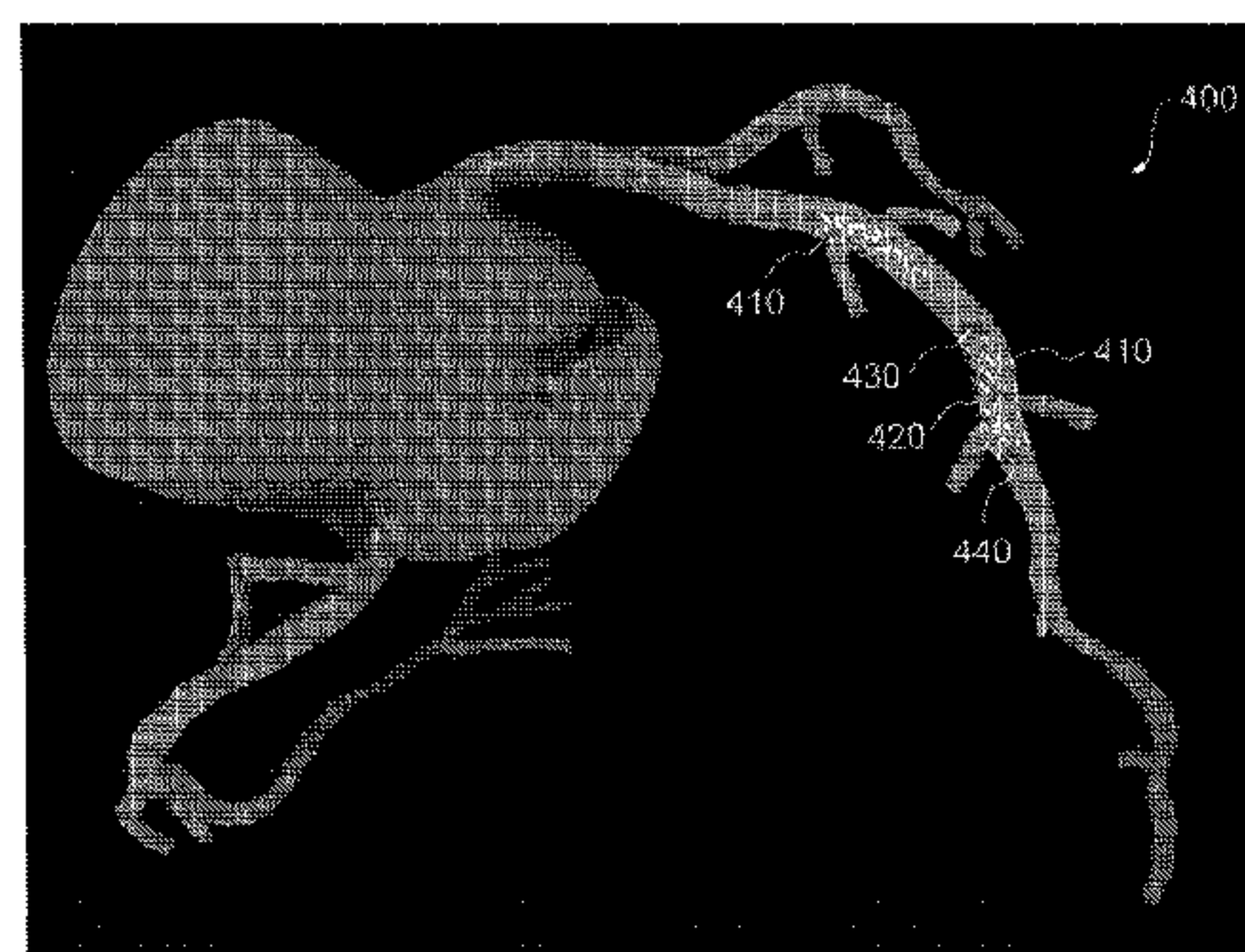
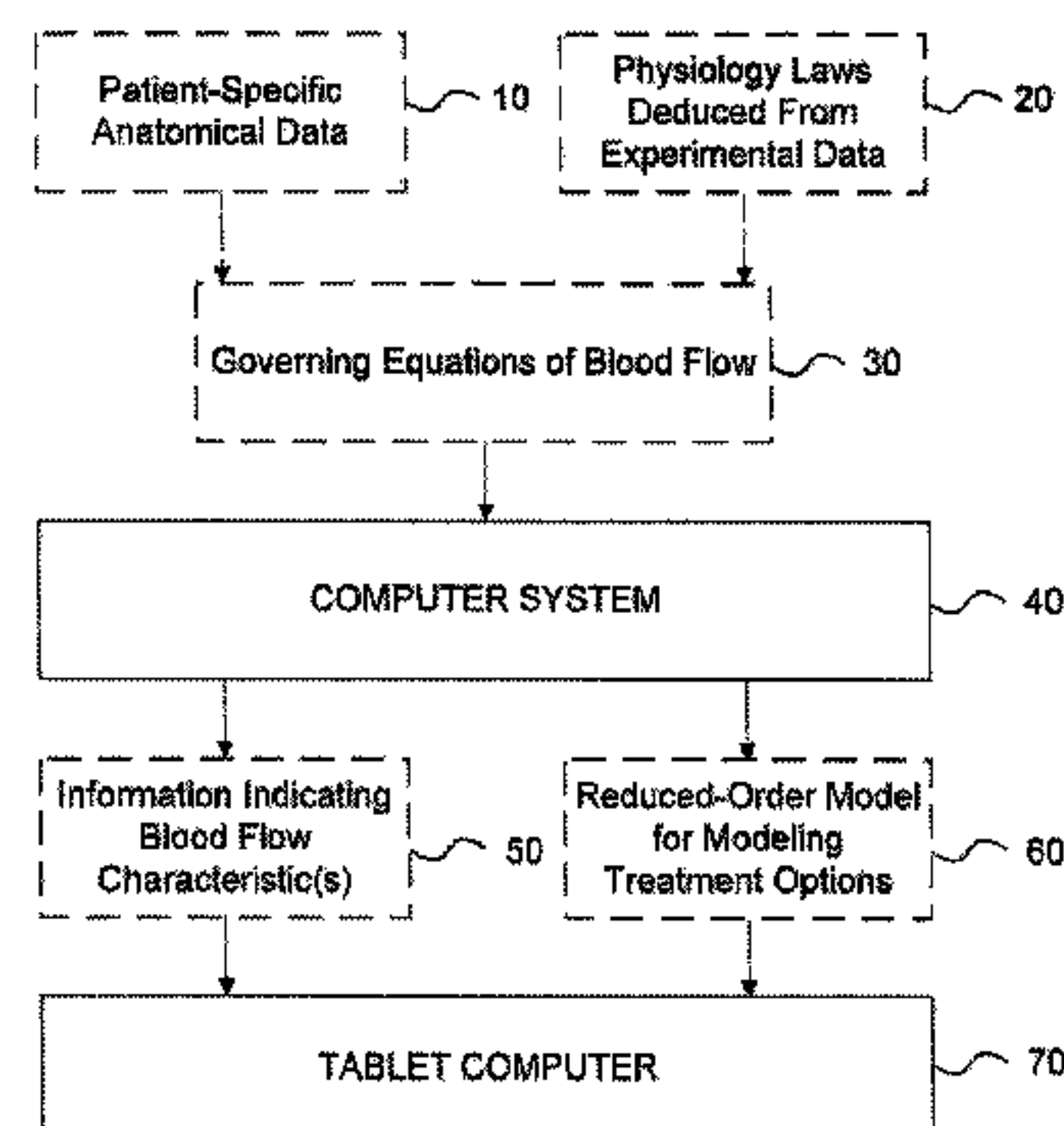




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(57) Abrégé/Abstract:

Embodiments include a system for providing blood flow information for a patient. The system may include at least one computer system including a touchscreen. The at least one computer system may be configured to display, on the touchscreen, a three-



(57) **Abrégé(suite)/Abstract(continued):**

dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data. The at least one computer system may also be configured to receive a first input relating to a first location on the touchscreen indicated by at least one pointing object controlled by a user, and the first location on the touchscreen may indicate a first location on the displayed three-dimensional model. The at least one computer system may be further configured to display first information on the touchscreen, and the first information may indicate a blood flow characteristic at the first location.

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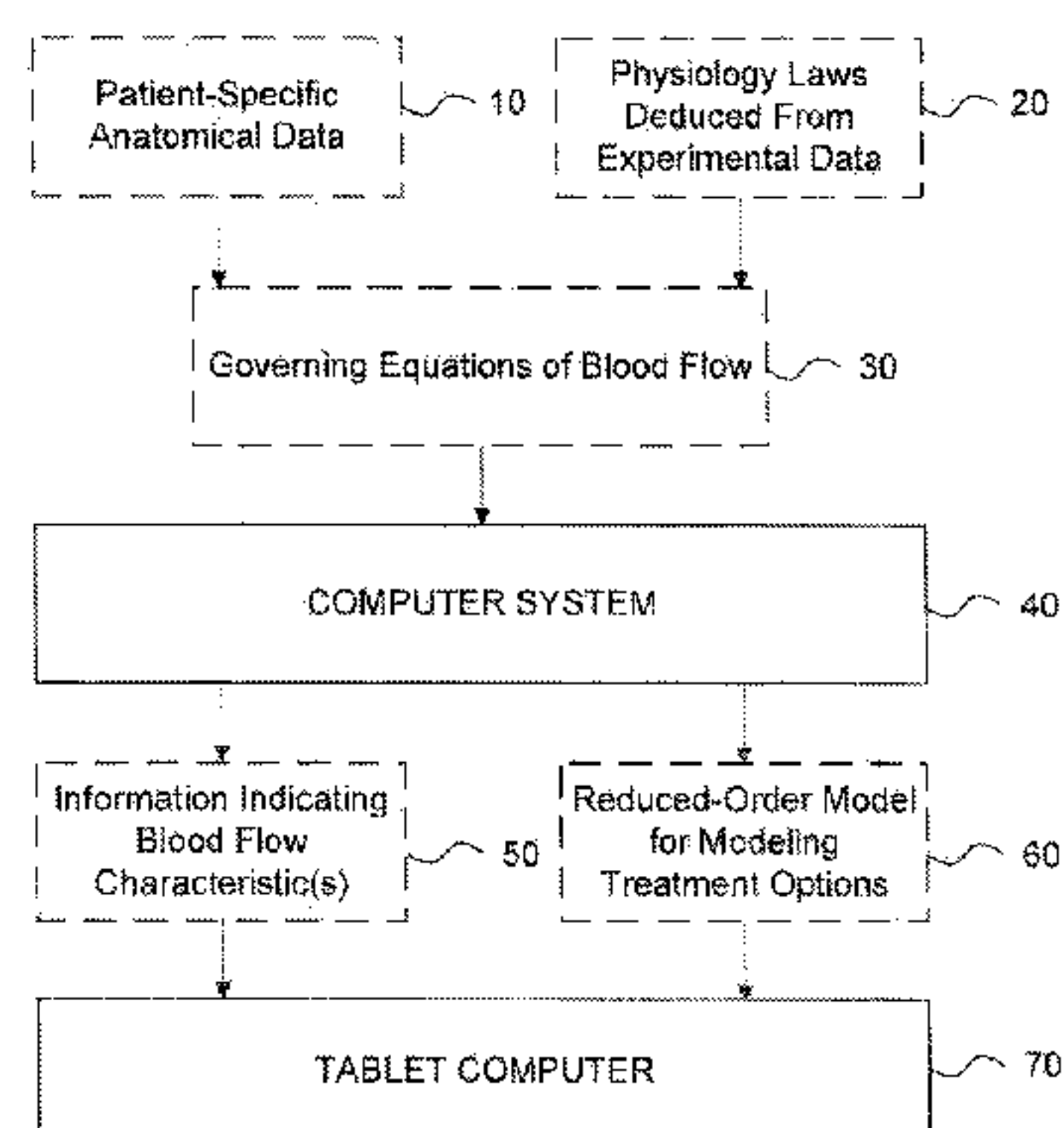


FIG. 1

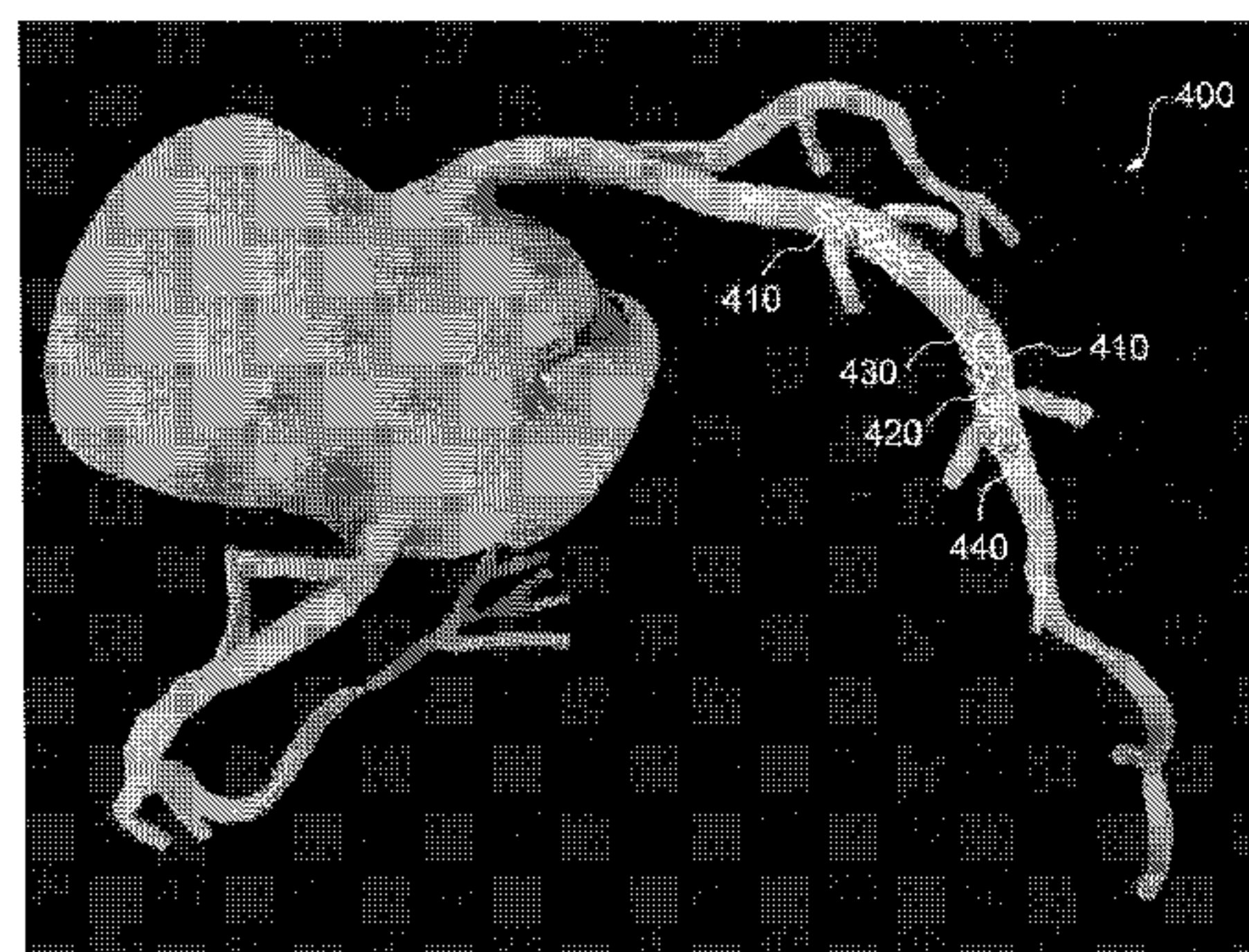


FIG. 5

(57) **Abstract:** Embodiments include a system for providing blood flow information for a patient. The system may include at least one computer system including a touchscreen. The at least one computer system may be configured to display, on the touchscreen, a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data. The at least one computer system may also be configured to receive a first input relating to a first location on the touchscreen indicated by at least one pointing object controlled by a user, and the first location on the touchscreen may indicate a first location on the displayed three-dimensional model. The at least one computer system may be further configured to display first information on the touchscreen, and the first information may indicate a blood flow characteristic at the first location.

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METHOD AND SYSTEM FOR PROVIDING INFORMATION FROM A PATIENT-SPECIFIC MODEL OF BLOOD FLOW

RELATED APPLICATION

[001] This application claims the benefit of priority to U.S. Patent Application No. 13/470,802, which was filed on May 14, 2012.

TECHNICAL FIELD

[002] Embodiments include methods and systems for using models of fluid flow and more particularly methods and systems for providing information from patient-specific models of blood flow.

BACKGROUND

[003] Coronary artery disease may produce coronary lesions in the blood vessels providing blood to the heart, such as a stenosis (abnormal narrowing of a blood vessel). As a result, blood flow to the heart may be restricted. A patient suffering from coronary artery disease may experience chest pain, referred to as chronic stable angina during physical exertion or unstable angina when the patient is at rest. A more severe manifestation of disease may lead to myocardial infarction, or heart attack.

[004] Patients suffering from chest pain and/or exhibiting symptoms of coronary artery disease may be subjected to one or more tests that may provide some indirect evidence relating to coronary lesions. For example, noninvasive tests may include electrocardiograms, biomarker evaluation from blood tests, treadmill tests, echocardiography, single positron emission computed tomography (SPECT), and positron emission tomography (PET). The noninvasive tests may provide indirect evidence of coronary lesions by looking for changes in electrical activity of the heart (e.g., using electrocardiography (ECG)), motion of the myocardium (e.g., using stress echocardiography), perfusion of the myocardium (e.g., using PET or SPECT), or metabolic changes (e.g., using biomarkers). These noninvasive tests, however, do not predict outcomes of interventions.

[005] For example, anatomic data may be obtained noninvasively using coronary computed tomographic angiography (CCTA). CCTA may be used for imaging

of patients with chest pain and involves using computed tomography (CT) technology to image the heart and the coronary arteries following an intravenous infusion of a contrast agent. However, CCTA cannot provide direct information on the functional significance of coronary lesions, e.g., whether the lesions affect blood flow. In addition, since CCTA is purely a diagnostic test, it does not predict outcomes of interventions.

