CLAIMS

1. An automated heart failure diagnostic device, comprising:

a trace feature detector to identify selected features and at least one of magnitude and timing of the identified features for received periodic vessel area traces representing changes in fluid state of a patient over time, wherein the selected features comprise one or more of interval time per respiration cycle, area magnitude of respiration modulation, interval time per cardiac cycle, area magnitude of cardiac modulation, dominant cardiac peaks, second cardiac peaks, respiration related area reduction, maneuver types and maximum and minimum areas associated with identified maneuvers;

a metrics generator to generate heart function-related parameters for each area trace based on said identified features, magnitudes and timing, said heart function-related parameters comprising one or more of maximum vessel area (A_{max}), minimum vessel area (A_{min}), mean vessel area (A_{mean}), heart rate (HR), respiration rate (RR), collapsibility index (CI), collapse (C) and cardiac output (CO);

a boundary generator to generate at least a vessel lower area boundary (LB) for the patient or a vessel upper area boundary (UB) for the patient using said generated heart function-related parameters; and

an index generator to set a patient congestion index based on one or more of said generated heart-function related parameters and at least one of a vessel lower area boundary (LB) or upper area boundary (UB) for the patient, said congestion index indicating patent fluid state on a normalized scale for each said trace period.

2. The device of claim 1, further comprising a trace generator configured to produce the periodic vessel area traces.

3. The device of claim 1 or claim 2, further comprising a decision logic configured to determine at least one of a diagnostic status and treatment protocol for the patient based at least on the congestion index from the index generator.

4. The device of claim 1, claim 2 or claim 3, wherein the boundary generator sets the lower area boundary (LB) according to one or more of the relationships:

as an average minimum area measured in the IVC using either multiple measurements from the patient or population information from multiple patients;

as equal to $(-1/S) \cdot C + A_{mean}$, wherein (S) is a received reference slope; and

as the minimum vessel area (A_{min}) for an area trace associated with a detected maneuver.

5. The device of any of claims 1-4, wherein the boundary generator sets the upper area boundary (UB) according to one or more of the relationships:

as an average maximum area measured in the IVC using at least one of multiple measurements from the patient or population information from multiple patients;

as equal to $(-1/S) \cdot CI + A_{mean}$, wherein (S) is a received reference slope; and

as the maximum vessel area (A_{max}) for an area trace associated with a detected maneuver.

6. The device of any preceding claim, wherein the index generator sets the congestion index according to one or more of the following relationships:

as equal to $(A_{max}-A_{min})/(A_{max}-LB) *100\%$;

as equal to $100 * (A_{mean} / UB)$;

as equal to $100 *((A_{mean}-LB) / (UB-LB))$; and

as equal to $100-(A_{max}-A_{min})/(A_{max}-LB) *100\%$.

7. The device of any preceding claim, wherein the metrics generator is further configure to generate one or more of right atrial pressure (RAP), IVC Tone, or systemic vascular resistance (SVR), wherein:

RAP is predicted based on correlation between received area traces and measured right atrial pressures;

IVC Tone is correlated to area trace maximum area over time using a training model; and

SVR is set as equal to measured mean atrial pressure less RAP divided by collapse (CO).

8. The device of any preceding claim, further comprising a machine learning based model applying weighting to the congestion index, generated heart function-

related parameters and input patient specific information to return a hospitalization probability score for the patient.

9. A system automatedly determining patient fluid state using periodic vessel area traces, the system comprising:

a trace feature detector to identify selected features of the vessel area traces and at least one of magnitude and timing of the identified features for the vessel area traces;

a metrics generator to generate heart function-related parameters for each area trace based on said identified magnitudes and timing, said heart function-related parameters including at least maximum vessel area (A_{max}) and minimum vessel area (A_{min}); and

an index generator to generate a patient congestion index based on at least said maximum vessel area (A_{max}), said minimum vessel area (A_{min}) and at least one of a vessel lower area boundary (LB) or upper area boundary (UB) for the patient, said congestion index indicating patent fluid state on a normalized scale for each said trace period.

10. The system of claim 9, further comprising a boundary generator to generate at least said lower area boundary (LB) or said upper area boundary (UB) using said generated heart function-related parameters.

11. The system of claim 10, wherein the boundary generator:

receives at least maneuver detection and minimum vessel area (A_{min}); and

sets the lower area boundary (LB) as the minimum vessel area (A_{min}) for an area trace associated with the maneuver detection; or

receives a collapse value (C) and mean area (A_{mean}) for an area trace, and a reference slope (S); and

sets the lower area boundary (LB) as equal to $(-1/S) \cdot C + A_{mean}$; or

receives minimum area (A_{min}) for a selected number of area traces; and

sets the lower area boundary (LB) as an average minimum area measured in the IVC using either multiple measurements from the individual patient or population information from multiple patients.

