CLAIMS

1. A system for controlling a heart pump, the system comprising:

a heart pump comprising:

an impeller;

a blood inlet;

a blood outlet;

a pump motor; and

a first portion configured to be positioned within a left ventricle of a patient's heart,

wherein, the heart pump, during operation, is configured to pull blood from the left ventricle of the patient into the impeller through the blood inlet and expel the blood through the blood outlet into an aorta of the patient;

a first sensor positioned within the left ventricle of the patient first portion of the heart pump and configured to generate an output used to measure or calculate a left ventricular systolic pressure (LVSP) within the left ventricle of the patienta heart; and

a controller coupled to a the heart pump and configured to measure or calculate the LVSP based on the output of the first sensor and to control an operation of the heart pump to maximize mechanical unloading of the left ventricle of the patient based on the measured or calculated LVSP,

wherein the heart pump has a pump speed and a flow rate, and the controller is configured to control one or more of the pump speed and the flow rate of the heart pump, such that the LVSP within the left ventricle of the patient is maintained at a target reference pressure, and

wherein the controller is configured to set the target reference pressure to a fraction of an end-systolic pressure in a normal ejecting beat, wherein the end-systolic pressure is measured by the first sensor, and wherein the fraction is between about 0.2 and about 0.4.

2. A system for cardiac support, the system comprising:

a heart pump comprising

a first portion configured to be positioned within a patient's heart;

a first sensor positioned within the first portion of the heart pump and configured to generate an output used to measure or calculate a left ventricular systolic pressure (LVSP) within a left ventricle of the patient; and

a controller coupled to the heart pump and configured to measure or calculate the LVSP based on the output of the first sensor and to control an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,

wherein the heart pump has a pump speed and a flow rate, and the controller is configured to control one or more of the pump speed and the flow rate of the heart pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and

wherein the system further comprises a second sensor positioned within a second portion of the heart pump and configured to generate an output used to measure or calculate a mean aortic pressure, and wherein the controller is configured to set the target reference pressure to a fraction of the mean aortic pressure, wherein the fraction is between about 0.2 and about 0.4.

3. A system for cardiac support, the system comprising:

a heart pump comprising

a first portion configured to be positioned within a patient's heart;

a first sensor positioned within the first portion of the heart pump and configured to generate an output used to measure or calculate a left ventricular systolic pressure (LVSP) within a left ventricle of the patient; and

a controller coupled to the heart pump and configured to measure or calculate the LVSP based on the output of the first sensor and to control an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,

wherein the heart pump has a pump speed and a flow rate, and the controller is configured to control one or more of the pump speed and the flow rate of the heart pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and

wherein the controller is configured to set the target reference pressure to reduce a pressure-volume area (PVA) of the left ventricle, wherein the controller

estimates PVA based on the measured or calculated LVSP and one or more measurements of a left ventricle volume.

4. The system of claim 3, wherein the controller is configured to set the target reference pressure to reduce the PVA of the left ventricle by about 90% to about 97%.

5. The system of claim 3, wherein the controller is configured to set the target reference pressure to reduce myocardial oxygen consumption (MVO_2) of the left ventricle, wherein the controller estimates the MVO_2 based on a linear relationship between the MVO_2 and the PVA.

6. The system of claim 5, wherein the controller is configured to set the target reference pressureto reduce the MVO_2 of the left ventricle by about 45% to about 48.5%.

7. A system for cardiac support, the system comprising:

a heart pump comprising

a first portion configured to be positioned within a patient's heart;

a first sensor positioned within the first portion of the heart pump and configured to generate an output used to measure or calculate a left ventricular systolic pressure (LVSP) within a left ventricle of the patient; and

a controller coupled to the heart pump and configured to measure or calculate the LVSP based on the output of the first sensor and to control an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,

wherein the heart pump has a pump speed and a flow rate, and the controller is configured to control one or more of the pump speed and the flow rate of the heart pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and

wherein the controller is configured to control the one or more of the pump speed and the flow rate of the heart pump to maintain the LVSP at the target reference pressure based on a plant transfer function that models changes in LVSP in response to changes in pump speed, wherein the system further comprises a non-transitory computer-readable storage medium or a non-transitory processor-readable storage

~~medium configured to store the plant transfer function as one or more instructions or code.~~

~~8. The system of claim 7, wherein the plant transfer function is a second order delay system with a time lag defined as:~~

$$~~H(f) = \frac{K}{1 + 2\zeta \frac{f}{f_N} j + \left(\frac{f}{f_N} j\right)^2} exp(-2\pi f L j)~~$$

~~where K is a gain, ζ is a damping factor, f_N is the natural frequency, and L is the time lag. r~~

~~9. The system of claim 8, wherein the gain K is equal to about 0.013 mmHg/rpm, the damping factor ζ is equal to about 1.9, the natural frequency f_N is equal to about 0.41 Hz and the time lag L is equal to about 0.03 seconds.~~