[006] Invasive testing may also be performed on patients. For example, diagnostic cardiac catheterization may include performing conventional coronary angiography (CCA) to gather anatomic data on coronary lesions by providing a doctor with an image of the size and shape of the arteries. However, CCA also does not predict outcomes of interventions.

[007] Thus, a need exists for a method to predict outcomes of medical, interventional, and surgical treatments on coronary artery blood flow.

[008] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure.

SUMMARY

[008-1] In accordance with an embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may include displaying, on the touchscreen, a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying, on the touchscreen, at least one blood flow characteristic value at the first location in the three-dimensional model indicated by the first input; and determining and dynamically updating a display of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

[008-2] In another embodiment, a system for providing patient-specific blood flow information for a patient may include at least: a display device including a

touchscreen and being configured to: display a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; and display at least one blood flow characteristic value at a location in the three-dimensional model indicated by a user input; a processor configured to: receive a user input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; and determine and dynamically update a display, on the touchscreen, of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

[008-3] In another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for: displaying, on the touchscreen, a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying, on the touchscreen, at least one blood flow characteristic value at the first location in the three-dimensional model indicated by the first input; and determining and dynamically updating a display of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

[008-4] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and a processor configured to: operate in a first mode to receive a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location on the displayed three-dimensional model, and generate a display of first information on the touchscreen, the first information indicating a blood flow characteristic at the first location; and operate in a second mode to

(i) receive a second input relating to a second location on the touchscreen, the second input causing a modification of the three-dimensional model, (ii) generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen, (iii) determine and display second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-5] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving, while operating in an inspection mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; receiving, while operating in a treatment modeling mode, a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen; determining second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-6] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow

information, the instructions being executable by the at least one touchscreen computer system for: displaying a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; receiving, while operating in a first mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; receiving, while operating in a second mode, a second input relating to a second location on the touchscreen indicated by the user, the second input indicating a location of a stent for placement in the anatomical structure; displaying the stent on the three-dimensional model on the touchscreen; determining second information regarding a blood flow characteristic at a plurality of locations in the three-dimensional model based on a modification of the three-dimensional model reflecting the placement of the stent at the location indicated in the second input; and enabling the user to interact with the touchscreen to drag the displayed stent along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-7] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; and determining and dynamically updating a display of second and subsequent information regarding the blood flow characteristic as a user drags a pointing object across the touchscreen, where the display of the second and subsequent information is generated based on a location of the pointing object relative to the displayed three-dimensional model of the anatomical structure of the patient.

[008-8] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on a first portion of the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; displaying, on a second portion of the touchscreen, a modified three-dimensional model based on the patient-specific data and on a received user intervention input of a proposed intervention to the three-dimensional model; receiving a user's input relating to a first location on the touchscreen indicating either a location in the displayed three-dimensional model or a location in the displayed modified three-dimensional model; displaying information indicating a blood flow characteristic at the first location in either the three-dimensional model or the modified three-dimensional model; and displaying information indicating the blood flow characteristic at a location corresponding to the first location in the other of the three-dimensional model or the modified three-dimensional model.

[008-9] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least a computer system and a tablet computer including a touchscreen, may comprise generating, at the computer system, based on patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; transmitting the three-dimensional model and the reduced-order model to the tablet computer; displaying the three-dimensional model on the touchscreen of the tablet computer; and receiving at the tablet computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model.

[008-10] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to

generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-11] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and a processor configured to: (i) receive an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-12] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for: displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-

dimensional model; and enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-13] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; receiving a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen; displaying second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-14] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least a computer system, may comprise receiving over an electronic network, at the computer system, patient-specific anatomical data; generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; transmitting over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen; receiving over the electronic network, at the computer system, a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of

the reduced-order model; calculating, at the computer system, at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and transmitting over the electronic network the calculated at least one blood flow characteristic to the portable computer.

[008-15] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise at least: a computer system including a processor configured to: receive over an electronic network patient-specific data anatomical data; generate, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; transmit over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen; receive over the electronic network a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of the reduced-order model; calculate at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and transmit over the electronic network the calculated at least one blood flow characteristic to the portable computer.

[008-16] In accordance with another embodiment, a non-transitory computer readable medium for use on at least a computer system may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the computer system for: receiving over an electronic network, at the computer system, patient-specific anatomical data; generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; transmitting over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen; receiving over the electronic network, at the computer system, a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of the reduced-order model; calculating at least one blood flow characteristic based on the received user intervention

input and the modification of the reduced-order model; and transmitting the calculated at least one blood flow characteristic to the portable computer.

[008-17] In accordance with another embodiment, a method for displaying patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient; displaying, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model; receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation; displaying a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and displaying a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

[008-18] In accordance with another embodiment, a method for displaying patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise generating a three-dimensional model based on patient-specific data representing at least a portion of an anatomical structure of the patient; displaying, in a first portion of the touchscreen, a first intervention simulation of the three-dimensional model that is modified based on an intervention input of a first proposed intervention to the three-dimensional model; displaying, in a second portion of the touchscreen, a second intervention simulation of the three-dimensional model that is modified based on an intervention input of a second proposed intervention to the three-dimensional model; receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed first intervention simulation or in the displayed second intervention simulation; displaying a first value of at least one blood flow characteristic at the first location in either the first intervention simulation or the second intervention simulation; and displaying a second value of the at least one blood flow characteristic at a location that mirrors the first

location in the other of the first intervention simulation or the second intervention simulation.

[008-19] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise at least: a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and a processor configured to cause the display device to: (i) display, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient; (ii) display, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model; (iii) receive a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation; (iv) display a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and (v) display a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

[008-20] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for: displaying, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient; displaying, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model; receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation; displaying a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and displaying a second value of the at least one

blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

[008-21] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system with at least one processor, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving, from a user, an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-22] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and a processor configured to: (i) receive, from a user, an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-23] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow

information, the instructions being executable by the at least one touchscreen computer system for: displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving, from a user, an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-24] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving, from a user, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; receiving, from the user, a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen; displaying second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-25] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of the patient's vasculature beyond the patient's coronary arteries; receiving an input relating to a location on the touchscreen, the input causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding a blood flow characteristic in the patient's vasculature based on the input; and enabling a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

[008-26] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of the patient's vasculature beyond the patient's coronary arteries; and a processor configured to: (i) receive an input relating to a location on the touchscreen, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding a blood flow characteristic in the patient's vasculature based on the input, and (iv) enable a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

[008-27] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer system may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer

system for: displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of the patient's peripheral vasculature; receiving an input relating to a location on the touchscreen, the input causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; determining and displaying information regarding the blood flow characteristic in the patient's vasculature based on the input; and enabling a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

[008-28] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least a computer system and a portable computer including a touchscreen, may comprise receiving over an electronic network, at the computer system, patient-specific data including images of at least a portion of a patient's anatomy; generating, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; displaying the three-dimensional model on the touchscreen of the portable computer; receiving at the portable computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model; calculating at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and displaying the calculated at least one blood flow characteristic on the touchscreen of the portable computer.

[008-29] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise at least: a computer system including a processor configured to: (i) receive over an electronic network patient-specific data including images of at least a portion of a patient's anatomy; (ii) generate, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; (iii) receive at the portable computer a user intervention input indicating a potential treatment of the anatomical

structure and initiating a modification of the reduced-order model; and (iv) calculate at least one blood flow characteristic based on the received user intervention input and modification of the reduced-order model; and a portable computer including a touchscreen and being configured to: and (i) display a three-dimensional model on the touchscreen of the portable computer; and (ii) display a calculated blood flow characteristic on the touchscreen of the portable computer.

[008-30] In accordance with another embodiment, a non-transitory computer readable medium for use on at least a computer system may contain computer-executable programming instructions for providing patient-specific blood flow information and a portable computer including a touchscreen, the instructions being executable by the computer system for: receiving over an electronic network, at the computer system, patient-specific data including images of at least a portion of a patient's anatomy; generating, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure; displaying the three-dimensional model on the touchscreen of the portable computer; receiving at the portable computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model; calculating at least one blood flow characteristic based on the received user intervention input and modification of the reduced-order model; and displaying the calculated at least one blood flow characteristic on the touchscreen of the portable computer.

[008-31] In accordance with another embodiment, a computer-implemented method for providing patient-specific blood flow information using at least one computer system, may comprise receiving over an electronic network, at the at least one computer system, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data; generating a display of the geometric model on the at least one computer system; receiving a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of the portion of the anatomical structure; calculating, by the at least one computer system, at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and

generating a display of the calculated at least one blood flow characteristic on the at least one computer system.

[008-32] In accordance with another embodiment, a computer system for providing patient-specific blood flow information for a patient, may be configured to: receive, over an electronic network, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data; generate a display of the geometric model; receive a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of a portion of the anatomical structure; calculate at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and generate a display of the calculated at least one blood flow characteristic.

[008-33] In accordance with another embodiment, a non-transitory computer readable medium for use on at least a computer may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the computer for: receiving, over an electronic network, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data; generating a display of the geometric model; receiving a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of a portion of the anatomical structure; calculating at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and generating a display of the calculated at least one blood flow characteristic.

[008-34] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least a computer including a screen, may comprise receiving patient-specific anatomical data over an electronic network; generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient; displaying the geometric model on the screen of the computer; receiving a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure;

receiving a second intervention input modifying the first potential location for treatment to a second potential location for treatment; modifying the geometric model based at least upon the second intervention input and the second potential location for treatment; calculating a characteristic of blood flow through the portion of the anatomical structure being treated based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and displaying the calculated characteristic of blood flow on the screen of the computer.

[008-35] In accordance with another embodiment, a computer system including a screen for providing patient-specific blood flow information for a patient, may be configured to: receive patient-specific anatomical data over an electronic network; generate, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient; display the geometric model on the screen; receive a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure; receive a second intervention input modifying the first potential location for treatment to a second potential location for treatment; modify the geometric model based at least upon the second intervention input and the second potential location for treatment; calculate a characteristic of blood flow through the portion of the anatomical structure being treated based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and display the calculated characteristic of blood flow on the screen.

[008-36] In accordance with another embodiment, a non-transitory computer readable medium for use on at least a computer including a screen may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the computer for: receiving patient-specific anatomical data over an electronic network; generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient; displaying the geometric model on the screen of the computer; receiving a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure; receiving a second intervention input modifying the first potential location for treatment to a second potential location for treatment; modifying the geometric model based at least upon the second

intervention input and the second potential location for treatment; calculating a characteristic of blood flow through the portion of the anatomical structure being treated by based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and displaying the calculated characteristic of blood flow on the screen.

[008-37] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system having a touchscreen, may comprise displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; displaying, on the touchscreen, information regarding a blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and receiving an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-38] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and a processor configured to: (i) receive an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) receive an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-39] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one touchscreen computer may contain containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for: displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen; displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and receiving an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

[008-40] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a display, may comprise displaying, on the display, a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient; receiving a first gesture relating to a first location on the display indicated by a user, the first gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display; displaying, on the display, at least one blood flow characteristic value at the first location of the geometric model indicated by the first gesture; and dynamically updating the display of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the updating causing the computer system to update the display of the potential treatment and update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

[008-41] In accordance with another embodiment, a system for providing patient-specific blood flow information for a patient, may comprise at least a device including a display and being configured to: display a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient; and display at least one blood flow characteristic value at a location of the geometric model indicated by a user gesture; a processor configured to: receive the user gesture relating to a first location on the display indicated by a user, the user gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display; and dynamically update a display, on the display, of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the update causing the processor to update the display of the potential treatment and update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

[008-42] In accordance with another embodiment, a non-transitory computer readable medium for use on at least one computer system including a display may contain computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one computer system for: displaying, on the display, a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient; receiving a first gesture relating to a first location on the display indicated by a user, the first gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display; displaying, on the display, at least one blood flow characteristic value at the first location of the geometric model indicated by the first gesture; and dynamically updating a display of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the updating causing the computer system to update the display of the potential treatment and update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

[009] In accordance with an embodiment, a system for providing blood flow information for a patient may include at least one computer system including a

touchscreen. The at least one computer system may be configured to display, on the touchscreen, a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data. The at least one computer system may also be configured to receive a first input relating to a first location on the touchscreen indicated by at least one pointing object controlled by a user, and the first location on the touchscreen may indicate a first location on the displayed three-dimensional model. The at least one computer system may be further configured to display first information on the touchscreen, and the first information may indicate a blood flow characteristic at the first location.

[010] In accordance with another embodiment, a method for providing patient-specific blood flow information using at least one computer system

including a touchscreen may include displaying, on the touchscreen, a three-dimensional model based on patient-specific data. The three-dimensional model may represent at least a portion of an anatomical structure of the patient. The method may also include receiving a first input relating to a first location on the touchscreen indicated by at least one pointing object controlled by a user, and the first location on the touchscreen may indicate a first location in the displayed three-dimensional model. The method may also include displaying first information on the touchscreen, and the first information may indicate a blood flow characteristic at the location in the three-dimensional model indicated by the first input. The method may further include receiving a second input indicating a modification of the three-dimensional model and determining second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model.

[011] In accordance with a further embodiment, a non-transitory computer readable medium for use on at least one computer system may contain computer-executable programming instructions for performing a method for providing patient-specific blood flow information. The at least one computer system may include a touchscreen, and the method may include displaying a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data and receiving a first input relating to a first location on the touchscreen indicated by at least one pointing object controlled by a user. The first input may indicate a location of a stent for placement in the anatomical structure. The method may also include displaying the stent on the three-dimensional model on the touchscreen and determining second information regarding a blood flow characteristic at a plurality of locations in the three-dimensional model based on a modification of the three-dimensional model reflecting the placement of the stent at the location indicated in the first input.

[012] Additional embodiments and advantages will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the disclosure. The embodiments and advantages will be realized and attained by means of the elements and combinations particularly pointed out below.

BRIEF DESCRIPTION OF THE DRAWINGS

[013] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments and together with the description, serve to explain the principles of the disclosure.

[014] Fig. 1 is a schematic diagram of a system for providing various information relating to blood flow in a specific patient, according to an embodiment;

[015] Fig. 2 is an image showing calculated fractional flow reserve (FFR) within a three-dimensional model representing a portion of a patient's aorta and a plurality of coronary arteries emanating from the patient's aorta, according to an embodiment;

[016] Fig. 3 is an image showing calculated pressure gradient within a three-dimensional model representing a portion of a patient's aorta and a plurality of coronary arteries emanating from the patient's aorta, according to an embodiment;

[017] Fig. 4 is an image showing calculated FFR within a three-dimensional model representing a portion of a patient's aorta and a plurality of coronary arteries emanating from the patient's aorta, and a stent for placement in a coronary artery, according to an embodiment;

[018] Fig. 5 is an image showing a three-dimensional model representing a portion of a patient's aorta and a plurality of coronary arteries emanating from the patient's aorta, and a plurality of stents for placement in a coronary artery, according to an embodiment; and

[019] Fig. 6 is an image showing a split screen with the model and stent of Fig. 4 in one screen portion and a three-dimensional model modified based on the placement of the stent in another screen portion, according to an embodiment.

DESCRIPTION OF THE EMBODIMENTS

[020] Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[021] In an exemplary embodiment, a method and system determines various information relating to blood flow in a specific patient using information retrieved from the patient. The determined information may relate to blood flow in the patient's coronary vasculature. Alternatively, the determined information may relate to blood flow in other areas of the patient's vasculature, such as carotid, peripheral, abdominal, renal, and cerebral vasculature.

[022] The coronary vasculature includes a complex network of vessels ranging from large arteries to arterioles, capillaries, venules, veins, etc. The coronary vasculature circulates blood to and within the heart and includes an aorta 2 (Fig. 2) that supplies blood to a plurality of main coronary arteries 4 (Fig. 2) (e.g., the left anterior descending (LAD) artery, the left circumflex (LCX) artery, the right coronary (RCA) artery, etc.), which may further divide into branches of arteries or other types of vessels downstream from the aorta 2 and the main coronary arteries 4. Thus, the exemplary method and system may determine various information relating to blood flow within the aorta, the main coronary arteries, and/or other coronary arteries or vessels downstream from the main coronary arteries. Although the aorta and coronary arteries (and the branches that extend therefrom) are discussed below, the disclosed method and system may also apply to other types of vessels.

[023] In an exemplary embodiment, the information determined by the disclosed methods and systems may include, but is not limited to, various blood flow characteristics or parameters, such as blood flow velocity, pressure gradient, pressure (or a ratio thereof), flow rate, and fractional flow reserve (FFR) at various locations in the aorta, the main coronary arteries, and/or other coronary arteries or vessels downstream from the main coronary arteries. This information may be used to determine whether a lesion is functionally significant and/or whether to treat the lesion, and/or to predict the results of various treatment options. This information may be determined using information obtained noninvasively from the patient. As a result, the decision whether to treat a lesion may be made without the cost and risk associated with invasive procedures.

[024] Fig. 1 shows aspects of a system for providing various information relating to coronary blood flow in a specific patient, according to an embodiment. Additional details relating to various embodiments of methods and systems for determining blood flow information in a specific patient are disclosed, for example,

in U.S. Patent Application Publication No. 2012/0041739 entitled "Method And System For Patient-Specific Modeling Of Blood Flow," which is incorporated by reference in its entirety.

[025] Patient-specific anatomical data 10 may be obtained, such as data regarding the geometry of the patient's heart, e.g., at least a portion of the patient's aorta, a proximal portion of the main coronary arteries (and the branches extending therefrom) connected to the aorta, and the myocardium. The patient-specific anatomical data 10 may be obtained noninvasively, e.g., using a noninvasive imaging method. For example, CCTA is an imaging method in which a user may operate a computer tomography (CT) scanner to view and create images of structures, e.g., the myocardium, the aorta, the main coronary arteries, and other blood vessels connected thereto. Alternatively, other noninvasive imaging methods, such as magnetic resonance imaging (MRI) or ultrasound (US), or invasive imaging methods, such as digital subtraction angiography (DSA), may be used to produce images of the structures of the patient's anatomy. The resulting imaging data (e.g., provided by CCTA, MRI, etc.) may be provided by a third-party vendor, such as a radiology lab or a cardiologist, by the patient's physician, etc. Other patient-specific anatomical data 10 may also be determined from the patient noninvasively, e.g., blood pressure in the patient's brachial artery (e.g., using a pressure cuff), such as the maximum (systolic) and minimum (diastolic) pressures.

