5.1.113).

For Shakespeare’s early modern English culture, the heartbeat or pulse was a sign of physiological health, an indicator of mental stability, a possible sign of spiritual distress (such as possession), a symptom of emotional extremes (such as desire, grief or pain), a musical rhythm, and proof of humanity. The interconnections between physical, psychological, spiritual and emotional health are interwoven in complex ways through Shakespeare’s representation of the pulse. Many of these connotations carry over into our modern culture; as Garber has reflected, ‘Shakespeare makes modern culture’. This is not, of course, to obfuscate the fact that ‘languages of emotion are problematic across different historical periods, as well as across cultures and genres.’⁵⁹ It is important to note the ‘historical shift in viewing the heart as science’ which took place in the late nineteenth century, and to acknowledge what Bound Alberti calls the detachment of ‘the medicalized heart’ from ‘its spiritual and emotional influence’ (although the success of this detachment is, we believe, contentious).⁶⁰ Bound Alberti argues that to examine a concept like the heart, we need a ‘*longue durée* approach’ that observes the changing status of the heart as a ‘cultural artefact’ not necessarily organised as a linear narrative.⁶¹ An examination of representations of the heartbeat in Shakespeare’s canon indicates the diversity and centrality of the pulse in expressing, interpreting and communicating the identity and wellbeing of both self and other.

LVADs – Evolution from Pulsed to Pulse-less devices

From the mid-twentieth century, the role of the heart and the heartbeat changed dramatically with the evolution of artificial hearts and specifically LVAD technology. Given the physical,

spiritual, figurative and cultural importance of the pulse, it is perhaps unsurprising that surgeons and engineers initially developed LVADs that could produce pulsatile flow like the native heart. This, however, would change, as engineers and clinicians realised the benefits of pulseless LVADs. This development generates a major perturbation across our physiological, emotional and historical conceptualisations of the heart and its pulse.

The heart moves blood throughout the body through a cycle of relaxation and excitation. During relaxation, the muscular walls of the heart soften, allowing the heart chambers to fill with blood. During excitation, the heart walls contract, squeezing the chambers and propelling blood out of the heart into the circulation. One-way valves inside the heart ensure that blood can only flow in one direction around the body. In heart failure, the heart is weaker and is not able to pump blood out of the heart chambers as strongly as it once could. Left ventricular assist devices, as their name implies, are designed to be implanted alongside the native failing heart and assist it to pump blood around the body. The first generation of LVADs, developed in the 1960s, were designed to mimic the pumping action of the native heart, with the belief that mimicking nature was the most efficient solution.

First generation LVADs usually consisted of a collapsible sac, designed to mimic the left ventricle of the heart. The inlet of the sac was connected to the apex of the left ventricle, while the outlet was connected to the aorta, providing a bypass of blood flow around the failing left ventricle. In the earliest iterations, the sac would be encased in a rigid chamber, with an air gap between the sac and the enclosure. This airgap was periodically pressurised by an external source (usually a large air-compressor), which would compress the sac and eject any blood from within. After ejection, the chamber would depressurise, allowing the sac to fill with blood from the left ventricle. These LVADs were positioned extracorporeally, resting on the abdomen of the patient, with the inlet and outlet cannulae crossing the skin to

connect to the heart and aorta. One-way valves connected to the inlet and outlet of the sac ensured that during compression, blood flowed in one direction through the device.

These devices were shown to provide better survival rates than optimal medical management alone, with a 48% reduction in risk of death after 12 months.⁶² However, these devices were not without their complications. The devices were usually so large that they had to be positioned outside the body, with large 25mm diameter cannulae crossing the skin. The large size of the devices was believed to contribute to excessive bleeding and infection.⁶³ To mimic the pulsatile pumping action of the native heart, first generation LVADs were also mechanically complex, with many moving and interacting parts (including heart valves). These moving components exhibited significant wear and tear over time,⁶⁴ which led to a high likelihood (~35%) of failure.⁶⁵ Finally, the fact that the patient was tethered to a large air compressor limited their mobility and their quality of life. One company attempted to correct this using an electrically powered pump that could be completely implantable, however its large size still prevented implantation in most patients.