~~10. The system of claim 9, wherein the controller is configured to control the one or more of the pump speed and the flow rate of the heart pump such that the LVSP reaches the target reference pressure in less than a clinically predetermined response time and with an overshoot less than 10% of the target reference pressure.~~

~~11. The system of claim 9, wherein the controller is configured to control the one or more of the pump speed and the flow rate of the heart pump to maintain the LVSP at the target reference pressure when an open loop gain of the plant transfer function changes by a factor of 16 or less.~~

~~12. The system of claim 9, wherein the controller includes a proportional-integral controller configured with a proportional gain equal to about 40, an integral gain equal to about 20, and a derivative gain equal to about 0.~~

~~13. The system of claim 9, wherein the controller includes an adaptive control mechanism configured to update the plant transfer function and reconfigure the controller to control the one or more of the pump speed and the flow rate of the heart pump in response to changes in the plant transfer function.~~

~~14~~2. A method for controlling operation of a heart pump, comprising:

positioning a first portion of the heart pump within a left ventricle of a patient~~'s heart~~,

wherein the heart pump further comprises an impeller, a blood inlet, a blood outlet, a pump motor, and

wherein, the heart pump, during operation, is configured to pull blood from the left ventricle of the patient into the impeller through the blood inlet and expel the blood through the blood outlet into an aorta of the patient;

measuring or calculating a left ventricular systolic pressure (LVSP) within ~~a~~ the left ventricle of the ~~AMI~~ patient using an output generated by at least one sensor positioned within the left ventricle of the patient~~first portion of the heart pump~~; and

controlling an operation of the heart pump to mechanically unload the left ventricle of the patient based on the measured or calculated LVSP,

wherein controlling the operation of the heart pump comprises controlling one or more of a pump speed and a flow rate of the heart pump, such that the LVSP within the left ventricle of the patient is maintained at a target reference pressure;~~, and~~

~~the method further comprising:~~

measuring or calculating end-systolic pressure in a normal ejecting beat; and

setting the target reference pressure to a fraction of the end-systolic pressure, wherein the fraction is between ~~about~~ 0.2 and ~~about~~ 0.4.

~~15. A method for controlling operation of a heart pump, comprising:~~

~~positioning a first portion of a heart pump within an AMI patient's heart;~~

~~measuring or calculating a left ventricular systolic pressure (LVSP) within a left ventricle of the AMI patient using an output generated by at least one sensor positioned within the first portion of the heart pump; and~~

~~controlling an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,~~

~~wherein controlling the operation of the heart pump comprises controlling one or more of a pump speed and a flow rate of the heart pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and~~

~~the method further comprising~~

~~measuring or calculating a mean aortic pressure; and~~

~~setting the target reference pressure to a fraction of the measured or calculated mean aortic pressure, wherein the fraction is between about 0.2 and about 0.4.~~

~~16. A method for controlling operation of a heart pump, comprising:~~

~~positioning a first portion of a heart pump within an AMI patient's heart;~~

~~measuring or calculating a left ventricular systolic pressure (LVSP) within a left ventricle of the AMI patient using an output generated by at least one sensor positioned within the first portion of the heart pump; and~~

~~controlling an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,~~

~~wherein controlling the operation of the heart pump comprises controlling one or more of a pump speed and a flow rate of the heart pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and further comprising~~

~~estimating a pressure-volume area (PVA) of the left ventricle based on the measured or calculated LVSP and one or more measurements of a left ventricle volume, and~~

~~setting the target reference pressure to reduce the PVA by about 90% to about 97%.~~

~~17. The method of claim 16, further comprising estimating a myocardial oxygen consumption (MVO_2) based on a linear relationship between the MVO2 and the PVA and~~

~~setting the target reference pressure to reduce myocardial oxygen consumption (MVO2) of the left ventricle by about 45% to about 48.5%.~~

~~18. A system for cardiac support, the system comprising:~~

~~a heart pump comprising~~

~~a first portion configured to be positioned within a patient's heart;~~

~~a first sensor positioned within the first portion of the heart pump and configured to generate an output used to measure or calculate a left ventricular systolic pressure (LVSP) within a left ventricle of the patient; and~~

~~a controller coupled to the heart pump and configured to measure or calculate the LVSP based on the output of the first sensor and to control an operation of the heart pump to mechanically unload the left ventricle based on the measured or calculated LVSP,~~

~~wherein the heart pump has a pump speed and a flow rate, and the controller is configured to control one or more of the pump speed and the flow rate of the heart~~

~~pump, such that the LVSP within the left ventricle is maintained at a target reference pressure, and~~

~~the system further comprising a storage medium configured to store a plant transfer function, wherein the controller is configured to control the heart pump to maintain the LVSP at a target reference pressure based on the plant transfer function that models changes in LVSP in response to changes in pump speed, wherein the plant transfer function is second order with a delay.~~

~~19. The system of claim 18, wherein the delay is based on a ratio between an exponential function and a second order function.~~

~~20. The system of claim 19, wherein the second order function includes a damping factor ζ that is a coefficient of a first order component of the second order function.~~