[026] A three-dimensional model 12 (Figs. 2 and 3) of the patient's anatomy may be created using the patient-specific anatomical data 10. In an embodiment, the portion of the patient's anatomy that is represented by the model 12 may include at least a portion of the aorta 2 and a proximal portion of the main coronary arteries 4 (and the branches extending or emanating therefrom) connected to the aorta 2. The three-dimensional model 12 may also include other portions of the patient's anatomy, such as the left and/or right ventricles, calcium and/or plaque within the coronary arteries 4 and/or the branches, other tissue connected to and/or surrounding the coronary arteries 4 and/or the branches, etc.

[027] Various physiological laws or relationships 20 relating to coronary blood flow may be deduced, e.g., from experimental data. Using the model 12 and the deduced physiological laws 20, a plurality of equations 30 relating to coronary

blood flow may be determined. For example, the equations 30 may be determined and solved using any numerical method, e.g., finite difference, finite volume, spectral, lattice Boltzmann, particle-based, level set, finite element methods, etc. The equations 30 may be solvable to determine information (e.g., pressure, pressure gradients, FFR, etc.) relating to the coronary blood flow in the patient's anatomy at various points in the anatomy represented by the model 12.

[028] In an embodiment, the model 12 may be prepared for analysis and boundary conditions may be determined. For example, the model 12 may be trimmed and discretized into a volumetric mesh, e.g., a finite element or finite volume mesh. The volumetric mesh may be used to generate the equations 30.

[029] Boundary conditions may be determined using the physiological laws 20 and incorporated into the equations 30. The boundary conditions may provide information about the model 12 at its boundaries, e.g., the inflow boundaries, the outflow boundaries, the vessel wall boundaries, etc. The inflow boundaries may include the boundaries through which flow is directed into the anatomy of the three-dimensional model, such as at an end of the aorta near the aortic root. Each inflow boundary may be assigned, e.g., with a prescribed value or field for velocity, flow rate, pressure, or other characteristic, by coupling a heart model and/or a lumped parameter model to the boundary, etc. The outflow boundaries may include the boundaries through which flow is directed outward from the anatomy of the three-dimensional model, such as at an end of the aorta near the aortic arch, and the downstream ends of the main coronary arteries and the branches that extend therefrom. Each outflow boundary can be assigned, e.g., by coupling a lumped parameter or distributed (e.g., a one-dimensional wave propagation) model. The prescribed values for the inflow and/or outflow boundary conditions may be determined by noninvasively measuring physiologic characteristics of the patient, such as, but not limited to, cardiac output (the volume of blood flow from the heart), blood pressure, myocardial mass, etc. The vessel wall boundaries may include the physical boundaries of the aorta, the main coronary arteries, and/or other coronary arteries or vessels of the model 12.

[030] The equations 30 may be solved using a computer system 40. Based on the solved equations 30, the computer system 40 may output information 50 indicating one or more blood flow characteristics, such as FFR,

blood pressure (or pressure gradient), blood flow, or blood velocity, determined based on the solution of the equations 30. The computer system 40 may output images generated based on the model 12 and the information 50 or other results of the computational analysis, as described below. The information 50 may be determined under simulated conditions of increased coronary blood flow or hyperemia conditions, e.g., conventionally induced by intravenous administration of adenosine. For example, the boundary conditions described above may specifically model conditions of increased coronary blood flow, hyperemia conditions, and/or the effect of adenosine.

[031] Fig. 2 shows a computed FFR model 100 that may be output from the computer system 40. The computed FFR model 100 may include the geometry of the anatomical structure based on the model 12 and may also indicate the information 50 output from the computer system 40, such as the values of FFR at various locations along three-dimensions in the model 12. FFR may be calculated as the ratio of the blood pressure at a particular location in the model 12 (e.g., in a coronary artery) divided by the blood pressure in the aorta, e.g., at the inflow boundary of the model 12, under conditions of increased coronary blood flow or hyperemia conditions. A corresponding color, shade, pattern, or other visual indicator may be assigned to the respective FFR values throughout the computed FFR model 100 such that the computed FFR model 100 may visually indicate the variations in FFR throughout the model 100 without having to visually indicate the individual numerical values for each point in the model 100.

[032] A scale or key 110 may be provided that indicates which numerical values of FFR correspond to which colors, shades, patterns, or other visual indicators. For example, the computed FFR model 100 may be provided in color, and a color spectrum may be used to indicate variations in computed FFR throughout the model 100. The color spectrum may include red, yellow, green, cyan, and blue, in order from lowest computed FFR (indicating functionally significant lesions) to highest computed FFR. For example, the upper limit (blue) may indicate an FFR of 1.0, and the lower limit (red) may indicate approximately 0.7 (or 0.75 or 0.8) or less, with green indicating approximately 0.85 (or other value approximately halfway between the upper and lower limits). For example, the lower limit may be determined based on a lower limit (e.g., 0.7, 0.75, or 0.8)

used for determining whether the computed FFR indicates a functionally significant lesion or other feature that may require intervention. Thus, the computed FFR model 100 for some patients may show a majority or all of the aorta as blue or other color towards the higher end of the spectrum, and the colors may change gradually through the spectrum (e.g., towards the lower end of the spectrum (down to anywhere from red to blue)) towards the distal ends of the coronary arteries and the branches that extend therefrom. The distal ends of the coronary arteries for a particular patient may have different colors, e.g., anywhere from red to blue, depending on the local values of computed FFR determined for the respective distal ends.

[033] For example, the computed FFR model 100 of Fig. 2 may show that, for this particular patient, under simulated hyperemia conditions, the computed FFR is generally uniform and approximately 1.0 in the aorta (e.g., as indicated by the color blue), and that the computed FFR gradually and continuously decreases (e.g., to values ranging from near 1.0 down to approximately 0.9, as indicated by gradually changing colors from blue to cyan or a mix of blue and cyan) as the blood flows downstream into the main coronary arteries and into the branches. However, at certain areas, such as areas 112 and 114, there may be sharper decreases in computed FFR. For example, between the aorta and area 112 in one of the coronary arteries, the computed FFR model 100 may indicate generally constant values (e.g., approximately 1.0, as indicated by the color blue) or gradually decreasing values in computed FFR (e.g., to values ranging from near 1.0 down to approximately 0.9, as indicated by gradually changing colors from blue to cyan or a mix of blue and cyan). At area 112, the computed FFR model 100 may indicate a drop in computed FFR to approximately 0.8 (e.g., as indicated by colors changing from blue and/or cyan, to green and/or yellow). Between the areas 112 and 114, the computed FFR model 100 may indicate generally constant values (e.g., approximately 0.8, as indicated by the colors green and/or yellow) or gradually decreasing values in computed FFR (e.g., to values slightly less than 0.8, as indicated by colors that are more yellow than green). At area 114, the computed FFR model 100 may indicate a drop in computed FFR to approximately 0.7 or below (e.g., as indicated by colors changing from green and/or yellow, to red). Downstream of the area 114 and to the distal end of the coronary artery, the

computed FFR model 100 may indicate that the computed FFR is approximately 0.7 or below (e.g., as indicated by the color red).

[034] Based on the computed FFR model 100, a user may determine that the computed FFR has dropped below the lower limit used for determining the presence of a functionally significant lesion or other feature that may require intervention (e.g., based on the location(s) of areas colored red in the computed FFR model 100 or otherwise indicating a value of computed FFR that is below the lower limit), and the user may also be able to locate the functionally significant lesion(s). The user may locate the functionally significant lesion(s) based on the geometry of the artery or branch (e.g., using the computed FFR model 100). For example, the functionally significant lesion(s) may be located by finding a narrowing or stenosis located near (e.g., upstream from) the location(s) of the computed FFR model 100 indicating the local minimum FFR value.

[035] Fig. 3 shows a computed pressure gradient model 200 that may be output from the computer system 40. The computed pressure gradient model 200 may include the geometry of the anatomical structure based on the model 12 and may also indicate the information 50 output from the computer system 40, such as the values of blood pressure gradient at various locations along three-dimensions in the model 12. The computed pressure gradient model 200 may show the local blood pressure gradient (e.g., in millimeters of mercury (mmHg) per centimeter) throughout the model 12 under simulated hyperemia conditions or other conditions. A corresponding color, shade, pattern, or other visual indicator may be assigned to the respective pressures gradients such that the model 200 may visually indicate variations in pressure gradient throughout the model 200 without having to visually indicate the individual pressure gradient numerical values for each point in the model 200.

[036] A scale or key 210 may be provided that indicates which numerical values of pressure gradient correspond to which colors, shades, patterns, or other visual indicators. For example, the computed pressure gradient model 200 may be provided in color, and a color spectrum may be used to indicate variations in pressure throughout the model 200. The color spectrum may include red, yellow, green, cyan, and blue, in order from highest pressure gradient, which may indicate functionally significant lesions, to lowest pressure gradient. For

example, the upper limit (red) may indicate approximately 20 mmHg/cm or more, and the lower limit (blue) may indicate approximately 0 mmHg/cm or less, with green indicating approximately 10 mmHg/cm (or other value approximately halfway between the upper and lower limits). Thus, the computed pressure gradient model 200 for some patients may show a majority or all of the aorta as blue and/or cyan, or other color towards the lower end of the spectrum, and the colors may change gradually through the spectrum (e.g., towards the higher end of the spectrum (up to red)) at areas having higher pressure gradients.

[037] For example, the computed pressure gradient model 200 of Fig. 3 may show that, for this particular patient, under simulated hyperemia conditions, the pressure gradient may be generally uniform and approximately zero mmHg/cm (e.g., as indicated by the colors blue and/or cyan) in the aorta and in most of the main coronary arteries and the branches. The computed pressure gradient model 200 may indicate a gradual increase in pressure gradient such that some areas 212 in the main coronary arteries and the branches indicate values of approximately 5 mmHg/cm to approximately 10 mmHg/cm (e.g., as indicated by the colors cyan and/or green), some areas 214 in the main coronary arteries and the branches indicate values of approximately 10 mmHg/cm to approximately 15 mmHg/cm (e.g., as indicated by the colors green and/or yellow), and some areas 216 in the main coronary arteries and the branches indicate values of greater than approximately 15 mmHg/cm (e.g., as indicated by the colors yellow and/or red).

[038] Based on the computed pressure gradient model 200, a user may determine that the computed pressure gradient has increased above a certain level (e.g., approximately 20 mmHg/cm), which may indicate the presence of a functionally significant lesion or other feature that may require intervention, and the user may also be able to locate the functionally significant lesion(s). The user may locate the functionally significant lesion(s) based on the geometry of the artery or branch (e.g., using the computed pressure gradient model 200). For example, the functionally significant lesion(s) may be located by finding a narrowing or stenosis located near the location(s) of the computed pressure gradient model 200 indicating a value of approximately 20 mmHg/cm or higher.

[039] The computer FFR model 100, the computed blood pressure gradient model 200, or other model may also include other information, such as

geometry information (e.g., numerical values for vessel inner diameter, thickness, etc.), throughout the model 100 or 200. The information relating to a particular location on the model may be displayed to the user upon selection of the location of the model as described below.

[040] The computer system 40 may allow the user to select whether to output the computed FFR model 100, the computed blood pressure gradient model 200, or other model, and/or to specify other color mappings or rendering styles (e.g., x-ray rendering).

[041] Referring back to Fig. 1, the computer system 40 may include one or more non-transitory computer-readable storage devices that store instructions that, when executed by a processor, computer system, etc., may perform any of the actions described herein for providing various information relating to blood flow in the patient. The computer system 40 may include a desktop or portable computer, a workstation, a server, a personal digital assistant, or any other computer system. The computer system 40 may include a processor, a read-only memory (ROM), a random access memory (RAM), an input/output (110) adapter for connecting peripheral devices (e.g., an input device, output device, storage device, etc.), a user interface adapter for connecting input devices such as a keyboard, a mouse, a touch screen, a voice input, and/or other devices, a communications adapter for connecting the computer system 40 to a network, a display adapter for connecting the computer system 40 to a display, etc. For example, the display may be used to display the model 12 and/or any images generated by solving the equations 30 (e.g., the computed FFR model 100, the computed blood pressure gradient model 200, and/or the other models described below).

[042] The patient-specific anatomical data 10 may be transferred over a secure communication line (e.g., via a wireless or wired network) to the computer system 40, which may create the model 12 and solve the equations 30. For example, in an embodiment, the data 10 may be transferred from the third-party vendor that obtains the patient-specific anatomical data 10 to the computer system 40 operated by the patient's physician or other user.

[043] In an embodiment, the computer system 40 may output the information 50 indicating one or more blood flow characteristics, the computed FFR model 100, the computed blood pressure gradient model 200, and/or other output from the computer system 40 based on the solution of the equations 30 to a tablet computer 70 (or other mobile or handheld computing device), such as Apple Inc.'s iPad®, over a secure communication line (e.g., via a wireless or wired network, using a web-based service, etc.). The tablet computer 70 may be operated by the patient's physician or other user, such as the patient. The tablet computer 70 may include a touchscreen. Various screenshots of the touchscreen are shown in Figs. 2-6 and described below. The touchscreen may be configured to receive input from the user based on contact by at least one of the user's digits (e.g., at least one of the user's fingers or thumbs) on a surface of the touchscreen as described below. The following description relates to embodiments in which the touchscreen is configured to receive input from contact by the user's finger(s) on the surface of the touchscreen. However, it is understood that the touchscreen may be configured to receive input from the user based on contact or sensed proximity to the touchscreen by the user's finger(s), the user's thumb(s), a stylus, another pointing object or instrument, or a combination thereof.

[044] Thus, in an embodiment, the computer system 40 may perform more complicated operations, such as solving the equations 30, while the tablet computer 70 may be a portable system for displaying the results of the solution of the equations 30 by the computer system 40 and for performing less complicated computations. The tablet computer 70 may allow the patient's physician, the patient, or other user to access information from the model 12, 100, or 200, and manipulate the model 12, 100, or 200 as described below. The tablet computer 70 may also be configured to allow the user to select treatment options using the tablet computer 70. The tablet computer 70 may determine or predict the blood flow characteristic(s) (e.g., FFR, blood pressure (or pressure gradient), etc.) in the patient's anatomical structure based on the selected treatment options as described below.

[045] For example, as shown in Figs. 2-4, the tablet computer 70 may provide two mode selection buttons 310 and 320 that allow the user to switch between two modes. Touching the first button 310 allows the user to select the first operating mode (e.g., an inspection mode), and touching the second button 320

allows the user to select the second operating mode (e.g., a percutaneous coronary intervention (PCI) mode).

[046] Figs. 2 and 3 are images illustrating screen shots of the tablet computer 70 operating in the first operating mode. In the first operating mode, the tablet computer 70 may display information indicating one or more blood flow characteristics of the patient in the patient's current condition, e.g., the computed FFR model 100 (Fig. 2), the computed pressure gradient model 200 (Fig. 3), or other model providing the information 50 output from the computer system 40. Inputs received from the user using the tablet computer 70 in the first operating mode may allow the user to interact with and manipulate the displayed information regarding the patient's current condition.

[047] The tablet computer 70 may be configured to determine when the user's finger(s) contact the surface of the touchscreen at a location corresponding to a location on the displayed model 100 or 200 (and a corresponding location in the patient's anatomical structure). Based on this input, the tablet computer 70 may determine the numerical value of a blood flow characteristic (e.g., FFR, blood pressure (or pressure gradient), and/or other blood flow characteristic selected by the user) at the indicated location on the displayed model 100 or 200, and may display the determined numerical value. The displayed numerical value may be dynamically updated as the user drags the finger(s) along the surface of the touchscreen and along the displayed model 100 or 200. Thus, the user may touch any point on the model 12, 100, or 200 to determine the numerical value of any of the blood flow characteristics described above, e.g., FFR, blood pressure (or pressure gradient), and/or other blood flow characteristic, at that point. Additional information relating to the indicated point on the model 12, 100, or 200 may also be displayed to the user, such as geometry information (e.g., a numerical value of the vessel inner diameter, etc.).

[048] For example, the tablet computer 70 may be configured to determine when the user's finger(s) contact the surface of the touchscreen for a predetermined time (e.g., a touch and hold) at a location corresponding to a location on the displayed model 100 or 200. Based on this input, the tablet computer 70 may create a tag or pin 330 that points to the indicated location within the displayed model 100 or 200. The user can then drag or move the pin 330

anywhere within the displayed model 100 or 200 to determine the numerical value of a blood flow characteristic at the indicated location on the displayed model 100 or 200 to which the pin 330 has been dragged. The numerical value may be dynamically updated as the pin 330 is dragged. The tablet computer 70 may display the determined numerical value within or near the pin 330. For example, in Figs. 2 and 3, the pin 330 points to a location in one of the coronary arteries illustrated in the model 100 where the FFR value is 0.58. The pin 330 may also indicate other information regarding the indicated location, such as a dimension (e.g., diameter) of the vessel at the indicated location. The tablet computer 70 may allow the user to create more than one pin 330 to drag separately around the model 100 or 200, and remove the pin(s) 330, as desired.

[049] When the user's finger(s) contact the surface of the touchscreen (e.g., for less than the amount of time associated with creating the pin 330) at a location corresponding to a location on the displayed model 100 or 200, then the tablet computer 70 may determine that the user has selected a particular coronary artery (and/or the branches connected thereto) and may fade (e.g., dim or decrease the brightness of) the other coronary arteries and branches.

[050] Alternatively, or in addition, the selected location may become a new focal point of view for the displayed model 100 or 200, and/or a new local origin for transformations, such as rotation and zoom. This allows the user to focus in on a potential stenosis, and to rotate around or zoom to (or away from) any user-defined point.

[051] The tablet computer 70 may also be configured to determine when the user's finger(s) swipe or drag on the surface of the touchscreen (e.g., at a location away from the pin 330). Based on this input, the tablet computer 70 may rotate the displayed model 100 or 200. The amount and direction of rotation may depend on the distance that the finger(s) travel in contacting the surface of the touchscreen during the swipe and the direction of the swipe along the surface of the touchscreen.

[052] The tablet computer 70 may also be configured to determine when the user's fingers pinch the surface of the touchscreen. If the user's fingers move closer together, the tablet computer 70 may zoom out from the displayed model 100 or 200. If the user's fingers move away from each other, the tablet computer

70 may zoom in on the displayed model 100 or 200. The amount of the zoom may depend on the distance that the finger(s) travel in the pinch along the surface of the touchscreen.

