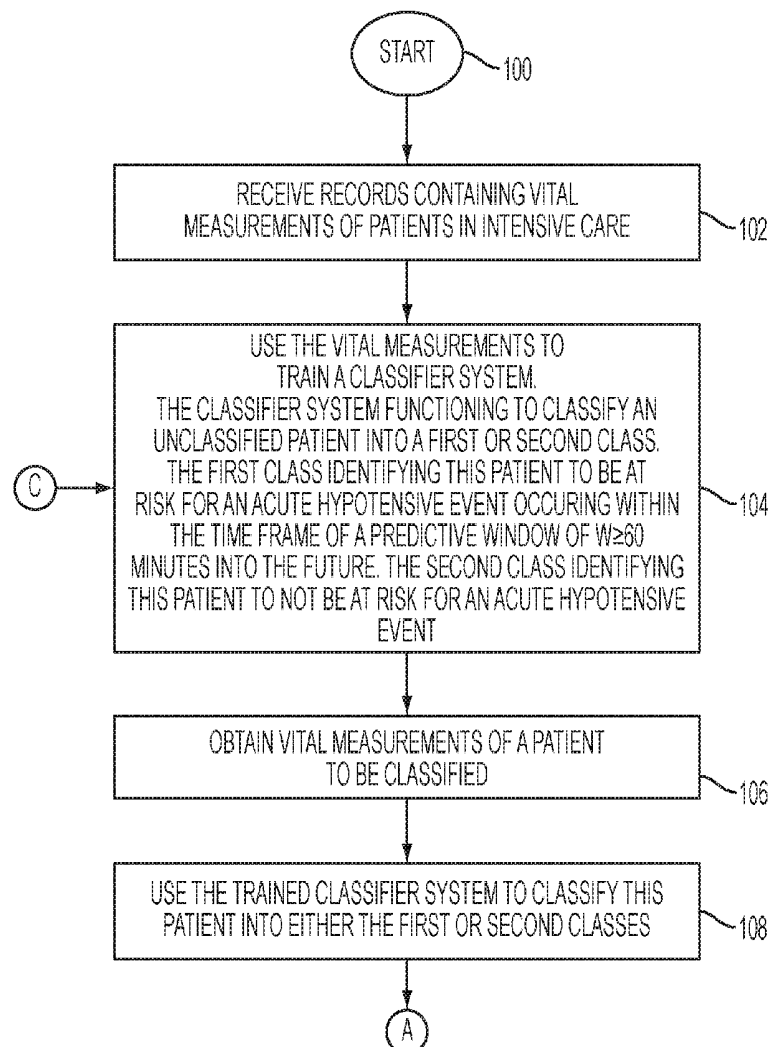




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BHATTACHARYA et al.(10) **Pub. No.: US 2016/0143596 A1**(43) **Pub. Date: May 26, 2016**(54) **ASSESSING PATIENT RISK OF AN ACUTE
HYPOTENSIVE EPISODE WITH VITAL
MEASUREMENTS****G06F 19/00** (2006.01)**A61B 5/0205** (2006.01)(52) **U.S. Cl.**CPC **A61B 5/7275** (2013.01); **A61B 5/7267**
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Vijay HUDDAR, Bijuapur (IN)(21) Appl. No.: **15/013,549**(22) Filed: **Feb. 2, 2016****Related U.S. Application Data**(63) Continuation-in-part of application No. 14/254,232,
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A61B 5/00 (2006.01)
G06N 99/00 (2006.01)**ABSTRACT**

What is disclosed is a system and method for assessing patient risk for an occurrence of an acute hypotensive episode within the timeframe of a prospective prediction window using multiple vitals to improve predictive accuracy. In one embodiment, the present method involves the following. A training set is retrieved from a database. The training set comprises vital measurements for a plurality of intensive care patients. Each vital measurement x_t has been obtained at time t , where $t=1, \dots, N$, and N is the number of measurements obtained for that patient, with t being reckoned from a start of the vital measurement at pre-defined time intervals. The training set is used to train the present classifier system. The classifier classifies a yet unclassified patient into a first at risk for an acute hypotensive episode or into a second class not at risk for the occurrence of an acute hypotensive episode.