12. The system of any of claims 10-11, wherein the boundary generator:

receives at least maneuver detection and maximum vessel area; and

sets the upper area boundary (UB) as the maximum vessel area for an area trace associated with the maneuver detection; or

receives a collapsibility index value (CI) and mean area (A_{mean}) for an area trace, and a reference slope (S); and

sets the upper boundary (UB) as equal to $(-1/S) \cdot CI + A_{mean}$; or

receives maximum area (A_{max}) for a selected number of area traces; and

sets the upper area boundary (UB) as an average maximum area measured in the IVC using at least one of multiple measurements from the patient or population information from multiple patients.

13. A computer-based method, comprising:

receiving a quiet respiration vessel area trace for a patient within at least one processing device;

receiving patent specific information comprising at least patient weight and patient age within said processing device;

filtering the quiet respiration vessel area trace at said processing device to identify component signals comprising at least a respiration trace, a cardiac trace, and a mean trace;

extracting magnitude and timing features from said traces at said processing device corresponding to at least one or more of area maximum, area minimum, collapse, respiration collapse, cardiac collapse, heart rate and respiration rate;

generating at said processing device heart function-related parameters using executable program instructions defining said heart function-related parameters based on said extracted magnitude and timing features, the heart function-related parameters comprising one or more of respiration rate, cardiac output, heart rate, collapsibility index, collapse, maximum vessel area, minimum vessel area and mean vessel area;

generating a patient congestion index based on one or more of said magnitude features and heart function-related parameters; and

applying weighting to the congestion index, heart function-related parameters and patient specific information using a machine learning based model to return a hospitalization probability score for the patient.

14. The method of claim 13, further comprising generating a user directed alert with instructions to modify or maintain treatment in response to the returned hospitalization probability.

15. The method of claim 13 or 14, further comprising receiving external sensor inputs comprising at least patient worn accelerometer data indicating patient activity levels, wherein said external sensor inputs are incorporated into the machine learning model weighting.

16. The method of claim 13, 14 or 15, further comprising generating and weighting additional heart-function related parameters including one or more of right atrial pressure (RAP), IVC Tone, or systemic vascular resistance (SVR), wherein:

RAP is predicted based on correlation between received area traces and measured right atrial pressures;

IVC Tone is correlated to area trace maximum area over time using a training model; and

SVR is set as equal to measured mean atrial pressure less RAP divided by collapse (CO).

17. A computer-based system comprising one or more processing and memory devices configured and programed to execute the method of any of claims 13, 14, 15 or 16.

18. A method for automatedly determining patient fluid state using periodic vessel area traces, comprising:

receiving a vessel area trace;

identifying selected features and at least one of magnitude and timing of the identified features for the vessel area traces;

generating heart function-related parameters for each area trace based on said identified magnitudes and timing, said heart function-related parameters including measured vessel areas and a vessel area boundary;

generating a patient congestion index representing a relationship between measured vessel area as determined for an area trace and a vessel area

boundary for the patient, said congestion index indicating patent fluid state on a normalized scale for each said trace period.

19. The method of claim 18, further comprising generating at least one of a lower area boundary (LB) or an upper area boundary (UB) using said generated heart function-related parameters, and wherein said generating the patient congestion index is based on at least one of said lower area boundary or upper area boundary.

20. The method of claim 19, wherein said generating at least one of a lower area boundary (LB) or an upper area boundary (UB) comprises:

detecting a maneuver in the received area trace;

detecting a minimum vessel area corresponding to the detected maneuver; and

setting the lower area boundary (LB) as said detected minimum vessel area; or

receiving a collapse value (C) and mean area (A_{mean}) for an area trace;

receiving a reference slope (S); and

setting the lower area boundary (LB) as equal to $(-1/S) \cdot C + A_{mean}$: or

receiving a minimum area (A_{min}) for a selected number of area traces; and

setting the lower area boundary (LB) as an average minimum sensor size measured in the IVC using either multiple measurements from the individual patient or population information from multiple patients; or .

detecting a maneuver in the received area trace;

detecting a maximum vessel area corresponding to the detected maneuver; and

setting the upper area boundary (UB) as said detected maximum vessel area; or

receiving a collapsibility index value (CI) and mean area (A_{mean}) for an area trace;

receiving a reference slope (S); and

setting the upper boundary (UB) as equal to $(-1/S) \cdot CI + A_{mean}$; or

receiving a maximum area (A_{max}) for a selected number of area traces; and

setting the upper area boundary (UB) as an average maximum sensor size measured in the IVC using at least one of multiple measurements from the patient or population information from multiple patients.