[053] As the user manipulates the view of the displayed model 100 or 200 (e.g., by rotating, zooming in or away, changing the focal point, etc.), the tube angulation or other information for characterizing the direction from which the anatomical structure is being viewed may be displayed to the user and dynamically updated. For example, the information may be provided in the form of left anterior oblique (LAO), right anterior oblique (RAO), caudal (GAUD), and/or cranial (GRAN) angles, e.g., LAO 20° and GRAN 0°, as known in the art.

[054] Figs. 4-6 are images illustrating screen shots of the tablet computer 70 operating in the second operating mode (e.g., the PGI mode) selected by the user by touching the second button 320. Inputs received from the user using the tablet computer 70 in the second operating mode allow the user to plan treatment options using the displayed model 400, which may be created based on the model 12 (e.g., a model reflecting the geometry of the patient's anatomical structure without additional information indicating blood flow characteristic(s)), the computed FFR model 100 (Fig. 2), the computed pressure gradient model 200 (Fig. 3), or other model providing information 50 indicating a blood flow characteristic of the patient in the patient's current condition. The tablet computer 70 may display predicted information regarding the blood flow characteristic(s) (e.g., FFR, blood pressure (or pressure gradient), etc.) based on the selected the treatment option.

[055] Fig. 4 shows a screen shot of the tablet computer 70 operating in the second operating mode to allow the user to select a treatment option using the model 400. In the embodiment shown in Fig. 4, the model 400 is created based on the computed FFR model 100. Alternatively, the model 400 may be created based on the model 12, the computed pressure gradient model 200, and/or other model. The tablet computer 70 may be configured to determine when the user's finger(s) contact the surface of the touchscreen (e.g., for a predetermined time (e.g., a touch and hold)) at a location corresponding to a location on the displayed model 400 (and a corresponding location in the patient's anatomical structure).

Based on this input, the tablet computer 70 may display a stent 410 for planned insertion into the patient's anatomical structure (e.g., in a coronary artery). The tablet computer 70 may allow the user to place more than one stent 410 on the model 400, as shown in Fig. 5, and remove the stent(s) 410, as desired.

[056] When initially placed on the model 400, the stent 410 may have a predetermined size or dimension, or other characteristics (e.g., diameter, length, material, wire thickness, wire configuration, etc.). The stent 410 may be initially placed so that the stent 410 is centered longitudinally with respect to the location selected by the user.

[057] The user may then provide additional inputs to define and/or adjust the stent 410. For example, the tablet computer 70 may be configured to determine when the user's finger(s) swipe or drag on the surface of the touchscreen. Based on this input, the tablet computer 70 may move the stent 410 along the model 400. For example, the stent 410 may move parallel to the centerline(s) of the coronary artery or arteries (or branches connected thereto). Also, the shape of the stent 410 may conform to bends and curves in the centerline(s), as shown in Figs. 4-6, as the stent 410 is dragged or moved along the centerline(s). The amount and direction (e.g., upstream or downstream along the centerline(s)) of movement of the stent 410 may depend on the distance that the finger(s) travel in contacting the surface of the touchscreen during the swipe and the direction of the swipe along the surface of the touchscreen.

[058] The tablet computer 70 may also be configured to determine when the user's fingers pinch the surface of the touchscreen. If the user's fingers move closer together, the tablet computer 70 may shorten the stent 410 (e.g., in the longitudinal direction and/or the direction of the centerline(s)). If the user's fingers move away from each other, the tablet computer 70 may lengthen the stent 410 (e.g., in the longitudinal direction and/or the direction of the centerline(s)). The amount of the change in length may depend on the distance that the finger(s) travel along the surface of the touchscreen to form the pinch. Also, the change in length may be continuous or may be provided in increments (e.g., approximately 4 millimeter increments or other increment). For example, if the stent 410 has a sequential ring configuration (e.g., a series of sequential rings that are joined together to form a tubular structure), then the change in length may be provided in

increments that are generally equivalent to a length of one ring, and the touchscreen may show the ring(s) being added or removed from the stent 410 to shorten or lengthen the stent 410.

[059] Other features may be provided that allow the user to adjust and manipulate the stent 410. Fig. 5 shows a screen shot of the tablet computer 70 operating in the second operating mode to allow the user to plan a treatment option associated with the placement of the stent 410 using the model 400, according to another embodiment.

[060] When displaying the stent 410 for planned insertion into the patient's anatomical structure (e.g., in a coronary artery), the tablet computer 70 may create one or more handles, such as a first handle 420, a second handle 430, and/or a third handle 440. The first handle 420 may be located at or near the center of the stent 410 along the longitudinal direction. The user may drag or move the stent 410 along the model 400 by pressing the first handle 420 and dragging the first handle 420 to a desired location on the model 400. Movement of the first handle 420 results in movement of the stent 410. As the user drags the first handle 420 along the model 400, the stent 410 may also move parallel to the centerline(s) of the coronary artery or arteries (or branches connected thereto) until the user removes the finger(s) from the first handle 420. Also, the shape of the stent 410 may conform to bends and curves in the centerline(s) as the stent 410 is dragged or moved along the centerline(s) with the first handle 420.

[061] The second and third handles 430, 440 may be located at or near the proximal and distal ends of the stent 410, respectively. The user may adjust the length of the stent 410 by pressing the second and/or the third handles 430, 440 and dragging the respective second and/or third handles 430, 440 along the model 400, thereby adjusting the locations of the respective proximal and distal ends of the stent 410. Movement of the second and/or third handles 430, 440 results in lengthening/shortening of the stent 410. For example, when the user drags the second handle 430 along the model 400 in a proximal direction away from the third handle 440, the stent 410 may lengthen and extend along the proximal direction. Similarly, when the user drags the third handle 440 along the model 400 in a distal direction away from the second handle 430, the stent 410 may lengthen and extend along the distal direction. The new portion of the stent 410 that is added due to the

lengthening may be formed parallel to the centerline(s) of the coronary artery or arteries (or branches connected thereto) and may conform to bends and curves in the centerline(s). Alternatively, the stent 410 may shorten when the user drags the second handle 430 along the model 400 in a distal direction toward the third handle 440 or when the user drags the third handle 440 along the model 400 in a proximal direction toward the second handle 430. As the length of the stent 410 is altered, the placement of the first handle 420 may be automatically adjusted so that the first handle 420 stays at or near the center of the stent 410. As a result, the handles 420, 430, 440 are user-friendly and allow the user to manipulate and adjust the stent 410 as desired.

[062] Various characteristics of the stent 410 may be displayed on the touchscreen. For example, the numerical values of the length, the proximal diameter, and/or the distal diameter of the stent 410 may be displayed on the touchscreen, e.g., in a stent legend. The numerical values may be dynamically updated as the user adjusts the stent 410.

[063] Other characteristics of the stent 410, e.g., the material, wire thickness, wire configuration, etc., may be selected by the user. For example, the tablet computer 70 may provide a selection of stent models that are available for placement into the patient and may store the characteristics of those stent models. The user may select from the stent models, and the tablet computer 70 may retrieve the stored characteristics corresponding to the stent model selected by the user to determine the various characteristics of the stent 410, such as the dimensions of the stent 410. In addition, other characteristics of the stent 410 may be determined based on the stent model selected, such as the dimensions of the incremental changes in length (e.g., the size of the rings in a ring configuration) described above and/or the flexibility of the stent 410 (e.g., the ability to conform to the bends and curves in the centerlines of the coronary arteries and branches).

[064] Alternatively, the various characteristics of the stent 410 and/or the stent model may be determined automatically and recommended by the tablet computer 70 based on various factors, such as the location of any FFR values that are less than 0.75 and the dimensions of the vessels at those locations, locations and dimensions of significant narrowing of the vessels, etc.

[065] The tablet computer 70 may also provide other treatment options for selection by the user, such as other types of surgery on the modeled anatomy that may result in a change in the geometry of the modeled anatomy. For example, the tablet computer 70 may be used to plan a coronary artery bypass grafting procedure. Coronary artery bypass grafting may involve creating new lumens or passageways in the model 400. After selecting this type of treatment option, the tablet computer 70 may be configured to determine when the user's finger(s) contact the surface of the touchscreen (e.g., for a predetermined time (e.g., a touch and hold)) at a location corresponding to a location on the displayed model 400. Based on this first input, the tablet computer 70 may display a bypass segment (not shown) for planned connection to the patient's anatomical structure (e.g., in a coronary artery), which has one end that is connected to the model 400 at the location indicated by the first input. The tablet computer 70 may then prompt the user to provide a second input identifying a second location for connecting the opposite end of the bypass segment to the patient's anatomical structure. Alternatively, the tablet computer 70 may recommend where to connect the bypass segment at one or both ends of the bypass segment. The tablet computer 70 may allow the user to place more than one bypass segment in the model, and remove the bypass segment(s), as desired. The tablet computer 70 may also allow the user to provide inputs (e.g., similar to the inputs described above, such as swiping and pinching) to change the location or dimension (e.g., diameter, length, etc.) of the bypass segment.

[066] Once the treatment option(s) have been selected by the user, the user may touch a calculate button 340, as shown in Fig. 4. When the user selects the calculate button 340, the tablet computer 70 recalculates the blood flow characteristic(s).

[067] For example, referring back to Fig. 1, after the computer system 40 solves the equations 30 as described above, the computer system 40 may create and transmit to the tablet computer 70 a reduced-order (e.g., zero-dimensional or one-dimensional) model 60 for modeling various treatment options, in addition to (or instead of) the information 50 indicating the blood flow characteristics in the patient's current condition, as disclosed, for example, in U.S. Patent Application Publication No. 2012/0041739 entitled "Method And System For Patient-Specific Modeling Of Blood Flow." For example, the reduced-order model 60 may be a

lumped parameter model or other simplified model of the patient's anatomy that may be used to determine information about the coronary blood flow in the patient without having to solve the more complex system of equations 30 described above. The reduced-order model 60 may be created using information extracted from the computed models 100 and 200 (e.g., the blood pressure, flow, or velocity information determined by solving the equations 30 described above).

[068] After the user touches the calculate button 340, the tablet computer 70 may adjust the reduced-order model 60 based on the treatment option selected by the user, and may solve a simplified set of equations based on the reduced-order model 60 to output information indicating one or more predicted blood flow characteristics (e.g., FFR, blood pressure (or pressure gradient), etc.) of the patient. The information may then be mapped or extrapolated to the three-dimensional model 12 of the patient's anatomical structure to display the effects of the selected treatment option on the coronary blood flow in the patient's anatomy, e.g., in a post-intervention model 500, as shown in Fig. 6.

[069] Since the reduced-order model 60 may be solved with a simplified set of equations (compared to the equations 30), the reduced-order model 60 permits relatively rapid computation (e.g., compared to a full three-dimensional model) using the tablet computer 70 and may be used to solve for flow rate and pressure that may closely approximate the results of a full three-dimensional computational solution. Thus, the reduced-order model 60 allows for relatively rapid iterations to model various different treatment options.

[070] Alternatively, instead of creating the reduced-order model 60 and transmitting the reduced-order model 60 to the tablet computer 70, the inputs provided by the user to select the treatment option may be transmitted to the computer system 40 via the tablet computer 70 (e.g., via a wired or wireless connection). After the user touches the calculate button 340, the computer system 40 may recalculate the information indicating the blood flow characteristic(s), e.g., by re-solving the equations 30 using the inputs provided by the user to select the treatment option. The computer system 40 may then transmit to the tablet computer 70 the information indicating the blood flow characteristic(s) based on this solution to the equations 30, and may also output

to the tablet computer 70 images generated based on the model 12 and the determined information, such as the post-intervention model 500 shown in Fig. 6.

[071] Fig. 6 shows a screen shot of the tablet computer 70 operating in the second operating mode after determining the information indicating the blood flow characteristic(s) of the patient based on the selected treatment option, according to an embodiment. Specifically, the screen shot shows a split screen provided by touchscreen, and the split screen may divide the screen into two or more portions. In the embodiment shown in Fig. 6, two portions may be provided. The first portion of the split screen (the left side portion shown in Fig. 6) may show the pre-intervention model 400 (Fig. 4) with the treatment option selected by the user (placement of the stent 410, as described above in connection with Fig. 4).

[072] The second portion of the split screen (the right side portion shown in Fig. 6) may show the post-intervention model 500 that reflects the information indicating the blood flow characteristic(s) of the patient based on selected treatment option. The post-intervention model 500 may show any change in geometry of the anatomical structure due to the selected treatment option. For example, in the embodiment shown in Fig. 6, the post-intervention model 500 shows a widening 510 of the lumen where the simulated stent 410 is placed. The post-intervention model 500 may also display the start and end points of the stent 410.

[073] In the embodiment shown in Fig. 6, the pre-intervention and post-intervention models 400, 500 indicate computed FFR. The split screen allows the user to view and compare information relating to the untreated patient (e.g., without the stent(s)), such as the model 400, side-by-side with information relating to the simulated treatment for the patient, such as the model 500. For example, the same color, shade, pattern, or other visual indicators as the model 400 may be assigned to the respective FFR values for the model 500. Thus, the model 500 may also visually indicate the variations in FFR throughout the model 500 without having to specify the individual values for each point in the model 500. The model 500 shown in Fig. 6 shows that, for this particular patient, under the treatment plan selected by the user, FFR is generally uniform and approximately 1.0 in the aorta (e.g., as indicated by the color blue), and that FFR gradually and continuously decreases (e.g., to values ranging from 1.0 down to approximately 0.9, as indicated by gradually changing colors from blue to cyan or a mix of blue and

cyan) in the main coronary arteries and the branches. In this embodiment, the post-interventional model 500 does not include the areas 112 and 114 of sharper decreases in FFR that are shown in the pre-interventional model 400. Thus, the split screen provides a comparison of the pre-interventional model 400 of the untreated patient (showing the patient's current condition) and the post-interventional model 500 for the proposed treatment to help the physician or other user to assess the results of various treatment options.

[074] Either portion of the split screen may be configured to receive inputs from the user and may respond to the inputs as described above in connection with the first operating mode. For example, the user may touch any location on the model(s) 400 and/or 500 to determine the numerical value of any of the blood flow characteristic(s) and/or geometry information at that location, e.g., by creating one or more pins 330 for moving around the model(s) 400 and/or 500. In an embodiment, when the user touches a location (or creates the pin 330) on one of the models 400 or 500 to determine the numerical value of the blood flow characteristic(s) and/or geometry information at the indicated location, the numerical value of the blood flow characteristic(s) and/or geometry information at the same location in the other model 400 or 500 may also be displayed for comparison. For example, another pin 330 may be automatically created at the same location in the other model 400 or 500. As a result, the split screen may provide mirrored pins 330 in the two displayed models such that movement of one pin 330 in one of the models due to user input is automatically mirrored by the pin 330 in the other model and the numerical values of the blood flow characteristic(s) and/or geometry information at the respective locations may be compared and updated dynamically as the pins 330 move.

[075] Also, the user may adjust the rotation, zoom, and/or focal point for the model(s) 400 and/or 500. In an embodiment, when the user adjusts the rotation, zoom, and/or focal point for one of the models 400 or 500, the rotation, zoom, and/or focal point for the other model 400 or 500 is adjusted similarly.

[076] The first portion of the split screen (showing the pre-intervention model 400) may be configured to receive inputs from the user and may respond to the inputs as described above in connection with the second operating mode. For example, the user may select or adjust the treatment option using the pre-

intervention model 400. After making the desired changes, the user may touch the calculate button 340, which may cause the tablet computer 70 to modify the reduced-order model 60 based on the new treatment option selected by the user. After solving the equations associated with the modified reduced-order model 60, the tablet computer 70 may output a modified post-intervention model 500 that reflects the new treatment option selected by the user. Alternatively, the tablet computer 70 may transmit the new treatment option to the computer system 40, which will re-solve the equations 30 based on the new selected treatment option, and send the modified post-intervention model 500 to the tablet computer 70 for displaying to the user.

[077] Alternatively, the split screen may provide two portions for comparing the results of different treatment options. In such an embodiment, each portion of the split screen may be configured to receive inputs associated with selecting treatment options using the pre-intervention model 400 as described above and may be able to display different post-intervention models 500 based on the different treatment options selected.

[078] Accordingly, the split screen allows the user to repeatedly select new treatment options and use the tablet computer 70 to predict and compare the effects of various treatment options to each other and/or to information relating to the untreated patient. The reduced-order model 60 may allow the user to analyze and compare different treatment options more easily and quickly without having to solve the equations 30 each time a different treatment option is selected.

[079] The system may be used to predict a potential benefit of percutaneous coronary interventions on coronary artery blood flow in order to select the optimal interventional strategy, and/or to predict a potential benefit of coronary artery bypass grafting on coronary artery blood flow in order to select the optimal surgical strategy.

[080] The systems and methods disclosed herein may be incorporated into a portable software tool accessed by physicians and other users to provide patient-specific blood flow information and to plan treatment options. In addition, physicians and other users may use the portable software tool to predict the effect of medical, interventional, and/or surgical treatments on coronary artery blood flow. The portable software tool may be used to prevent, diagnose, manage, and/or treat disease in other portions of the cardiovascular system including arteries of the

neck (e.g., carotid arteries), arteries in the head (e.g., cerebral arteries), arteries in the thorax, arteries in the abdomen (e.g., the abdominal aorta and its branches), arteries in the arms, or arteries in the legs (e.g., the femoral and popliteal arteries). The portable software tool may be interactive to enable physicians and other users to develop optimal personalized therapies for patients.

[081] The computer system 40 for solving the equations 30 governing blood flow may be provided as part of a web-based service or other service, e.g., a service provided by an entity that is separate from the physician. The service provider may, for example, operate the web-based service and may provide a web portal or other web-based application (e.g., run on a server or other computer system operated by the service provider) that is accessible to physicians or other users via a network or other methods of communicating data between computer systems. For example, the patient-specific anatomical data 10 obtained noninvasively from the patient may be provided to the service provider, and the service provider may use the data to produce the three-dimensional model 12 or other models/meshes and/or any simulations or other results determined by solving the equations 30 described above in connection with Fig. 1, such as the reduced-order model 60, the computed FFR model 100, and/or the computed blood pressure gradient model 200. Then, the web-based service may transmit the models 60, 100, and/or 200 to the physician's tablet computer 70 (or other portable device). The physician may use the tablet computer 70 to interact with the models 100 or 200, and to provide inputs, e.g., to select possible treatment options and determine blood flow information based on the selected possible treatment options.