The issues with first generation LVADs stemmed from the fact that these pumps were attempting to mimic the pulsatile pumping action of the native heart. This could be interpreted as a logical design decision, given the medical importance of the pulse. However, from an engineering perspective, pumping any fluid in a pulsatile manner is inefficient, compared to moving fluid in a continuous stream. This is why water flows from taps and hoses in a continuous stream, rather than pulses. Continuous flow can be achieved using rotary pumps, which are devices that use a rotating impeller to impart energy to fluid. Rotary pumps are used in a range of applications today, from circulating water in fish tanks and swimming pools to moving liquids on a larger scale (such as in sewerage and desalination plants). These pumps also have an advantage over pulsatile pumps in that they only have one moving part and do not require one-way valves, making them easier to maintain and giving

them a longer service life. Another advantage of these devices is that they only require electricity to operate, which is more efficient than using pulses of compressed air. Therefore, using rotary pumps to propel fluid continuously is preferred over moving it in a pulsatile manner. Given that blood is a fluid (albeit more complex than water), it was logical to develop LVADs that utilised rotary pumps. Second-generation LVADs marked the first attempt to use rotary pumps as implantable cardiac assist devices.

Second generation LVADs use rotary pumps to impart energy to the blood to propel it around the body. Blood enters the small pump through the inlet, then is energised by a rotating impeller before exiting through the outlet. These devices are small enough to completely implant inside the patient, and the only thing crossing the skin is a driveline (8mm in diameter) that connects the pump to two small battery packs worn by the patient. This significantly reduces infection, while their implantability increases patient mobility (and thus quality of life). Additionally, as they only have one moving part, they have a significantly higher durability. As a result, second generation devices have a considerably better two-year survival rate than first generation devices.⁶⁶ Second generation LVADs have provided long-term support of heart failure patients, with both the Abbott HeartMate II and the Medtronic HVAD approved for destination therapy.⁶⁷ One of the most famous LVAD patients, former US Vice President Dick Cheney, was supported for nearly two years.⁶⁸

One possible downside of these devices is that the impeller is supported by a mechanical bearing. This mechanical bearing, known as a thrust bearing, is used to keep the impeller simultaneously spinning freely and located centrally in the housing. However, much like ball bearings in skateboard wheels, there is still mechanical contact between moving parts, resulting in high shear stresses that can destroy blood cells. As a result, there are some reports of thrombus (blood clot) formation at these bearings.⁶⁹

To overcome this limitation of mechanical bearings, third generation LVADs were designed to substitute the mechanical contact bearings of second generation LVADs with contactless bearings. This means that there is no mechanical wear and tear inside the LVADs, suggesting that they are even more reliable. Development of third generation LVADs began in the mid-1990s, with the first device approved for implant in Europe in 2003.⁷⁰ Examples of these devices include the Medtronic HVAD (Medtronic, Minneapolis, Minnesota, USA) and Abbott HeartMate 3 (Abbott Park, Illinois, USA).⁷¹ These devices use hydraulic and/or magnetic bearings to levitate and locate the impeller in the housing, eliminating any mechanical contact and potentially reducing thrombotic events.

Second and third generation LVADs, like their first-generation counterparts, are implanted alongside the native heart. While the native heart is still present and beating, it is only producing a small effort compared to the LVAD. Therefore the patient's blood flow is mostly continuous, like water through a garden hose. These patients have no discernible pulse, which at first glance may sound disconcerting. However, the numerous advantages these LVADs offer has resulted in an exponential increase in the number of patients supported by an LVAD. Annual worldwide implantation rates of all LVADs have increased from 95/year in 2006 to 2,501/year in 2014. This increase was primarily due to a massive uptake of second and third generation LVADs (no second and third generation devices were implanted in 2006, compared to 2423/year in 2014).⁷²

While patient outcomes have improved dramatically, there remain a number of physiological side effects to living a pulseless life. Physical side effects include reduced arterial wall stiffness and gastrointestinal bleeding.⁷³ In addition, there are significant amounts of post-surgery care, monitoring and restrictions that make daily life on an LVAD challenging, including daily dressing changes, ensuring batteries are charged and ensuring the electronic driveline isn't damaged.

The increase in patient numbers is a sign that this technology is accepted by the medical community as a heart failure therapy, but also means that there is an increasing number of people in the community living without a pulse. These pulseless patients are embedded in cultures driven by powerful, centuries-old understandings of the criticality of the heartbeat to our identity – not only in medical discourse but in religious, philosophical, and literary contexts. Formative cultural works like Shakespeare can be re-examined in an effort to reconceptualise this relationship between the pulse and selfhood. The representation of pulselessness in Shakespeare’s *Romeo and Juliet* offers one case study for reimagining the silent heart, as in the character of Juliet the tragedy provides an early modern example of a living, pulseless body.