[082] It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed systems and processes without departing from the scope of the disclosure. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying, on the touchscreen, at least one blood flow characteristic value at the first location in the three-dimensional model indicated by the first input; and

determining and dynamically updating a display of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

2. The method of claim 1, wherein the display of the at least one blood flow characteristic value is generated based on a location of the finger or the pointing object relative to the displayed three-dimensional model of the anatomical structure of the patient.

3. The method of claim 1 or claim 2, further comprising:

forming a pin at the first location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the at least one blood flow characteristic value in the anatomical structure as the pin is moved by the user.

4. The method of any one of claims 1 to 3, further comprising:
updating the at least one blood flow characteristic value in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the at least one blood flow characteristic value on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

5. The method of any one of claims 1 to 4, further comprising:
rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and a direction of rotation depending on a characteristic of the swipe.

6. The method of any one of claims 1 to 5, further comprising:
adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

7. The method of any one of claims 1 to 6, further comprising:
switching between operating in a first mode for receiving the first input and at least one subsequent input requesting the at least one blood flow characteristic value,

and operating in a second mode for receiving a request for modeling a coronary intervention based upon an intervention input received on the touchscreen.

8. The method of any one of claims 1 to 7, further comprising:
receiving, while operating in a treatment modeling mode, an intervention input relating to an intervention location on the touchscreen, the intervention input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the intervention location on the touchscreen.

9. The method of claim 8, wherein the intervention input includes a selection of a stent or a bypass, and a change in a location or a size of the selected stent or bypass.

10. The method of claim 9, wherein the display of the coronary intervention indicates at least one selected stent characteristic chosen from stent length, proximal diameter, and distal diameter.

11. The method of any one of claims 8 to 10, further comprising:
providing a split screen including a first portion and a second portion, the two portions being configured to receive different intervention inputs indicating different modifications of the respective displayed three-dimensional models.

12. The method of any one of claims 1 to 11, further comprising receiving the first input and at least one subsequent input from at least one pointing object controlled by the user, where the at least one pointing object includes at least one digit of the user or a stylus.

13. The method of any one of claims 1 to 12, wherein the at least one blood flow characteristic value is chosen from at least one of a pressure gradient value, a fractional flow reserve value, a pressure value, a flow rate value, and a velocity value.

14. The method of any one of claims 1 to 13, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

15. The method of claim 14, wherein the at least one blood flow characteristic value includes a fractional flow reserve value indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

16. The method of any one of claims 1 to 15, wherein the display of the at least one blood flow characteristic value further comprises at least one of a computed fractional flow reserve model and a computed pressure gradient model.

17. The method of any one of claims 1 to 16, wherein the display of the at least one blood flow characteristic value further comprises geometry information chosen from at least one of vessel inner diameter and thickness.

18. The method of any one of claims 1 to 17, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

19. A system for providing patient-specific blood flow information for a patient, the system comprising at least:

a display device including a touchscreen and being configured to:

- (i) display a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient; and
- (ii) display at least one blood flow characteristic value at a location in the three-dimensional model indicated by a user input;

a processor configured to:

- (i) receive a user input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; and
- (ii) determine and dynamically update a display, on the touchscreen, of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

20. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, on the touchscreen, a three-dimensional model generated based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying, on the touchscreen, at least one blood flow characteristic value at the first location in the three-dimensional model indicated by the first input; and

determining and dynamically updating a display of the at least one blood flow characteristic value as a user drags a finger or a pointing object across the touchscreen.

21. A system for providing patient-specific blood flow information for a patient, the system comprising:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and

a processor configured to:

operate in a first mode to receive a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first

location on the displayed three-dimensional model, and generate a display of first information on the touchscreen, the first information indicating a blood flow characteristic at the first location; and

operate in a second mode to (i) receive a second input relating to a second location on the touchscreen, the second input causing a modification of the three-dimensional model, (ii) generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen, (iii) determine and display second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

22. The system of claim 21, wherein the processor is further configured to update the displayed first information as the user modifies the first location on the touchscreen and on the displayed three-dimensional model.

23. The system of claim 21, wherein the processor is further configured to: form a pin at the first location, the pin being movable by the user within the three-dimensional model; and

update, on the touchscreen, the first information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

24. The system of claim 21, wherein the processor is further configured to determine the first information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicate the first information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

25. The system of claim 21, wherein the processor is further configured to rotate the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

26. The system of claim 21, wherein the processor is further configured to adjust a zoom on the displayed three-dimensional model in response to the user pinching two of the at least one pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

27. The system of claim 21, wherein the processor is configured to switch between operating in the first mode and operating in the second mode based upon a third input received on the touchscreen.

28. The system of claim 21, wherein the second location on the touchscreen indicates a second location in the three-dimensional model for the modification.

29. The system of claim 21, wherein the modification corresponds to placement of a stent, and the processor is further configured to display the stent as the coronary intervention.

30. The system of claim 29, wherein the processor is further configured to receive a third input indicating a size of the stent.

31. The system of claim 21, wherein the processor is further configured to receive a third input indicating a change in location or change in size of the coronary intervention.

32. The system of claim 29, wherein, in the second mode, the processor is further configured to provide a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

33. The system of claim 21, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the coronary intervention.

34. The system of claim 33, wherein the processor is further configured to receive at least one third input indicating at least one location for connecting the bypass to the displayed three-dimensional model.

35. The system of claim 33, wherein the processor is further configured to receive a third input indicating a change in location or a change in size of the bypass.

36. The system of claim 21, wherein the processor is further configured to provide a split screen including a first portion and a second portion, the two portions being configured to receive different second inputs indicating different modifications of the respective displayed three-dimensional models.

37. The system of claim 21, wherein the processor is configured to receive the first and second inputs from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

38. The system of claim 21, wherein the first information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

39. The system of claim 21, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

40. The system of claim 39, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

41. The system of claim 21, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

42. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving, while operating in an inspection mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input;

receiving, while operating in a treatment modeling mode, a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen;

determining second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

43. The method of claim 42, further including:

receiving a mode selection input corresponding to a selection of the inspection mode or a selection of the treatment modeling mode.

44. The method of claim 42, wherein the second input relates to the second location on the touchscreen indicated by at least one pointing object controlled by the user, the second location on the touchscreen indicating a second location in the three-dimensional model for the modification.

45. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming

instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

- displaying a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data;

- receiving, while operating in a first mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

- displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input;

- receiving, while operating in a second mode, a second input relating to a second location on the touchscreen indicated by the user, the second input indicating a location of a stent for placement in the anatomical structure;

- displaying the stent on the three-dimensional model on the touchscreen;

- determining second information regarding a blood flow characteristic at a plurality of locations in the three-dimensional model based on a modification of the three-dimensional model reflecting the placement of the stent at the location indicated in the second input; and

- enabling the user to interact with the touchscreen to drag the displayed stent along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

46. The non-transitory computer readable medium of claim 45, the method further including:

receiving a third input indicating a size of the stent; and

determining third information regarding the blood flow characteristic at the plurality of locations in the three-dimensional model based on a modification of the three-dimensional model reflecting the indicated size of the stent.

47. The non-transitory computer readable medium of claim 46, wherein receiving the third input includes:

pinching two of the at least one pointing objects located at separate locations with respect to the touchscreen, and

determining a change in the size of the stent based on a characteristic of the pinch.

48. The non-transitory computer readable medium of claim 46, wherein the size of the stent includes a length, a proximal diameter, or a distal diameter.

49. The non-transitory computer readable medium of claim 45, wherein the method further includes:

receiving a third input indicating a change in location of the stent; and
determining third information regarding the blood flow characteristic at the plurality of locations in the three-dimensional model based on a modification of the three-dimensional model reflecting the indicated change in location of the stent.

50. The non-transitory computer readable medium of claim 49, wherein receiving the third input includes:

dragging the at least one pointing object along the displayed three-dimensional model, and

determining the change in the location of the stent based on a characteristic of the drag.

51. The method of claim 42, further comprising:

updating the displayed first information as the user modifies the first location on the touchscreen and on the displayed three-dimensional model.

52. The method of claim 42, further comprising:

forming a pin at the first location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the first information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

53. The method of claim 42, further comprising:

determining the first information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the first information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

54. The method of claim 42, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

55. The method of claim 42, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

56. The method of claim 42, wherein the modification corresponds to placement of a stent, and the processor is configured to display the stent as the coronary intervention.

57. The method of claim 56, further comprising:

receiving a third input indicating a size of the stent.

58. The method of claim 56, further comprising:

receiving a third input indicating a change in location or change in size of the stent.

59. The method of claim 56, further comprising:
in the treatment modeling mode, providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.
60. The method of claim 42, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the coronary intervention.
61. The method of claim 60, further comprising:
receiving at least one third input indicating at least one location for connecting the bypass to the displayed three-dimensional model.
62. The method of claim 60, further comprising:
receiving a third input indicating a change in location or a change in size of the bypass.
63. The method of claim 42, further comprising:
providing a split screen including a first portion and a second portion, the two portions being configured to receive different second inputs indicating different modifications of the respective displayed three-dimensional models.

64. The method of claim 42, wherein receiving the first and second inputs includes receiving the first and second inputs from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

65. The method of claim 42, wherein the first information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

66. The method of claim 42, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

67. The method of claim 66, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

68. The method of claim 42, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

69. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input; and

determining and dynamically updating a display of second and subsequent information regarding the blood flow characteristic as a user drags a pointing object across the touchscreen, where the display of the second and subsequent information is generated based on a location of the pointing object relative to the displayed three-dimensional model of the anatomical structure of the patient.

70. The method of claim 69, further comprising:

forming a pin at the first location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the first information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

71. The method of claim 69, further comprising:
updating the first information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the first information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.
72. The method of claim 69, further comprising:
rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.
73. The method of claim 69, further comprising:
adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.
74. The method of claim 69, further comprising:
switching between operating in a first mode for receiving first, second, and subsequent inputs requesting the first, second, and subsequent information regarding the blood flow characteristic, and operating in a second mode for receiving a request for

modeling a coronary intervention based upon an intervention input received on the touchscreen.

75. The method of claim 69, further comprising:

receiving, while operating in a treatment modeling mode, an intervention input relating to an intervention location on the touchscreen, the intervention input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the intervention location on the touchscreen.

76. The method of claim 75, wherein the intervention input includes a selection of a stent or a bypass, and a change in a location or size of the selected stent or bypass.

77. The method of claim 69, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different intervention inputs indicating different modifications of the respective displayed three-dimensional models.

78. The method of claim 69, further comprising receiving first, second, and subsequent inputs from at least one pointing object controlled by the user, where the at least one pointing object includes at least one digit of the user or a stylus.

79. The method of claim 69, wherein the first information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

80. The method of claim 69, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

81. The method of claim 80, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

82. The method of claim 69, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

83. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on a first portion of the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

displaying, on a second portion of the touchscreen, a modified three-dimensional model based on the patient-specific data and on a received user intervention input of a proposed intervention to the three-dimensional model;

receiving a user's input relating to a first location on the touchscreen indicating either a location in the displayed three-dimensional model or a location in the displayed modified three-dimensional model;

displaying information indicating a blood flow characteristic at the first location in either the three-dimensional model or the modified three-dimensional model; and

displaying information indicating the blood flow characteristic at a location corresponding to the first location in the other of the three-dimensional model or the modified three-dimensional model.

84. The method of claim 83, further including:

receiving a mode selection input corresponding to a selection of an inspection mode or a selection of a treatment modeling mode.

85. The method of claim 83, further comprising:

updating the displayed information indicating the blood flow characteristic at corresponding locations of the three-dimensional model and the modified three-dimensional model as the user drags a pointing device along the touchscreen over the displayed three-dimensional model or the modified three-dimensional model.

86. The method of claim 83, further comprising:

determining the information regarding the blood flow characteristic in the anatomical structure at a plurality of corresponding locations of the three-dimensional model and the modified three-dimensional model using at least one of shading, patterns, or coloring.

87. The method of claim 83, further comprising:

rotating the displayed three-dimensional model and the modified three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

88. The method of claim 83, further comprising:

adjusting a zoom on the displayed three-dimensional model and the modified three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

89. The method of claim 83, further comprising:

receiving, while operating in a treatment modeling mode, the intervention input relating to an intervention location on the touchscreen, the intervention input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the intervention location on the touchscreen;

wherein the intervention input includes a selection of a stent or a bypass, and a change in a location or size of the selected stent or bypass.

90. The method of claim 83, wherein receiving a user's input relating to a first location on the touchscreen includes receiving a user's input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

91. The method of claim 83, wherein the first information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

92. The method of claim 83, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

93. The method of claim 92, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

94. The method of claim 83, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

95. A method for providing patient-specific blood flow information using at least a computer system and a tablet computer including a touchscreen, the method comprising:

generating, at the computer system, based on patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

transmitting the three-dimensional model and the reduced-order model to the tablet computer;

displaying the three-dimensional model on the touchscreen of the tablet computer; and

receiving at the tablet computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model.

96. The method of claim 95, further comprising:

receiving, while operating in an inspection mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; and

displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input.

97. The method of claim 96, further comprising:

updating the displayed first information as the user modifies the first location on the touchscreen and on the displayed three-dimensional model.

98. The method of claim 96, further comprising:

forming a pin at the first location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the first information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

99. The method of claim 95, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

100. The method of claim 95, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

101. The method of claim 95, further comprising:

receiving, while operating in a treatment modeling mode, the user intervention input, causing the tablet computer to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to a location of the user intervention input on the touchscreen;

determining, at the computer system, second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

102. The method of claim 96, further including:

receiving a mode selection input corresponding to a selection of the inspection mode or a selection of the treatment modeling mode.

103. The method of claim 95, wherein the modification corresponds to placement of a stent, and the tablet computer is further configured to display the stent.

104. The method of claim 103, further comprising:

receiving a user input indicating a size of the stent.

105. The method of claim 103, further comprising:

receiving a user input indicating a change in location or change in size of the stent.

106. The method of claim 103, further comprising:

providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

107. The method of claim 95, wherein the modification corresponds to a formation of a bypass, and the tablet computer is further configured to display the bypass.

108. The method of claim 107, further comprising:

receiving a user input indicating at least one location for connecting the bypass to the displayed three-dimensional model.

109. The method of claim 107, further comprising:

receiving a user input indicating a change in location or a change in size of the bypass.

110. The method of claim 95, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different user intervention inputs indicating different modifications of respective displayed three-dimensional models.

111. The method of claim 95, wherein receiving the user intervention input includes receiving an input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

112. The method of claim 96, wherein the first information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

113. The method of claim 95, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

114. The method of claim 113, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

115. The method of claim 95, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

116. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

117. The method of claim 116, wherein the input relates to the location on the touchscreen indicated by at least one pointing object controlled by the user, the location on the touchscreen indicating a location in the three-dimensional model for the modification.

118. The method of claim 116, further comprising:

updating the displayed information as the user modifies the location on the touchscreen and on the displayed three-dimensional model.

119. The method of claim 116, further comprising:

forming a pin at the location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

120. The method of claim 116, further comprising:

determining the information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

121. The method of claim 116, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

122. The method of claim 116, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with

respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

123. The method of claim 116, wherein the modification corresponds to placement of a stent, and the processor is configured to display the stent as the coronary intervention.

124. The method of claim 123, further comprising:
receiving an input indicating a size of the stent or a change in location or change in size of the stent.

125. The method of claim 123, further comprising:
providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

126. The method of claim 116, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the coronary intervention.

127. The method of claim 126, further comprising:

receiving an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, and an input indicating a change in location or a change in size of the bypass.

128. The method of claim 116, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of the respective displayed three-dimensional models.

129. The method of claim 116, wherein receiving the input includes receiving the input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

130. The method of claim 116, wherein the information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

131. The method of claim 116, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

132. The method of claim 131, wherein the information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary

arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

133. The method of claim 116, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

134. A system for providing patient-specific blood flow information for a patient, the system comprising:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and

a processor configured to: (i) receive an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

135. The system of claim 134, wherein the processor is further configured to update the displayed information as the user modifies the location on the touchscreen and on the displayed three-dimensional model.

136. The system of claim 134, wherein the processor is further configured to:
form a pin at the location, the pin being movable by the user within the three-dimensional model; and

update, on the touchscreen, the information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

137. The system of claim 134, wherein the processor is further configured to determine the information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicate the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

138. The system of claim 134, wherein the processor is further configured to rotate the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

139. The system of claim 134 wherein the processor is further configured to adjust a zoom on the displayed three-dimensional model in response to the user

pinching two of the at least one pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

140. The system of claim 134, wherein the modification corresponds to placement of a stent, and the processor is further configured to display the stent as the coronary intervention, and receive an input indicating a size of the stent, or a change in location or change in size of the coronary intervention.

141. The system of claim 134, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the coronary intervention, and to receive an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, or indicating a change in location or a change in size of the bypass.

142. The system of claim 134, wherein the processor is further configured to provide a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of the respective displayed three-dimensional models.

143. The system of claim 116, wherein the information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity; and

wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

144. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

145. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input;

receiving a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen;

displaying second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

146. A method for providing patient-specific blood flow information using at least a computer system, the method comprising:

receiving over an electronic network, at the computer system, patient-specific anatomical data;

generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

transmitting over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen;

receiving over the electronic network, at the computer system, a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of the reduced-order model;

calculating, at the computer system, at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and

transmitting over the electronic network the calculated at least one blood flow characteristic to the portable computer.

147. The method of claim 146, wherein the geometric model is a three-dimensional model.

148. The method of claim 146, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

149. The method of claim 146, wherein the modification of the reduced-order model is initiated on the portable computer.

150. The method of claim 146, wherein the modification of the reduced-order model is initiated on the computer system.

151. The method of claim 146, wherein the modification corresponds to placement of a stent.

152. The method of claim 146, wherein the modification corresponds to a formation of a bypass.

153. The method of claim 146, wherein the electronic network is chosen from a wired and a wireless network.

154. The method of claim 148, wherein the anatomical structure includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

155. The method of claim 148, wherein the anatomical structure includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

156. A system for providing patient-specific blood flow information for a patient, the system comprising at least:

- a computer system including a processor configured to:
 - receive over an electronic network patient-specific data anatomical data;
 - generate, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;
 - transmit over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen;
 - receive over the electronic network a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of the reduced-order model;
 - calculate at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and
 - transmit over the electronic network the calculated at least one blood flow characteristic to the portable computer.

157. The system of claim 156, wherein the geometric model is a three-dimensional model.

158. The system of claim 156, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

159. The system of claim 156, wherein the modification of the reduced-order model is initiated on the portable computer.

160. The system of claim 156, wherein the modification of the reduced-order model is initiated on the computer system.

161. The system of claim 156, wherein the modification corresponds to placement of a stent.

162. The system of claim 156, wherein the modification corresponds to a formation of a bypass.

163. The system of claim 156, wherein the electronic network is chosen from a wired and a wireless network.

164. The system of claim 158, wherein the anatomical structure includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

165. The system of claim 158, wherein the anatomical structure includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

166. A non-transitory computer readable medium for use on at least a computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the computer system for:

receiving over an electronic network, at the computer system, patient-specific anatomical data;

generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

transmitting over the electronic network one or both of the geometric model and the reduced-order model to a portable computer including a touchscreen;

receiving over the electronic network, at the computer system, a user intervention input entered by a user on the touchscreen indicating a potential treatment of the anatomical structure that initiates a modification of the reduced-order model;

calculating at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and

transmitting the calculated at least one blood flow characteristic to the portable computer.

167. The non-transitory computer readable medium of claim 166, wherein the geometric model is a three-dimensional model.

168. The non-transitory computer readable medium of claim 166, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

169. The non-transitory computer readable medium of claim 166, wherein the modification of the reduced-order model is initiated on the portable computer.

170. The non-transitory computer readable medium of claim 166, wherein the modification of the reduced-order model is initiated on the computer system.

171. The non-transitory computer readable medium of claim 166, wherein the modification corresponds to placement of a stent.

172. The non-transitory computer readable medium of claim 166, wherein the modification corresponds to a formation of a bypass.

173. The non-transitory computer readable medium of claim 166, wherein the electronic network is chosen from a wired and a wireless network.

174. The non-transitory computer readable medium of claim 168, wherein the anatomical structure includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

175. The non-transitory computer readable medium of claim 168, wherein the anatomical structure includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

176. A method for displaying patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient;

displaying, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model;

receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation;

displaying a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and

displaying a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

177. The method of claim 176, further including:

receiving a mode selection input corresponding to a selection of an inspection mode or a selection of a treatment modeling mode.

178. The method of claim 176, further comprising:

displaying an updated first or second value of the at least one blood flow characteristic at corresponding locations of the three-dimensional model and the intervention simulation as the user drags a pointing device along the touchscreen over the displayed three-dimensional model or the intervention simulation.

179. The method of claim 176, further comprising:

determining the first and second value of the at least one blood flow characteristic in the anatomical structure at a plurality of corresponding locations of the three-dimensional model and the intervention simulation using at least one of shading, patterns, or coloring.

180. The method of claim 176, further comprising:

rotating the displayed three-dimensional model and the intervention simulation in response to the user swiping a surface of the touchscreen, an amount and a direction of rotation depending on a characteristic of the swipe.

181. The method of claim 176, further comprising:

adjusting a zoom on the displayed three-dimensional model and the intervention simulation in response to the user pinching two of a plurality of pointing objects located

at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

182. The method of claim 176, further comprising:

receiving, while operating in a treatment modeling mode, an intervention input relating to an intervention location on the touchscreen, the intervention input indicating a modification of the three-dimensional model and causing the computer system to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to the intervention location on the touchscreen.

183. The method of claim 182, wherein:

the intervention input includes a selection of a stent or a bypass, and a change in a location or a size of the selected stent or bypass.

184. The method of claim 183, wherein the display of the coronary intervention indicates at least one selected stent characteristic chosen from stent length, proximal diameter, and distal diameter.

185. The method of claim 176, wherein receiving a user's input relating to a first location on the touchscreen includes receiving a user's input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

186. The method of claim 176, wherein the at least one blood flow characteristic is chosen from at least one of a pressure gradient, a fractional flow reserve, a pressure, a flow rate, and a velocity.

187. The method of claim 176, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

188. The method of claim 185, wherein the at least one blood flow characteristic includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

189. The method of claim 176, wherein the display of the at least one blood flow characteristic value further comprises at least one of a computed fractional flow reserve model and a computed pressure gradient model.

190. The method of claim 176, wherein the display of the at least one blood flow characteristic value further comprises geometry information chosen from at least one of vessel inner diameter and thickness.

191. The method of claim 176, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

192. The method of claim 176, wherein the at least one blood flow characteristic value is displayed in the three-dimensional model using at least one of color, shading, and pattern.

193. A method for displaying patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

generating a three-dimensional model based on patient-specific data representing at least a portion of an anatomical structure of the patient;

displaying, in a first portion of the touchscreen, a first intervention simulation of the three-dimensional model that is modified based on an intervention input of a first proposed intervention to the three-dimensional model;

displaying, in a second portion of the touchscreen, a second intervention simulation of the three-dimensional model that is modified based on an intervention input of a second proposed intervention to the three-dimensional model;

receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed first intervention simulation or in the displayed second intervention simulation;

displaying a first value of at least one blood flow characteristic at the first location in either the first intervention simulation or the second intervention simulation; and

displaying a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the first intervention simulation or the second intervention simulation.

194. A system for providing patient-specific blood flow information for a patient, the system comprising at least:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and

a processor configured to cause the display device to:

- (i) display, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient;
- (ii) display, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model;
- (iii) receive a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation;
- (iv) display a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and

(v) display a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

195. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, in a first portion of the touchscreen, a three-dimensional model generated based on patient-specific data representing at least a portion of an anatomical structure of the patient;

displaying, in a second portion of the touchscreen, an intervention simulation of the three-dimensional model that is modified based on an input of a proposed intervention to the three-dimensional model;

receiving a user's input relating to a first location on the touchscreen indicating a first location in either the displayed three-dimensional model or in the displayed intervention simulation;

displaying a first value of at least one blood flow characteristic at the first location in either the three-dimensional model or the intervention simulation; and

displaying a second value of the at least one blood flow characteristic at a location that mirrors the first location in the other of the three-dimensional model or the intervention simulation.

196. A method for providing patient-specific blood flow information using at least one computer system with at least one processor, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving, from a user, an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

197. The method of claim 196, wherein the input relates to the location on the touchscreen indicated by at least one pointing object controlled by the user, the location on the touchscreen indicating a location in the three-dimensional model for the modification.

198. The method of claim 196, further comprising:

updating the displayed information as the user modifies the location on the touchscreen and on the displayed three-dimensional model.

199. The method of claim 196, further comprising:

forming a pin at the location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

200. The method of claim 196, further comprising:

determining the information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

201. The method of claim 196, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

202. The method of claim 196, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with

respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

203. The method of claim 196, wherein the modification corresponds to placement of a stent, and the processor is configured to display the stent as the intervention.

204. The method of claim 203, further comprising:
receiving an input indicating a size of the stent or a change in location or change in size of the stent.

205. The method of claim 203, further comprising:
providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

206. The method of claim 196, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the intervention.

207. The method of claim 206, further comprising:

receiving an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, and an input indicating a change in location or a change in size of the bypass.

208. The method of claim 196, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of the respective displayed three-dimensional models.

209. The method of claim 196, wherein receiving the input includes receiving the input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

210. The method of claim 196, wherein the information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

211. The method of claim 196, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

212. The method of claim 211, wherein the information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary

arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

213. The method of claim 196, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

214. A system for providing patient-specific blood flow information for a patient, the system comprising:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and

a processor configured to: (i) receive, from a user, an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) enable the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

215. The system of claim 214, wherein the processor is further configured to update the displayed information as the user modifies the location on the touchscreen and on the displayed three-dimensional model.

216. The system of claim 214, wherein the processor is further configured to:
form a pin at the location, the pin being movable by the user within the three-dimensional model; and
update, on the touchscreen, the information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

217. The system of claim 214, wherein the processor is further configured to determine the information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicate the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

218. The system of claim 214, wherein the processor is further configured to rotate the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

219. The system of claim 214 wherein the processor is further configured to adjust a zoom on the displayed three-dimensional model in response to the user

pinching two of the at least one pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

220. The system of claim 214, wherein the modification corresponds to placement of a stent, and the processor is further configured to display the stent as the intervention, and receive an input indicating a size of the stent, or a change in location or change in size of the intervention.

221. The system of claim 214, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the intervention, and to receive an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, or indicating a change in location or a change in size of the bypass.

222. The system of claim 214, wherein the processor is further configured to provide a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of the respective displayed three-dimensional models.

223. The system of claim 214, wherein the information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity; and

wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

224. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving, from a user, an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

225. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving, from a user, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model;

displaying first information on the touchscreen, the first information indicating a blood flow characteristic at the first location in the three-dimensional model indicated by the first input;

receiving, from the user, a second input relating to a second location on the touchscreen, the second input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the second location on the touchscreen;

displaying second information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to move the displayed intervention along a vessel to update the displayed second information regarding the blood flow characteristic based on further modification of the three-dimensional model.

226. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of the patient's vasculature beyond the patient's coronary arteries;

receiving an input relating to a location on the touchscreen, the input causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding a blood flow characteristic in the patient's vasculature based on the input; and

enabling a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

227. The method of claim 226, wherein the portion of the patient's vasculature beyond the patient's coronary arteries includes the patient's peripheral vasculature.

228. The method of claim 226, wherein the portion of the patient's vasculature includes at least one of a portion of a plurality of arteries in the patient's neck, head, thorax, abdomen, arms, or legs.

229. The method of claim 226, further comprising:
updating the displayed information as the location on the touchscreen is modified.

230. The method of claim 226, further comprising:
forming a pin at the location, the pin being movable within the model by a user;
and

updating, on the touchscreen, the information regarding the blood flow characteristic in the patient's vasculature as the pin is moved by the user.

231. The method of claim 226, further comprising:
determining the information regarding the blood flow characteristic in the patient's vasculature at a plurality of locations in the three-dimensional model and indicating the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

232. The method of claim 226, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

233. The method of claim 226, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

234. The method of claim 226, wherein the processor is configured to display a stent as the intervention.

235. The method of claim 234, further comprising:

receiving an input indicating a size of the stent or a change in location or change in size of the stent.

236. The method of claim 234, further comprising:

providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the patient's vasculature and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

237. The method of claim 226, wherein the processor is further configured to display a bypass as the intervention.

238. The method of claim 237, further comprising:

receiving an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, and an input indicating a change in location or a change in size of the bypass.

239. The method of claim 226, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of respective displayed three-dimensional models.

240. The method of claim 226, wherein receiving the input includes receiving the input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

241. The method of claim 226, wherein the information includes at least one of pressure gradient, pressure, flow rate, and velocity.

242. The method of claim 226, wherein the input relates to the location on the touchscreen indicated by at least one pointing object controlled by a user, the location

on the touchscreen indicating a location in the three-dimensional model for the intervention.

243. The method of claim 226, wherein the information includes a ratio between a pressure at a first location in the patient's vasculature of the patient and a pressure at a second location in the patient's vasculature of the patient upstream of the first location.

244. A system for providing patient-specific blood flow information for a patient, the system comprising:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of the patient's vasculature beyond the patient's coronary arteries; and

a processor configured to: (i) receive an input relating to a location on the touchscreen, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) determine and display information regarding a blood flow characteristic in the patient's vasculature based on the input, and (iv) enable a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

245. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of the patient's peripheral vasculature;

receiving an input relating to a location on the touchscreen, the input causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

determining and displaying information regarding the blood flow characteristic in the patient's vasculature based on the input; and

enabling a user interaction with the touchscreen to change the position of the displayed intervention along a vessel to update the determined and displayed information regarding the blood flow characteristic based on the intervention at the location of the three-dimensional model corresponding to the location on the touchscreen.

246. A method for providing patient-specific blood flow information using at least a computer system and a portable computer including a touchscreen, the method comprising:

receiving over an electronic network, at the computer system, patient-specific data including images of at least a portion of a patient's anatomy;

generating, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

displaying the three-dimensional model on the touchscreen of the portable computer;

receiving at the portable computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model;

calculating at least one blood flow characteristic based on the received user intervention input and the modification of the reduced-order model; and

displaying the calculated at least one blood flow characteristic on the touchscreen of the portable computer.

247. The method of claim 246, wherein the at least one blood flow characteristic is calculated on the portable computer.

248. The method of claim 246, wherein the at least one blood flow characteristic is calculated on the computer system.

249. The method of claim 246, wherein the reduced-order model is modified on the portable computer.

250. The method of claim 246, wherein the reduced-order model is modified on the computer system.

251. The method of claim 246, further comprising:

receiving, while operating in an inspection mode, a first input relating to a first location on the touchscreen indicated by a user, the first location on the touchscreen indicating a first location in the displayed three-dimensional model; and

displaying first information on the touchscreen, the first information indicating the at least one blood flow characteristic at the first location in the three-dimensional model indicated by the first input.

252. The method of claim 251, further comprising:

updating the displayed first information as the user modifies the first location on the touchscreen and on the displayed three-dimensional model.

253. The method of claim 251, further comprising:

forming a pin at the first location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the first information regarding the at least one blood flow characteristic in the anatomical structure as the pin is moved by the user.

254. The method of claim 251, further including:

receiving a mode selection input corresponding to a selection of the inspection mode or a selection of a treatment modeling mode.

255. The method of claim 251, wherein the first information includes at least one of a pressure gradient, a fractional flow reserve, a pressure, a flow rate, a velocity, a computed fractional flow reserve model, and a computed pressure gradient model.

256. The method of claim 246, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and a direction of rotation depending on a characteristic of the swipe.

257. The method of claim 246, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

258. The method of claim 246, further comprising:

receiving, while operating in a treatment modeling mode, the user intervention input, causing the portable computer to generate a display of a coronary intervention at a location of the three-dimensional model corresponding to a location of the user intervention input on the touchscreen;

determining, at the computer system, second information regarding the at least one blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

enabling the user to interact with the touchscreen to drag the displayed coronary intervention along a vessel to update the determined and displayed second information regarding the at least one blood flow characteristic based on further modification of the three-dimensional model.

259. The method of claim 246, wherein the modification corresponds to placement of a stent, and the portable computer is further configured to display the stent.

260. The method of claim 258, further comprising:

providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

261. The method of claim 246, wherein the modification corresponds to a formation of a bypass, and the portable computer is further configured to display the bypass.

262. The method of claim 261, further comprising:

receiving a user input indicating at least one location for connecting the bypass to the displayed three-dimensional model; and

receiving a user input indicating a change in location or a change in size of the bypass.

263. The method of claim 246, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different user intervention inputs indicating different modifications of respective displayed three-dimensional models.

264. The method of claim 246, wherein receiving the user intervention input includes receiving an input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

265. The method of claim 246, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

266. The method of claim 265, wherein the first information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

267. The method of claim 246, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

268. A system for providing patient-specific blood flow information for a patient, the system comprising at least:

a computer system including a processor configured to:

(i) receive over an electronic network patient-specific data including images of at least a portion of a patient's anatomy;

(ii) generate, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

(iii) receive at the portable computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model; and

(iv) calculate at least one blood flow characteristic based on the received user intervention input and modification of the reduced-order model; and

a portable computer including a touchscreen and being configured to: and

(i) display a three-dimensional model on the touchscreen of the portable computer; and

(ii) display a calculated blood flow characteristic on the touchscreen of the portable computer.

269. A non-transitory computer readable medium for use on at least a computer system containing computer-executable programming instructions for providing patient-specific blood flow information and a portable computer including a touchscreen, the instructions being executable by the computer system for:

receiving over an electronic network, at the computer system, patient-specific data including images of at least a portion of a patient's anatomy;

generating, based on the received patient-specific data, a three-dimensional model representing at least a portion of an anatomical structure of a patient, and a reduced-order model of the portion of the anatomical structure;

displaying the three-dimensional model on the touchscreen of the portable computer;

receiving at the portable computer a user intervention input indicating a potential treatment of the anatomical structure and initiating a modification of the reduced-order model;

calculating at least one blood flow characteristic based on the received user intervention input and modification of the reduced-order model; and

displaying the calculated at least one blood flow characteristic on the touchscreen of the portable computer.

270. A computer-implemented method for providing patient-specific blood flow information using at least one computer system, the method comprising:

receiving over an electronic network, at the at least one computer system, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data;

generating a display of the geometric model on the at least one computer system;

receiving a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of the portion of the anatomical structure;

calculating, by the at least one computer system, at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and

generating a display of the calculated at least one blood flow characteristic on the at least one computer system.

271. The computer-implemented method of claim 270, wherein the geometric model is a three-dimensional model.

272. The computer-implemented method of claim 270, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

273. The computer-implemented method of claim 270, wherein the at least one blood flow characteristic is chosen from fractional flow reserve, blood pressure, blood pressure gradient, blood flow, and blood velocity.

274. The computer-implemented method of claim 270, wherein the modification is initiated on the at least one computer system.

275. The computer-implemented method of claim 270, wherein the modification corresponds to placement of a stent.

276. (New) The computer-implemented method of claim 270, wherein the modification corresponds to a formation of a bypass.

277. The computer-implemented method of claim 270, wherein the electronic network is chosen from a wired and a wireless network.

278. The computer-implemented method of claim 272, wherein the anatomical structure includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

279. The computer-implemented method of claim 272, wherein the anatomical structure includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

280. A computer system for providing patient-specific blood flow information for a patient, the computer system configured to:

receive, over an electronic network, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data;

generate a display of the geometric model;

receive a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of a portion of the anatomical structure;

calculate at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and

generate a display of the calculated at least one blood flow characteristic.

281. The computer system of claim 280, wherein the geometric model is a three-dimensional model.

282. The computer system of claim 280, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

283. The computer system of claim 280, wherein the at least one blood flow characteristic is chosen from fractional flow reserve, blood pressure, blood pressure gradient, blood flow, and blood velocity.