Rescripting the role of the heart: living pulselessness in *Romeo and Juliet*

If the physiological side effects are managed, long support durations with LVADs are possible. However, there are also long-term psychological side effects to consider. As described by Barg and colleagues, many LVAD patients feel they are in a liminal state where they see themselves as both simultaneously sick and well.⁷⁴ This is because even though the LVAD may have provided them the chance of a longer life, patients still face many challenges that prevent them returning to their life pre-heart failure. This liminal state is challenging to the patient, with patients and caregivers reporting that they weren’t adequately prepared for what life on an LVAD would be like.⁷⁵ Interviews with patients revealed that pre-implantation, the device was described as a miracle worker, something that would grant them life instead of death. But in patients who have lived with the device for more than two years, attitudes towards the LVAD change to an acute awareness that their life is entirely dependent on a machine functioning inside them, and if that machine fails then they die.⁷⁶

This state of mind is one that has not been experienced before and can be difficult to prepare the patient for. As Barg and colleagues state, ‘in simpler terms, they suffer the loss of a culturally scripted role, and lack the normative influences that could help make sense of their current situation’.⁷⁷ This questioning of self-identity in LVAD patients is confirmed by Sugarman et al, who argue that since heart transplant recipients commonly wonder if they are the same person, ‘similar questions about self-identity can occur, and perhaps be intensified, when a machine performs all or many of the functions previously carried out by the heart’.⁷⁸ The loss of the pulse function, which carries with it not only a physiological role but centuries of accumulated meaning linking the heartbeat to individual identity, may thus act as a catalyst for anxiety around the patient’s sense of self. The cultural weight of the heartbeat as a spiritual and emotional symbol and an indicator of life, feeling, passion and health, can have significant ramifications for LVAD patients.

For Braus and Mueller, the first step is acknowledging that ‘the problem is metaphorical and not technological’.⁷⁹ For LVAD patients, the silent heart is not indicative of a technological or medical problem; pulselessness becomes an emotional, cultural, and metaphorical challenge. If a consequence of pulselessness in LVAD patients is the ‘loss of a culturally scripted role’, then patients must look to other discourses to help them in scripting negotiated roles and ways of affirming their identity. Here, narrative and metaphor become essential tools for supporting a pulseless sense of self. For Oldfield and Jones,

Because of the limited ability of the biomedical narrative to convey the full meanings of disease and treatments, doctors and patients need to communicate through the nuanced and rich possibilities of metaphor. There are certainly inherent dangers in applying simplistic metaphors that can mislead patients and doctors, something too common in cardiology and cardiac surgery. The answer, though, cannot be to erase metaphor, or the

narratives that motivate them. Instead, caregivers and patients must learn to recognize, interpret, and act on them.⁸⁰

The heartbeat is pervasive in the narratives and metaphorical language of the heart. However, rather than ‘erasing’ pre-existing narratives and metaphors which conceive of the heartbeat as a critical sign of physical and emotional wellbeing, we can use them to address reactions to pulselessness and investigate dominant cultural and literary representations of the heartbeat. By examining representations of the pulse (and pulselessness) as both physiological symptom and metaphor in literature, we can begin to interrogate the relationship between the heartbeat, metaphor, and self-identification.

In its depiction of ‘star-crossed lovers’ (1.1.6), *Romeo and Juliet* reiterates the inseparability of literal and figurative associations of the heartbeat. The interplay between the literal and the metaphorical is important to the play: René Weis argues that ‘one of the distinctive strategies of *Romeo and Juliet* is “unmetaphoring”, Shakespeare’s trick of sinking conventional images back into “reality”’.⁸¹ The play’s denouement hinges on Juliet’s living, pulseless body, and thus provides a unique case study through which we can interrogate the literary and figurative construction of the heartbeat – and its absence.

When Juliet is informed by her parents that she is to marry Paris (after her secret marriage to Romeo), she believes her social condition is terminal. Forced into an arranged marriage when already wed, Juliet positions death itself as a more desirable alternative.

God joined my heart and Romeo’s, thou [the Friar] our hands,

And ere this hand by thee to Romeo’s sealed

Shall be the label to another deed,

Or my true heart with treacherous revolt

Turn to another, this shall slay them both.

(4.1.55-59)

Juliet here invokes the image of the heart, which, rather than be permitted to turn traitor and rebel against Juliet's body by marrying another man, she would herself 'slay'. She envisages her own heart as 'true' but also potentially 'treacherous'; the sense is that her figurative heart is not entirely under Juliet's control. This manifestation of the heart as the seat of her emotions and her loyalty to her husband is distinct from but related importantly to the physical heart whose pulse Juliet will shortly force to 'surcease' (4.1.97); what Juliet negotiates here is a complex territory of the figurative and literal spaces of the heart – the relationship between emotional expression and physiology. In effect, what Juliet does is precisely what she threatens here: she will in fact 'slay' her 'true heart' by (temporarily) stopping her heartbeat in order to prevent a 'treacherous revolt' of her figurative heart through a marriage to Paris. This dense interweaving of Juliet's physiological heart and the emotional 'heart' is a reminder that in Shakespeare's early modern culture, 'the psychological had not yet become divorced from the physiological.'⁸² While twenty-first century western culture tends 'to distinguish sharply between psychology and physiology, between the mental and the physical', for Juliet, her physical heart is absolutely implicated in her emotions, which are conceptualised as 'part of the fabric of the body.'⁸³

To escape the situation in which she finds herself, Juliet seeks 'a third option - something other than this marriage or suicide'.⁸⁴ Juliet's plan is to feign her death in order to be reunited with Romeo and avoid a forced marriage. For Paul A. Kottman, Juliet's actions are an individualised drive 'for freedom'; a freedom she finds not through

recognizable fidelity to social norms (marrying) or by openly transgressing the world's laws (suicide). On the contrary, by letting her body be buried in

the family vault in order to extricate herself from her family, she negates the difference between fidelity and betrayal, duty and transgression.⁸⁵

Juliet, with the aid of Friar Laurence, uses pulselessness to navigate a liminal third space between social norms and transgression in order to achieve freedom and her desires. Interestingly, this liminality echoes the experience of LVAD patients as described above. The Friar's plan for Juliet's freedom also reinforces the 'significant role' of Romeo and Juliet's physical bodies in the narrative.⁸⁶

To achieve her goal, Juliet must follow Friar Laurence's instructions:

Tomorrow night look that thou lie alone.
Let not the Nurse lie with thee in thy chamber.
Take thou this vial, being then in bed,
And this distilling liquor drink thou off,
When presently through all thy veins shall run
A cold and drowsy humour, for no pulse
Shall keep his native progress, but surcease.
No warmth, no breath, shall testify thou livest.
The roses in thy lips and cheeks shall fade
To wanny ashes, thy eyes' windows fall
Like death, when he shuts up the day of life.
Each part, deprived of supple government,
Shall stiff and stark and cold appear like death,

And in this borrowed likeness of shrunk death

Thou shalt continue two-and-forty hours,

And then awake as from a pleasant sleep.

(4.1.91-106)

The 'distilling liquor' will, the Friar promises, bring on the 'borrowed likeness' of death; Juliet's body will live but have 'no pulse'. Here, the heartbeat is personified as a moving, living traveller following his natural 'progress' through Juliet's veins and dispensing the 'roses' in her lips and cheeks. The Friar then develops his figurative language, turning Juliet's body into a home and the pulse into a tenant forcibly evicted and replaced by one who appears 'like death', who closes the 'windows' and 'shuts up' the home from the light of day. The passage moves swiftly from this metaphorical conceptualisation of Juliet's body as a home to her body as a political state, 'deprived of supple government'. This invokes the image of the body politic, which imagines the body as an organised government with various parts managed and maintained by distribution of resources through the veins.⁸⁷ A healthy pulse is reimagined as the life of a home and the stable function of a government. This indicates that the pulse is integrally connected to ideas of order, control, domestic and civil management – it is a symbol of the way things should be, of regularity and stability.

Thus, for Juliet, pulselessness is an opportunity to escape these dominant and oppressive controlling mechanisms. When her body mimics the physical 'likeness' of 'shrunk death', a silent heart becomes her 'remedy' (4.1.67; 76), a word both she and the Friar adopt to characterise the function of pulselessness: it acts as an antidote or countermeasure for Juliet and Romeo's situation. In her determination to stop her own pulse, Juliet reinforces what Weis calls 'her sense of her body and blood', which he notes is earlier encountered as she 'desires to lose her virginity' to Romeo.⁸⁸ In negotiating the control of her blood flow,

Juliet's pulselessness can be read as an attempt to wrest control of her body – and the sexualisation of her body as first virgin, then wife in a consummated marriage – from the dominant patriarchal forces of the play.