284. The computer system of claim 280, wherein the modification is initiated on at least one computer.

285. The computer system of claim 280, wherein the modification corresponds to placement of a stent.

286. The computer system of claim 280, wherein the modification corresponds to a formation of a bypass.

287. The computer system of claim 282, wherein the anatomical structure includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

288. The computer system of claim 282, wherein the anatomical structure includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

289. A non-transitory computer readable medium for use on at least a computer containing computer-executable programming instructions for providing

patient-specific blood flow information, the instructions being executable by the computer for:

receiving, over an electronic network, a geometric model representing at least a portion of an anatomical structure of a patient based on patient-specific anatomical data;

generating a display of the geometric model;

receiving a user intervention input entered by a user, the input indicating a potential treatment of the anatomical structure that initiates a modification of the geometric model or a reduced-order model of a portion of the anatomical structure;

calculating at least one blood flow characteristic based on the received user intervention input and the modification of one or both of the geometric model and the reduced-order model; and

generating a display of the calculated at least one blood flow characteristic.

290. A method for providing patient-specific blood flow information using at least a computer including a screen, the method comprising:

receiving patient-specific anatomical data over an electronic network;

generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient;

displaying the geometric model on the screen of the computer;

receiving a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure;

receiving a second intervention input modifying the first potential location for treatment to a second potential location for treatment;

modifying the geometric model based at least upon the second intervention input and the second potential location for treatment;

calculating a characteristic of blood flow through the portion of the anatomical structure being treated based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and

displaying the calculated characteristic of blood flow on the screen of the computer.

291. The method of claim 290, wherein the geometric model is a three-dimensional model.

292. The method of claim 290, wherein the patient-specific anatomical data includes imaging data of at least a portion of an anatomical structure of a patient.

293. The method of claim 290, wherein the calculated characteristic of blood flow is calculated on the computer.

294. The method of claim 290, wherein receiving the second intervention input indicating the second potential location for treatment of the portion of the anatomical structure initiates the modification of the geometric model.

295. The method of claim 290, further comprising:

receiving, while operating in an inspection mode, the first intervention input relating to the first potential location indicated by a user, the first potential location indicating a first location in the displayed geometric model; and

displaying first information on the screen, the first information indicating the calculated characteristic of blood flow at the first potential location in the geometric model indicated by the first intervention input.

296. The method of claim 295, further comprising:

updating the displayed first intervention information as the user modifies the first potential location and on the displayed geometric model.

297. The method of claim 295, further comprising:

forming a pin at the first potential location, the pin being movable by the user within the geometric model; and

updating, on the screen, the first information regarding the calculated characteristic of blood flow through the anatomical structure as the pin is moved by the user.

298. The method of claim 295, further including:

receiving a mode selection input corresponding to a selection of the inspection mode or a selection of a treatment modeling mode.

299. The method of claim 290, wherein the calculated characteristic of blood flow includes at least one of a pressure gradient, a pressure, a flow rate, a velocity, a computed fractional flow reserve model, and a computed pressure gradient model.

300. The method of claim 290, further comprising:
rotating the displayed geometric model in response to a user rotate input, an amount and a direction of rotation depending on a characteristic of the user input.

301. The method of claim 290, further comprising:
adjusting a zoom on the displayed geometric model in response to a user zoom input, an amount of the zoom depending on a characteristic of the user input.

302. The method of claim 290, further comprising:
receiving, while operating in a treatment modeling mode, the first intervention input, causing the computer to generate a display of an intervention at a location of the geometric model corresponding to a location of the first intervention input on the screen;
determining second information regarding the calculated characteristic of blood flow through the anatomical structure based on modification of the geometric model;
and
enabling a user to interact with the computer to move the displayed intervention along an anatomical structure to update the determined and displayed second information regarding the calculated characteristic of blood flow based on further modification of the geometric model.

303. The method of claim 294, wherein the modification of the geometric model corresponds to placement of a stent, and the computer is further configured to display the stent.

304. The method of claim 294, wherein the modification of the geometric model corresponds to a formation of a bypass, and the computer is further configured to display the bypass.

305. The method of claim 304, further comprising:
receiving a user input indicating at least one location for connecting the bypass to the displayed geometric model; and
receiving a user input indicating a change in location or a change in size of the bypass.

306. The method of claim 290, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

307. The method of claim 306, wherein the calculated characteristic of blood flow includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

308. A computer system including a screen for providing patient-specific blood flow information for a patient, the computer system configured to:

- receive patient-specific anatomical data over an electronic network;
- generate, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient;
- display the geometric model on the screen;
- receive a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure;
- receive a second intervention input modifying the first potential location for treatment to a second potential location for treatment;
- modify the geometric model based at least upon the second intervention input and the second potential location for treatment;
- calculate a characteristic of blood flow through the portion of the anatomical structure being treated based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and
- display the calculated characteristic of blood flow on the screen.

309. A non-transitory computer readable medium for use on at least a computer including a screen containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the computer for:

- receiving patient-specific anatomical data over an electronic network;

generating, based on the received patient-specific anatomical data, a geometric model representing at least a portion of an anatomical structure of a patient;

displaying the geometric model on the screen of the computer;

receiving a first intervention input indicating a first potential location for treatment of the portion of the anatomical structure;

receiving a second intervention input modifying the first potential location for treatment to a second potential location for treatment;

modifying the geometric model based at least upon the second intervention input and the second potential location for treatment;

calculating a characteristic of blood flow through the portion of the anatomical structure being treated by based on the received second intervention input at the second potential location for treatment, using the modified geometric model; and

displaying the calculated characteristic of blood flow on the screen.

310. A method for providing patient-specific blood flow information using at least one computer system having a touchscreen, the method comprising:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

displaying, on the touchscreen, information regarding a blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

receiving an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

311. The method of claim 310, wherein the input relates to the location on the touchscreen indicated by at least one pointing object controlled by the user, the location on the touchscreen indicating a location in the three-dimensional model for the modification.

312. The method of claim 310, further comprising:

updating the displayed information as the user modifies the location on the touchscreen and on the displayed three-dimensional model.

313. The method of claim 310, further comprising:

forming a pin at the location, the pin being movable by the user within the three-dimensional model; and

updating, on the touchscreen, the information regarding the blood flow characteristic in the anatomical structure as the pin is moved by the user.

314. The method of claim 310, further comprising:

displaying the information regarding the blood flow characteristic in the anatomical structure at a plurality of locations in the three-dimensional model and indicating the information on the displayed three-dimensional model using at least one of shading, patterns, or coloring.

315. The method of claim 310, further comprising:

rotating the displayed three-dimensional model in response to the user swiping a surface of the touchscreen, an amount and direction of rotation depending on a characteristic of the swipe.

316. The method of claim 310, further comprising:

adjusting a zoom on the displayed three-dimensional model in response to the user pinching two of a plurality of pointing objects located at separate locations with respect to the touchscreen, an amount of the zoom depending on a characteristic of the pinch.

317. The method of claim 310, wherein the modification corresponds to placement of a stent, and the processor is configured to display the stent as the intervention.

318. The method of claim 317, further comprising:

receiving an input indicating a size of the stent or a change in location or change in size of the stent.

319. The method of claim 317, further comprising:

providing a split screen including a first portion and a second portion, the first portion displaying the three-dimensional model representing at least the portion of the anatomical structure and the stent, and the second portion displaying the three-dimensional model after placement of the stent.

320. The method of claim 310, wherein the modification corresponds to a formation of a bypass, and the processor is further configured to display the bypass as the intervention.

321. The method of claim 320, further comprising:

receiving an input indicating at least one location for connecting the bypass to the displayed three-dimensional model, and an input indicating a change in location or a change in size of the bypass.

322. The method of claim 310, further comprising:

providing a split screen including a first portion and a second portion, the two portions being configured to receive different inputs indicating different modifications of the respective displayed three-dimensional models.

323. The method of claim 310, wherein receiving the input includes receiving the input from at least one pointing object controlled by the user, and the at least one pointing object includes at least one digit of the user or a stylus.

324. The method of claim 310, wherein the information includes at least one of pressure gradient, fractional flow reserve, pressure, flow rate, and velocity.

325. The method of claim 310, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

326. The method of claim 325, wherein the information includes a fractional flow reserve indicating a ratio between a pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

327. The method of claim 310, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

328. A system for providing patient-specific blood flow information for a patient, the system comprising:

a display device including a touchscreen and being configured to display a three-dimensional model representing at least a portion of an anatomical structure of the patient based on patient-specific data; and

a processor configured to: (i) receive an input relating to a location on the touchscreen, the input causing a modification of the three-dimensional model, (ii) generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen, (iii) display information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model, and (iv) receive an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

329. A non-transitory computer readable medium for use on at least one touchscreen computer system containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one touchscreen computer system for:

displaying, on the touchscreen, a three-dimensional model based on patient-specific data, the three-dimensional model representing at least a portion of an anatomical structure of the patient;

receiving an input relating to a location on the touchscreen, the input indicating a modification of the three-dimensional model and causing the computer system to

generate a display of an intervention at a location of the three-dimensional model corresponding to the location on the touchscreen;

displaying information regarding the blood flow characteristic in the anatomical structure based on the modification of the three-dimensional model; and

receiving an interaction from the user dragging the displayed intervention along the anatomical structure to update the displayed information regarding the blood flow characteristic based on further modification of the three-dimensional model.

330. A method for providing patient-specific blood flow information using at least one computer system, the at least one computer system including a display, the method comprising:

displaying, on the display, a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient;

receiving a first gesture relating to a first location on the display indicated by a user, the first gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display;

displaying, on the display, at least one blood flow characteristic value at the first location of the geometric model indicated by the first gesture; and

dynamically updating the display of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the updating causing the computer system to update the display of the potential treatment and

update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

331. The method of claim 330, wherein the display of the at least one blood flow characteristic value is generated based on an input object location of a finger or a pointing object of the user relative to the displayed geometric model of the anatomical structure of the patient.

332. The method of claim 330, further comprising:
forming a pin at the first location, the pin being movable by the user; and
updating, on the display, the at least one blood flow characteristic value corresponding to the anatomical structure as the pin is moved by the user.

333. The method of claim 330, further comprising:
updating the at least one blood flow characteristic value in the anatomical structure at a plurality of locations of the geometric model and indicating the at least one blood flow characteristic value on the displayed geometric model using at least one of shading, patterns, or coloring.

334. The method of claim 330, further comprising:
rotating the displayed geometric model in response to a user movement in relation to and in sensed proximity to the display, an amount and a direction of rotation depending on a characteristic of the movement.

335. The method of claim 330, further comprising:

adjusting a zoom on the displayed geometric model in response to the user providing a zoom input, an amount of the zoom depending on a characteristic of the zoom input.

336. The method of claim 330, further comprising:

switching between operating in a first mode for receiving the first gesture and at least one subsequent gesture requesting the at least one blood flow characteristic value, and operating in a second mode for receiving a request for modeling a coronary intervention based upon an intervention gesture received on the display.

337. The method of claim 330, further comprising:

receiving, while operating in a treatment modeling mode, an intervention gesture relating to an intervention location on the display, the intervention gesture indicating a modification of the geometric model and causing the computer system to generate a display of a coronary intervention at a location of the geometric model corresponding to the intervention location on the display.

338. The method of claim 337, wherein the intervention gesture includes a selection of a stent or a bypass, and/or a change in location or size of the selected stent or bypass.

339. The method of claim 338, wherein the display of the coronary intervention indicates at least one selected stent characteristic chosen from stent length, proximal diameter, and distal diameter.

340. The method of claim 330, further comprising:
providing a split screen including a first portion and a second portion, the two portions being configured to receive different intervention gestures indicating different modifications of the respective displayed geometric models.

341. The method of claim 330, further comprising receiving the first gesture and at least one subsequent gesture from at least one movement of the user in relation to and in sensed proximity of the display.

342. The method of claim 330, wherein the at least one blood flow characteristic value is chosen from at least one of a pressure gradient value, a fractional flow reserve value, a pressure value, a flow rate value, and a velocity value.

343. The method of claim 330, wherein the anatomical structure of the patient includes at least a portion of an aorta and at least a portion of a plurality of coronary arteries emanating from the portion of the aorta.

344. The method of claim 343, wherein the at least one blood flow characteristic value includes a fractional flow reserve value indicating a ratio between a

pressure at a location in the plurality of coronary arteries and a pressure at a location upstream from the location in the plurality of coronary arteries.

345. The method of claim 330, wherein the display of the at least one blood flow characteristic value further comprises at least one of a computed fractional flow reserve model and a computed pressure gradient model.

346. The method of claim 330, wherein the display of the at least one blood flow characteristic value further comprises geometry information chosen from at least one of vessel inner diameter and thickness.

347. The method of claim 330, wherein the anatomical structure of the patient includes at least one of a portion of a plurality of arteries in the patient's heart, neck, head, thorax, abdomen, arms, or legs.

348. A system for providing patient-specific blood flow information for a patient, the system comprising at least:

- a device including a display and being configured to:

- display a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient; and

- display at least one blood flow characteristic value at a location of the geometric model indicated by a user gesture;

a processor configured to:

receive the user gesture relating to a first location on the display indicated by a user, the user gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display;

and

dynamically update a display, on the display, of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the update causing the processor to update the display of the potential treatment and update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

349. A non-transitory computer readable medium for use on at least one computer system including a display and containing computer-executable programming instructions for providing patient-specific blood flow information, the instructions being executable by the at least one computer system for:

displaying, on the display, a geometric model generated based on patient-specific data, the geometric model representing at least a portion of an anatomical structure of the patient;

receiving a first gesture relating to a first location on the display indicated by a user, the first gesture indicating a potential treatment of the anatomical structure and initiating a modification of the geometric model at a location of the geometric model corresponding to the first location on the display;

displaying, on the display, at least one blood flow characteristic value at the first location of the geometric model indicated by the first gesture; and

dynamically updating a display of the at least one blood flow characteristic value as a user moves in relation to and in sensed proximity to the display, the updating causing the computer system to update the display of the potential treatment and update the displayed at least one blood flow characteristic value based upon further modification of the geometric model.

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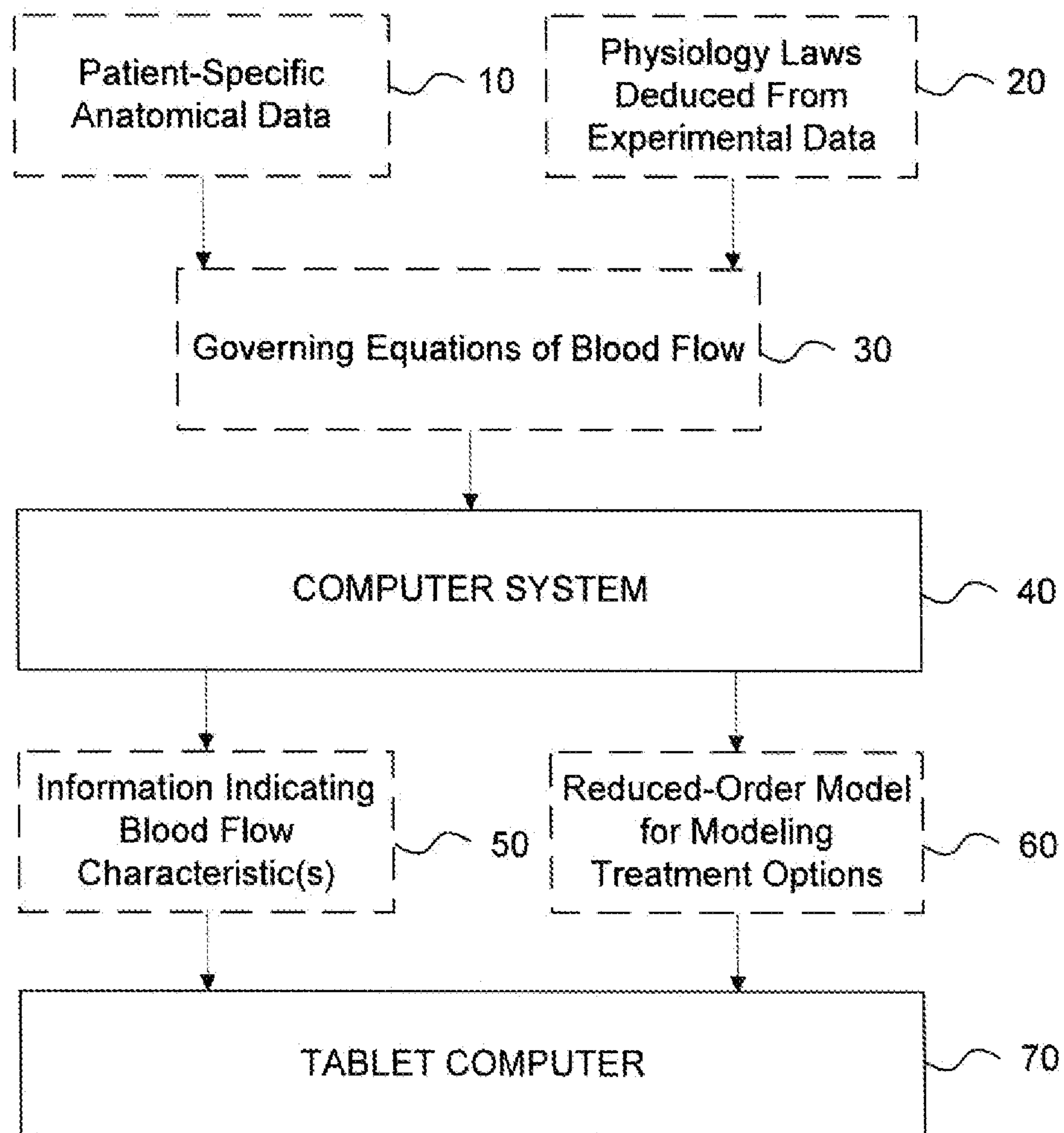