As Jeffrey Kleiner has pointed out, however, Juliet's false death does not remove all signs of life. 'On entering the tomb, Romeo is struck by Juliet's beauty and, more particularly, her complexion. Juliet has been dead for some forty hours; nonetheless her corpse is blushing.'⁸⁹ Despite the Friar's promise that 'The roses in thy lips and cheeks shall fade' (4.1.99), her pulse does not remove what Romeo describes as the 'crimson in thy lips and in thy cheeks' (5.3.95). For Kleiner, Juliet's blush is 'an important innovation' that 'alters' and 'it might be said, inverts the meaning of false death'.⁹⁰ This inversion negates the supposedly integral connection between life and the heartbeat; Juliet in this moment 'rescripts' pulselessness.

Pulselessness, for Shakespeare, is simultaneously an indicator of lifelessness and the potential means to achieve a desired quality of life for 'Juliet and her Romeo' (5.3.310). Just as the Friar's 'liquor' provides Juliet not with a death but rather metamorphoses the signs of death into a means to achieve the life she wants, so do artificial heart technologies like the LVAD replace 'native' signs of life (like the pulse) to enable patients to achieve longer life. Juliet's pulselessness is symbolic of her desire not only for survival but for freedom; her choice to still her own living heart transforms the meaning of the heartbeat in this context. *Romeo and Juliet* challenges the metaphors of the heart and its beat, offering pulselessness as a 'remedy' and a vehicle to protect and champion individual freedom and, through this, identity. The fact that the plan is ultimately 'thwarted' (5.3.154) does not undo the power of Juliet's choice and her reconfiguration of the symbolism of the still heart in *Romeo and Juliet*.

Conclusion

Juliet's 'remedy' of pulselessness (4.1.67) is 'thwarted' (5.3.154) by the fact that Romeo receives 'no notice' of the Friar's plan (5.2.26) and then mistakes Juliet's pulseless living body for a dead one. He does, though, notice the seeming vivacity of her body:

Death, that hath sucked the honey of thy breath

Hath had no power yet upon thy beauty.

Thou art not conquered. Beauty's ensign yet

Is crimson in thy lips and in thy cheeks,

And death's pale flag is not advanced there.

(5.3.92-96)

Juliet's body is transformed into a battlefield, where life and death rage. Death is not yet victorious; his flag – a metaphor for the paleness of death – has not yet been raised, because Juliet's circulatory system is still somehow operational, flushing her lips and cheeks 'crimson'. Her physical appearance confuses Romeo: 'Why art thou yet so fair?' he asks of her unconscious body (5.3.102). The heart is functioning although the pulse is absent. The problem is not Juliet's health, it is Romeo's inability to process a pulseless (and, to be fair, unconscious) body as living. He embodies something akin to our own reactions to living bodies made pulseless by LVAD technology. If Romeo's reaction teaches us anything, it is that we need to adjust our metaphorical and literal conceptualisations of the heart and the heartbeat to accommodate for living, pulseless bodies. There is a need for interdisciplinary scholarship to expand its interpretations of pulselessness to ensure that we have not only the biomedical but the cultural tools to support LVAD patients and those around them. The rise

of patients with LVAD devices necessitates our adaptation to the fact that a pulse is no longer a requisite sign of life.

Modern cultural developments in our understanding of the pulse are already underway. With the rise of LVAD implantations comes a corresponding increase in their visibility in pop culture and online. LVADs have appeared in popular television series like *30 Rock*, *Grey's Anatomy* and *The Unbreakable Kimmy Schmidt*.⁹¹ In the latter two shows, characters respond to the introduction of the LVAD by interpreting it with tropes drawn from fantasy and science fiction. When Denny, a patient in *Grey's Anatomy*, is told that his heart failure necessitates the implantation of an LVAD, he says: 'Battery-operated? I knew it. People are trying to turn me into a robot. All part of your evil plan to take over the hospital.'⁹² In *Kimmy Schmidt*, Lillian believes her partner is dead after checking his pulse while he sleeps. Unaware of his LVAD implementation, when he is later seen alive and well, Kimmy responds: 'We don't know he's not a zombie. Mr Goodman, say something only an alive person would say.' Interestingly, both shows rely on established literary and cultural humanoid figures (the robot and zombie respectively) and generic tropes of horror and science fiction to attempt to understand the LVAD and the living pulseless body.

Real-life LVAD patients have used online social platforms to share information and experiences. Support groups have formed online, while others use YouTube to share their stories via video blogs.⁹³ Ashley Paige uses YouTube to introduce her LVAD, which she names 'Gus':

Me and Gus are in a love-hate relationship right now, mostly love right now. I love him because he's keeping me alive and I feel great right now, and me and my mom just went on a 1 and a half mile walk the other day and I felt great. It's a hate because I'm always in and out of the hospital

with my GI bleeds and stuff like that. But he's keeping me alive and I'm really thankful for that. Thankful that I'm born in this era of time.⁹⁴

Similarly, in his YouTube video on 'Life with an LVAD', Richard Hendrix expresses his experience with the 'limitations' and 'amazing' benefits of the LVAD.⁹⁵ Paige is able to hike, while Hendrix demonstrates his golf swing and gives advice on how the LVAD can be worn for sports and social outings. For these LVAD patients, it appears that the LVAD offers a sense of individual freedom. In this way contemporary LVADs offer similar benefits to those Juliet strives for: freedom and the protection of individual identity.

In addition to these contemporary cultural responses to the biomedical development of the LVAD, it is important to critically evaluate the potent historical and cultural phenomena that have shaped today's understandings of the heart and the pulse. This includes works like Shakespeare's *Romeo and Juliet*, which features a protagonist whose innovative adoption of living pulselessness functions as a literal and symbolic vehicle to control her body and her sense of self. This demonstrates that narrative and metaphor offer a potent means by which to 'rescript' the relationship between the heartbeat and questions of self and to adapt our conceptualisations of the pulse in medicine, literature and culture.

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⁵² Stephen Orgel, "What is a character?" *Text* 8 (1995): 107.

⁵³ Slight, *The Heart in the Age of Shakespeare*, 180.

⁵⁴ William Shakespeare, *King Lear*, in *The Arden Shakespeare Complete Works*, edited by Richard Proudfoot, Ann Thompson and David Scott Kastan, (London: Thomson Learning, 2001), 2.4.281-2, 3.4.4, 1.1.91-2. All references to Shakespeare's works (except *Romeo and Juliet*) are taken from Proudfoot, Thompson and Kastan (eds), *The Arden Shakespeare Complete Works* (London: Thomson Learning, 2001). All further references to the *Complete Works* included in the body of the article.

⁵⁵ Also retained are correlations between gender and the heart. In *Twelfth Night*, Orsino claims that his masculine heart is larger and more passionate than a woman's. He argues:

There is no woman's sides
Can bide the beating of so strong a passion
As love doth give my heart; no woman's heart
So big, to hold so much
(2.4.94-97)

In this way, Orsino affirms Robert A. Erickson's argument that in early modern 'heart lore', the 'languaged heart' was also 'a powerfully gendered heart' (cited in Slight, *The Heart in the Age of Shakespeare*, 23). This gendered comparison between the relative figurative heart sizes of men and women is replicated literally in the earliest model of LVADs which were not designed for the female body. In a study of 115 thoracic CT scans from patients with cardiac pathologies, the CARMAT total artificial heart was found to fit in 86% of male patients but only 14% of female patients (P. Mohacsi and P. Leprince, "The CARMAT total artificial heart," *European Journal of Cardio-thoracic Surgery* 46. no 6 (2014): 933-4). Thus, as Orsino says, very few 'woman's sides / [could] bide the beating' of this LVAD design. Oldfield and Jones also detect 'gendered understandings of heart disease in 20th-century America, not just in popular culture but in medicine as well' ('Languages of the heart', 432). Bound Alberti concurs that in charting the development of 'medical and cultural beliefs about the interconnectedness of the heart, mind, body and soul' across the seventeenth to nineteenth centuries, much is revealed about gender-based analyses which influenced how cardiac patients were understood (*Matters of the Heart*, 13). Therefore, gendered understandings of the heart are prevalent across the sixteenth century to the twentieth century.

⁵⁶ Shakespeare Concordance, Open Source Shakespeare, George Mason University, <https://www.opensourceshakespeare.org/concordance/>.