FIG. 1

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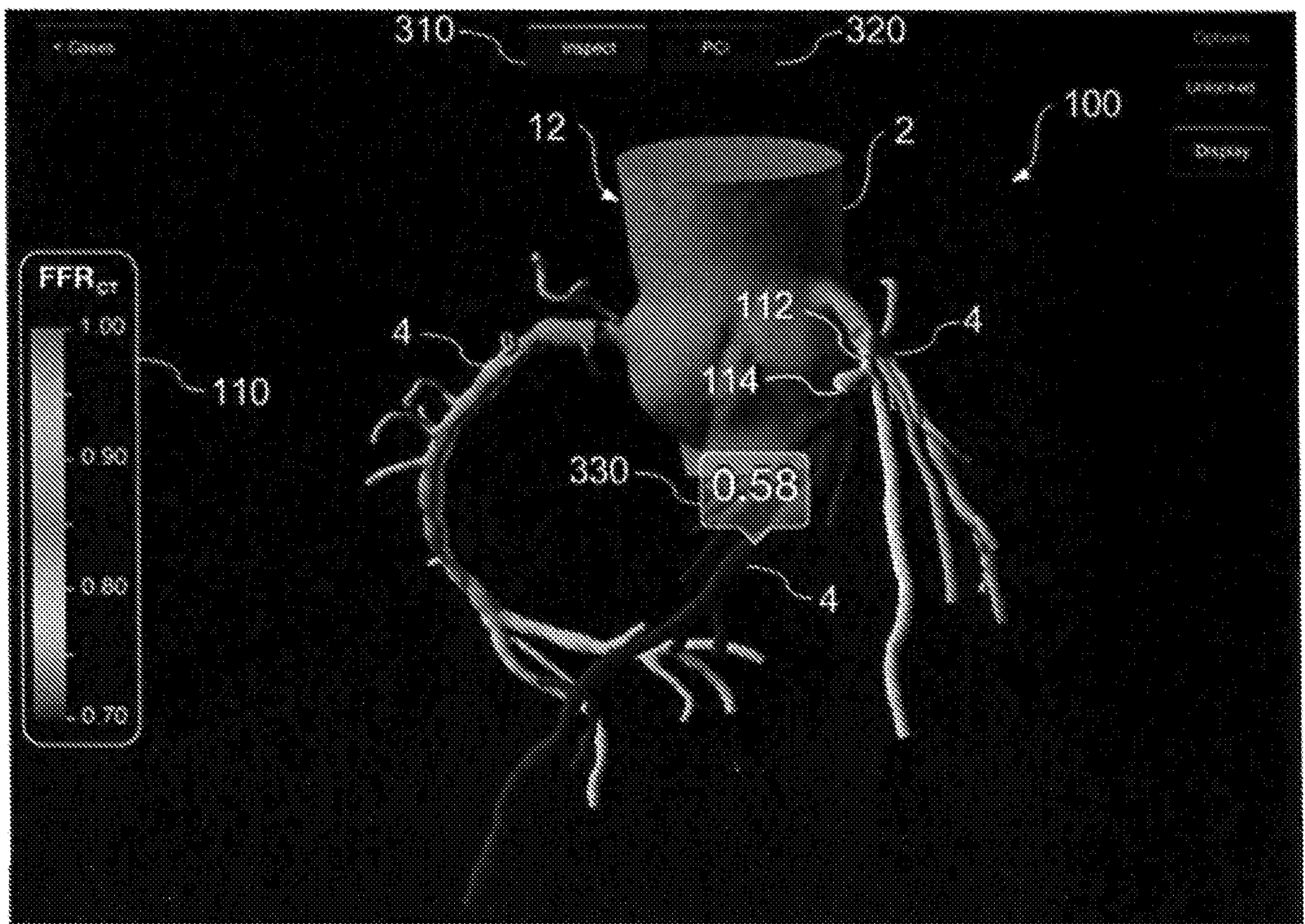


FIG. 2

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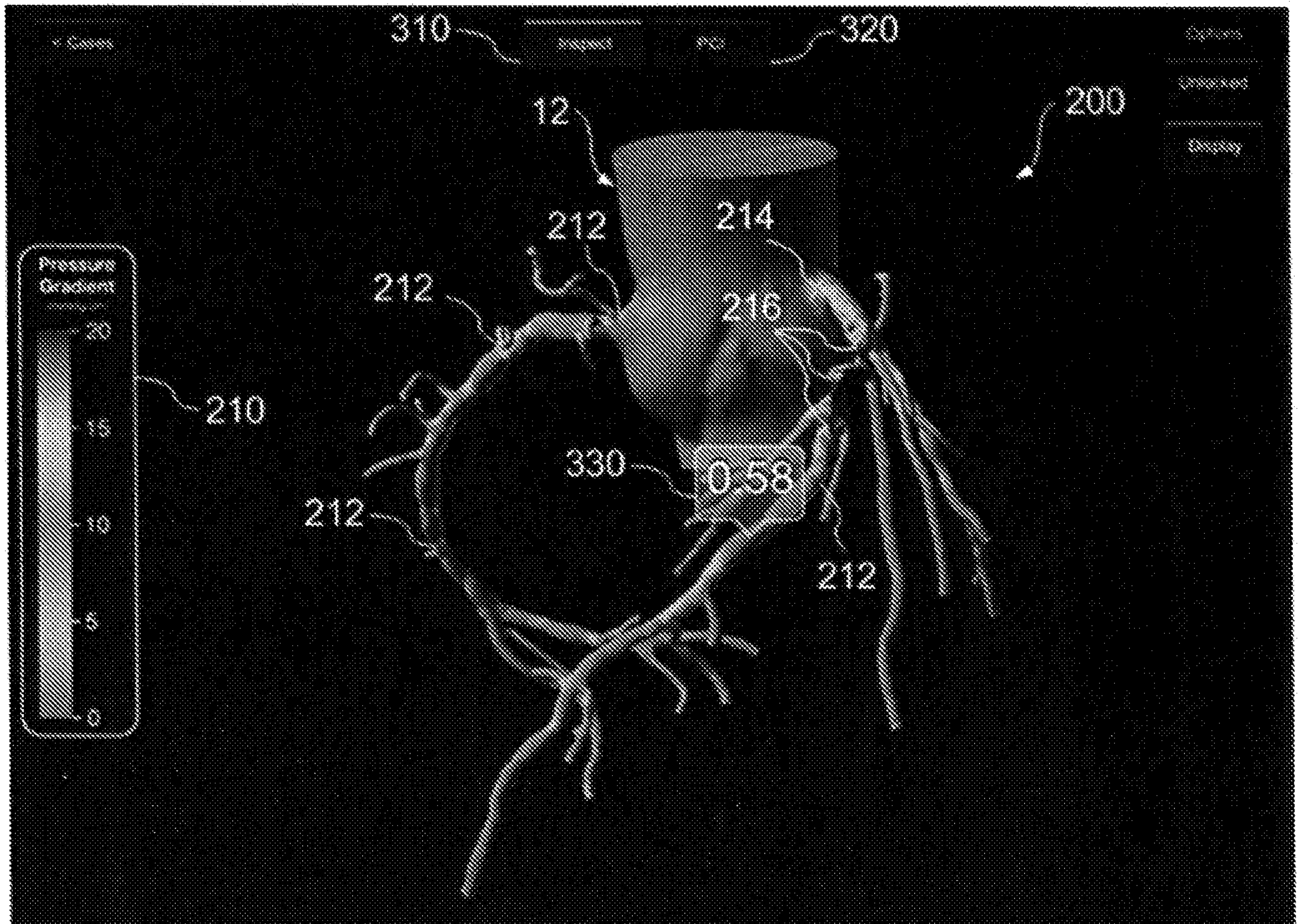


FIG. 3

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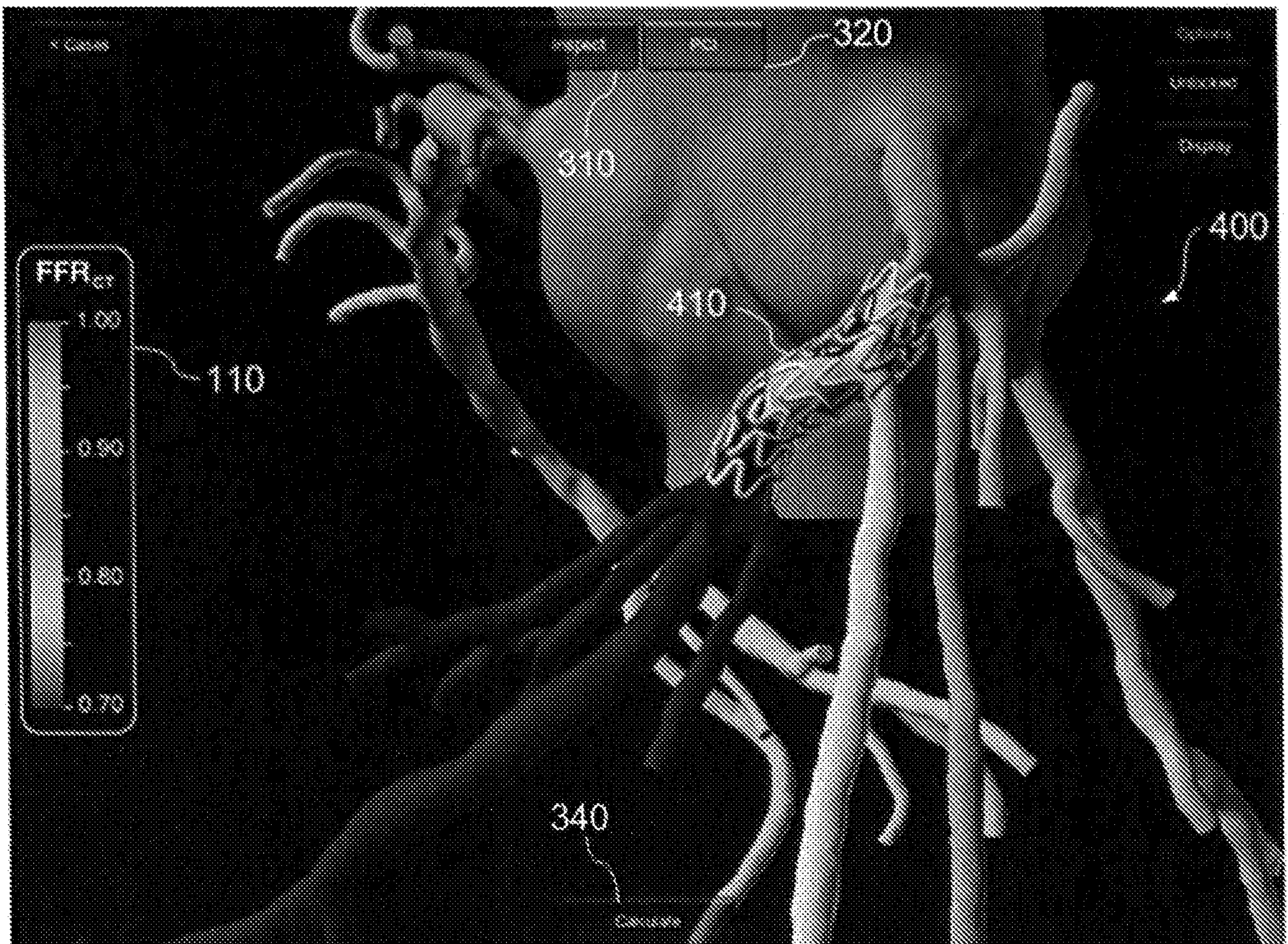


FIG. 4

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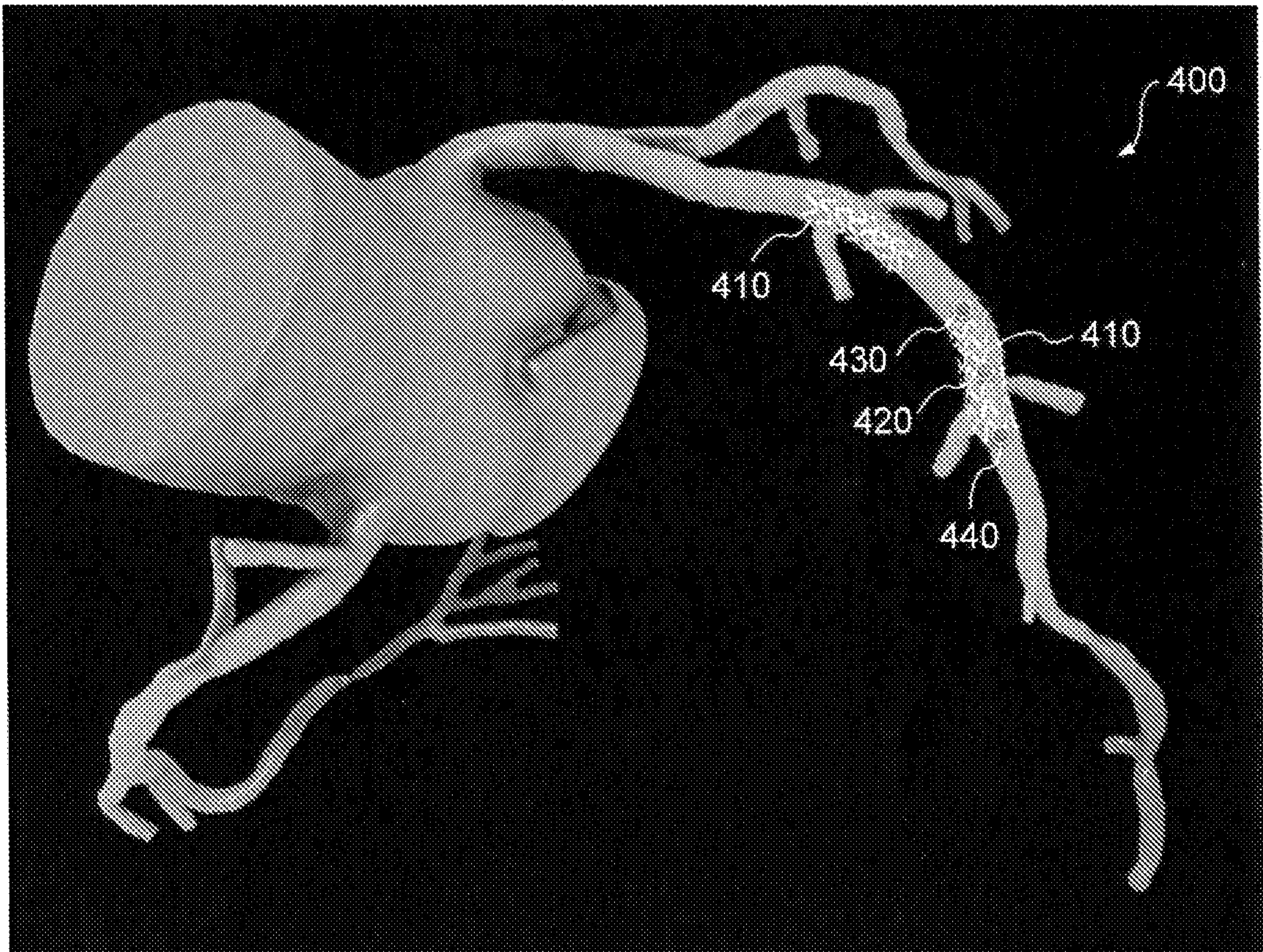


FIG. 5

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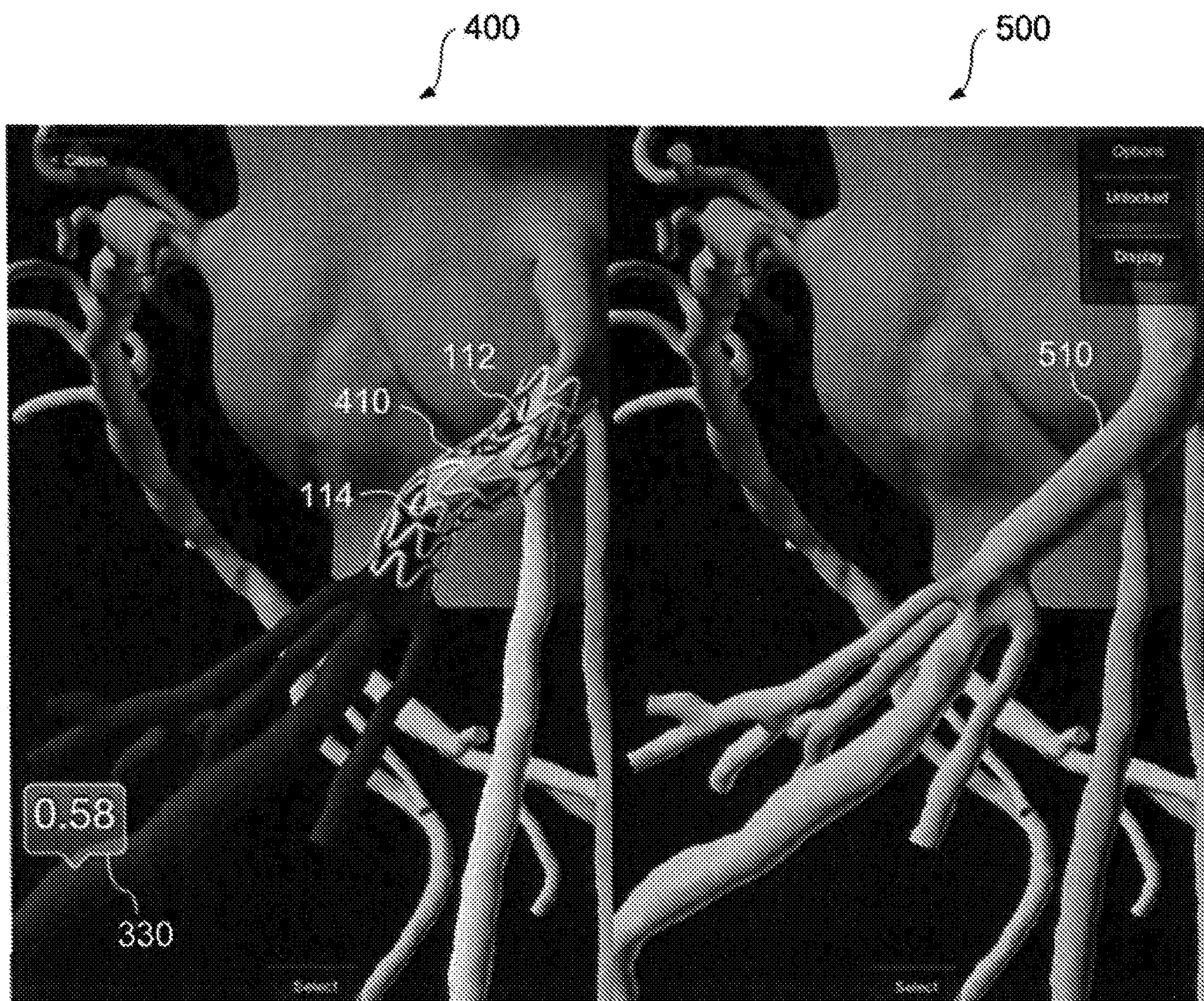


FIG. 6