⁵⁷ References to the heart's 'beat' appear in *King John*, 2.1.108; *King Richard II* 3.3.140; *King Richard III*, 4.1.34; *The Rape of Lucrece*, 590; *The Tempest*, 5.1.103. In its plural form, 'beats' is used by Shakespeare over 30 times, with at least five of these referring to the heart. See *King Henry IV Part 2*, 2.4.22; *The Tempest*, 5.1.113-14; *Titus Andronicus* 3.2.10; *Troilus and Cressida*, 3.2.34; *Venus and Adonis* 647. Of the multiple references to 'beating', three are in relation to the heart: see *The Rape of Lucrece* 433, 467; *Titus Andronicus* 3.2.13; *Twelfth Night* 2.4.95. Shakespeare's characters also 'beat' their hearts in a physical movement communicating extreme emotional distress. Venus 'beats her heart, whereat it groans' (*Venus and Adonis* 829) while Ophelia also 'beats her heart' (*Hamlet* 4.5.5). Claudio describes Beatrice weeping as she 'sobs, beats her heart, tears her hair' (*Much Ado About Nothing* 2.3.146). Interestingly, the 'beat' is not confined to the heart. Beating is enacted by another organ: the brain. In *The Tempest*, Prospero plans to take a walk 'to still my beating mind' (4.1.163). See also *The Tempest* 1.2.176; *Romeo and Juliet* 2.5.48-9.

⁵⁸ The Royal Shakespeare Company describes the rhythm of iambic pentameter as 'like a heartbeat, with one soft beat and one strong beat repeated five times.' See '*Romeo and Juliet: Key Terms*', <https://www.rsc.org.uk/shakespeare-learning-zone/romeo-and-juliet/language/key-terms>. See also Kelly Hunter, *Shakespeare's Heartbeat: Drama games for children with autism*, London and New York: Routledge, 2015; Alfred Corn, *The Poem's Heartbeat: A Manual of Prosody*, Port Townsend: Copper Canyon Press, 2008.

⁵⁹ Bound Alberti, *Matters of the Heart*, 11.

⁶⁰ Bound Alberti, *Matters of the Heart*, 163. Related to this is the relocation of 'the centre of life and of emotions' from the brain to the heart. This transition is outside the scope of the article, but for more, see Bound Alberti, 15 and 165.

⁶¹ Bound Alberti, *Matters of the Heart*, 160.

- ⁶² Eric A. Rose et al, “Long-Term Use of a Left Ventricular Assist Device for End-Stage Heart Failure,” *The New England Journal of Medicine* 345, no. 20 (2001): 1435–43.
- ⁶³ O.H. Frazier et al, “Multicenter Clinical Evaluation of the HeartMate Vented Electric Left Ventricular Assist System in Patients Awaiting Heart Transplantation,” *The Journal of Thoracic and Cardiovascular Surgery* 122, no. 6 (2001): 1186–95, <https://doi.org/10.1067/mtc.2001.118274>.
- ⁶⁴ Evgenij V. Potapov et al, “Longest Time of Support by the Novacor Left Ventricular Assist Device without Pump Exchange,” *The Annals of Thoracic Surgery* 80, no. 6 (2005): 2421; Giuseppe Faggian et al, “Insights from Continued Use of a Novacor Left Ventricular Assist System for a Period of 6 Years,” *Journal of Heart and Lung Transplantation* 24, no. 9 (2005): 17–19, <https://doi.org/10.1016/j.healun.2004.12.115>.
- ⁶⁵ Rose et al, “Long-term use of a Left Ventricular Assist Device”.
- ⁶⁶ Mark S. Slaughter et al, “Advanced Heart Failure Treated with Continuous-Flow Left Ventricular Assist Device,” *New England Journal of Medicine* 361, no. 23 (2009): 2241–51.
- ⁶⁷ T. C. Hanff and E. Y. Birati, “Left Ventricular Assist Device as Destination Therapy: a State of the Science and Art of Long-Term Mechanical Circulatory Support,” *Current Heart Failure Reports* 16, no. 5 (2019): 168–179.
- ⁶⁸ A. Pandey, A., K. Abdullah, and M. H. Drazner, “Impact of vice president cheney on public interest in left ventricular assist devices and heart transplantation,” *American Journal of Cardiology* 113, no. 9 (2014): 1529–1531.
- ⁶⁹ J. K. Kirklin et al., “Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) analysis of pump thrombosis in the HeartMate II left ventricular assist device,” *Journal of Heart and Lung Transplantation* 33, no. 1 (2014): 12–22.
- ⁷⁰ G. Foster, “Third-generation ventricular assist devices,” in *Mechanical Circulatory and Respiratory Support*, ed. S.D Gregory, M.C Stevens, J.F. Fraser, (London: Elsevier Inc., 2018), 151–186.
- ⁷¹ Abbott (the company responsible for HeartMate) used roman numerals for HeartMate II and Arabic numerals for HeartMate 3.
- ⁷² J. K. Kirklin et al, “Seventh INTERMACS annual report: 15,000 patients and counting,” *Journal of Heart and Lung Transplantation* 34, no. 12 (2015): 1495–1504.
- ⁷³ E. L. Wu, M. Kleinheyer, and A. Ündar, “Pulsatile vs. continuous flow,” in *Mechanical Circulatory and Respiratory Support*, ed. S. D. Gregory, M. C. Stevens, J. F. Fraser (London: Elsevier Inc, 2018), 379–406.
- ⁷⁴ F. K. Barg et al, “LVAD-DT: Culture of Rescue and Liminal Experience in the Treatment of Heart Failure,” *American Journal of Bioethics* 17, no. 2 (2017): 3–11.
- ⁷⁵ Barg et al, “LVAD-DT”, 7.
- ⁷⁶ Barg et al, “LVAD-DT”, 7.
- ⁷⁷ Barg et al, “LVAD-DT”, 4.
- ⁷⁸ J. Sugarman et al, “Medical Devices Policy and the Humanities: Examining Implantable Cardiac Devices,” in *Altering Nature Volume II: Religion, Biotechnology and Public Policy*, ed. B. A. Lustig, B. A. Brody, and G. P. McKenny (Dordrecht: Springer Netherlands, 2008), 260.
- ⁷⁹ Braus and Mueller, “Destination LVAD therapy”, 17.
- ⁸⁰ Oldfield and Jones, “Languages of the Heart”, 439.
- ⁸¹ Weis, *Romeo and Juliet*, 11.
- ⁸² Kern Paster, *Humoring the Body*, 7.
- ⁸³ Kern Paster, *Humoring the Body*, 6.
- ⁸⁴ Paul A. Kottman, “Defying the stars: tragic love as the struggle for freedom in *Romeo and Juliet*,” *Shakespeare Quarterly* 61, no. 1 (2012): 30.
- ⁸⁵ Kottman, “Defying the stars”, 30.
- ⁸⁶ Weis, *Romeo and Juliet*, 11.
- ⁸⁷ Shakespeare uses the body politic metaphor extensively in plays such as *Coriolanus*. See Andrew Gurr, “*Coriolanus* and the Body Politic,” *Shakespeare Survey* 28 (1975): 63-69. The use of heart imagery as a political metaphor recurs outside of Shakespeare – see James Harrington’s 1656 *Commonwealth of Oceana* (discussed above).
- ⁸⁸ Weis, *Romeo and Juliet*, 13.
- ⁸⁹ John Kleiner, “Live boys - dead girls: death and false death in *Romeo and Juliet*,” *Literary Imagination* 17, no. 1 (2015): 20.
- ⁹⁰ Kleiner, “Live boys”, 22.
- ⁹¹ “Meet the Woggles”, *30 Rock*, season 6, episode 17, NBC Universal Television; “Kimmy and the Trolley Problem”, *Unbreakable Kimmy Schmidt*, season 3, episode 12, Universal Television; “Band-Aid Covers the Bullet Hole”, “Superstition”, “Blues for Sister Someone”, “Damage Case”, “Seventeen Seconds”, “Deterioration of the Fight or Flight Response”, “Losing my Religion”, *Grey's Anatomy*, season 2, episodes 20-21, 23-27, ABC Studios.

⁹² “Band-Aid Covers the Bullet Hole”, *Grey’s Anatomy*, season 2, episode 20, ABC Studios. The full arc of character Denny Duquette’s experience with two LVAD implantations is beyond the scope of this paper but serves as a potential area for further research into cultural responses to LVAD technology.

⁹³ For example, see <https://www.mylvad.com/>;

⁹⁴ Ashley Paige, “My LVAD Gus”, Uploaded 21 October 2014, <https://www.youtube.com/watch?v=HxDufhpmfvg>.

⁹⁵ Richard Hendrix, “Life with a LVAD”, Uploaded 12 March 2011, https://www.youtube.com/watch?v=_eqC_oDQe1g.