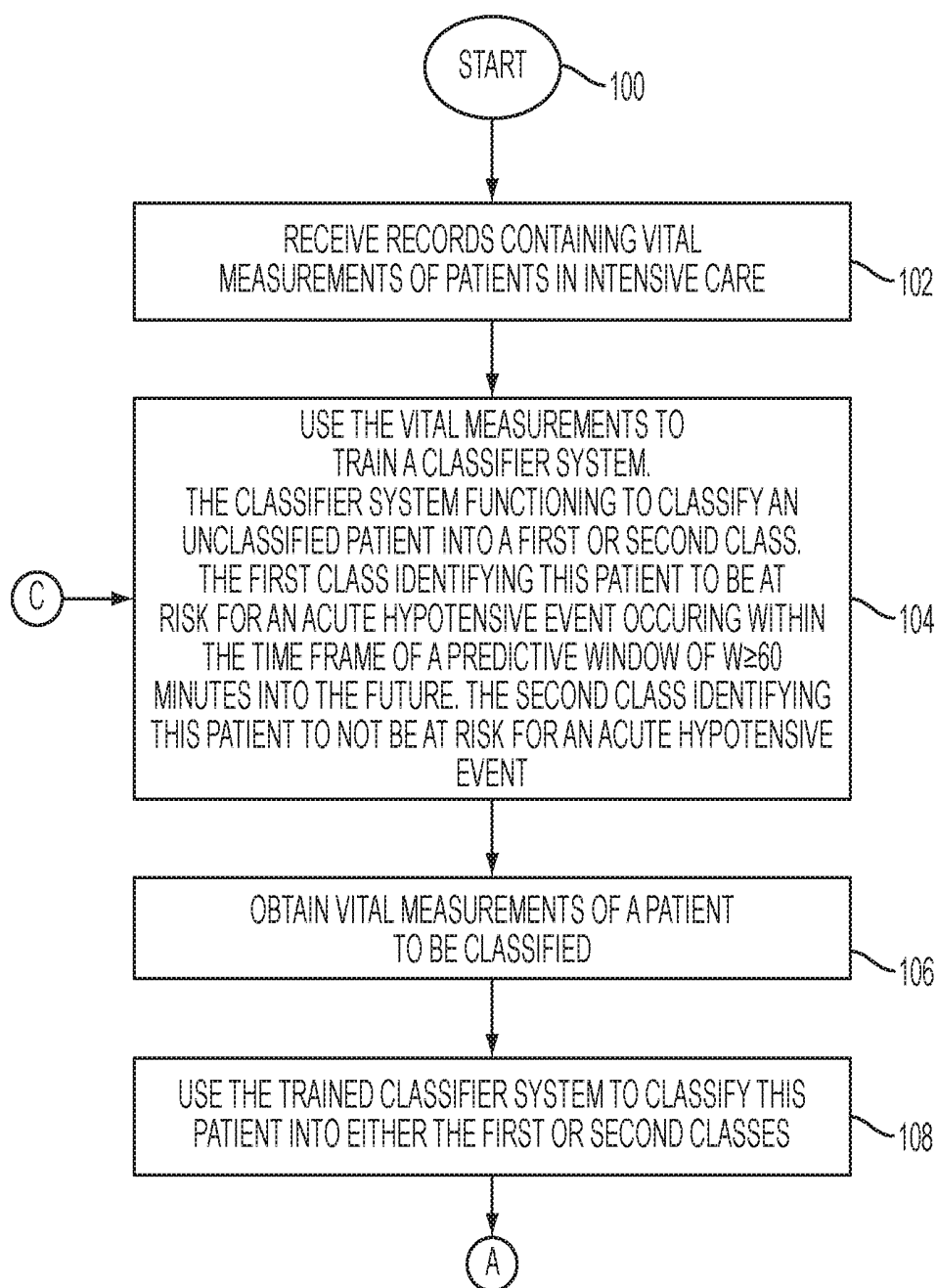


FIG. 1

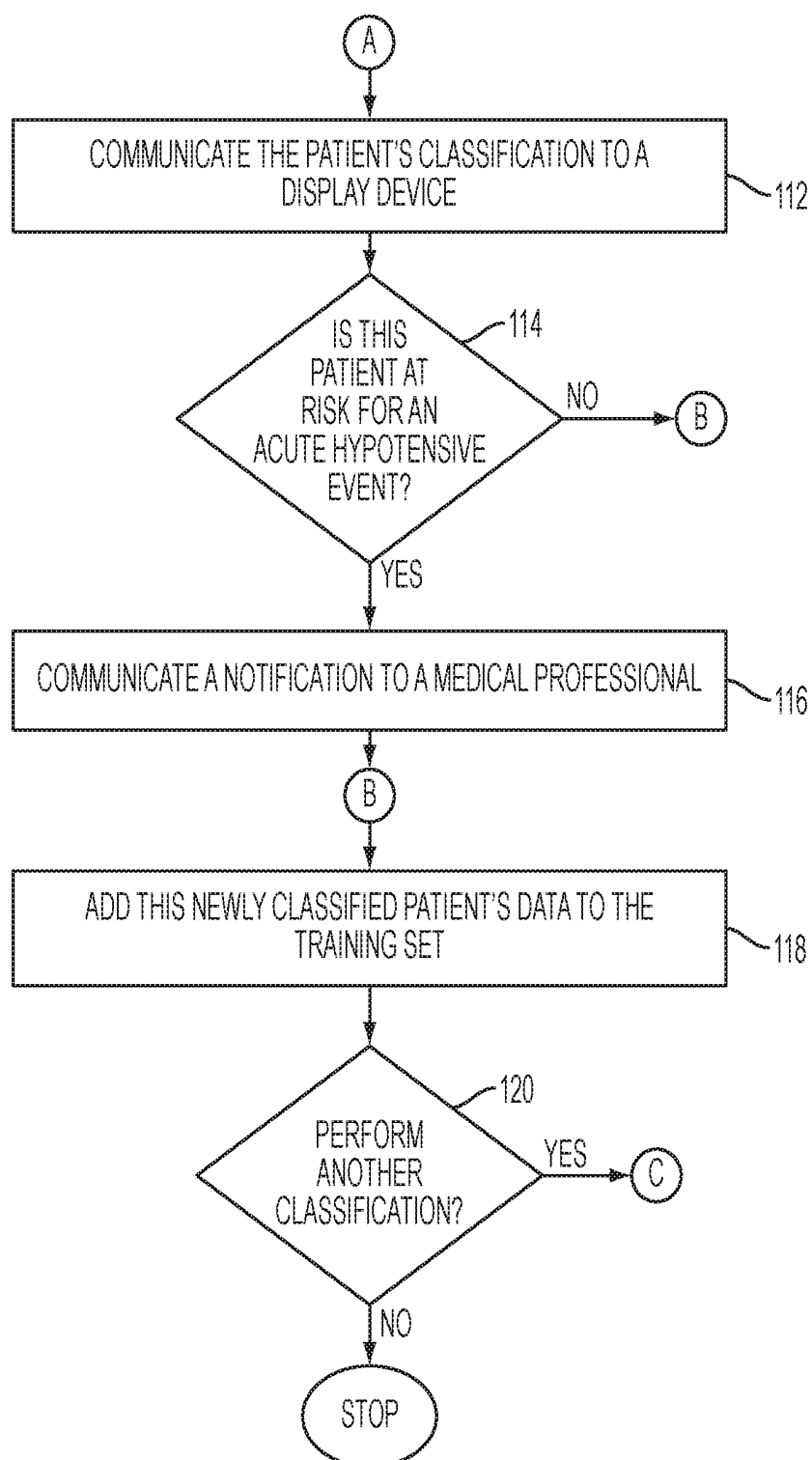


FIG. 2

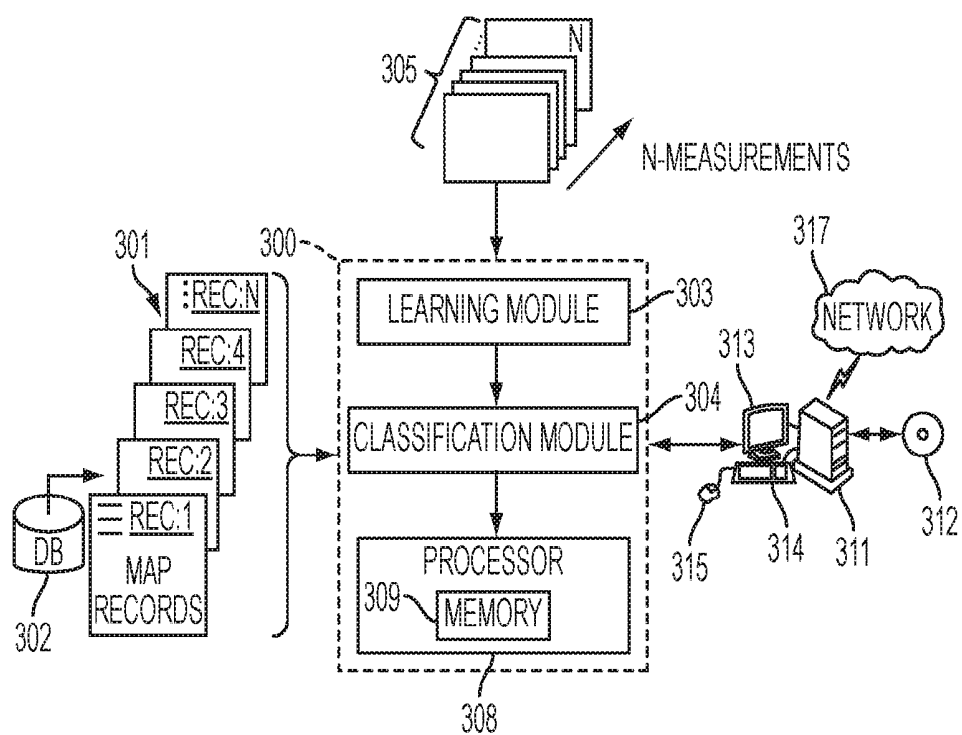


FIG. 3

ASSESSING PATIENT RISK OF AN ACUTE HYPOTENSIVE EPISODE WITH VITAL MEASUREMENTS

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present patent application is a continuation-in-part of commonly owned and co-pending U.S. patent application Ser. No. 14/254,232, entitled “Assessing Patient Risk Of An Acute Hypotensive Episode”, which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present invention is directed to systems and methods for assessing patient risk for an occurrence of an acute hypotensive episode within the timeframe of a prospective prediction window using multiple vitals to improve predictive accuracy.

BACKGROUND

[0003] An acute hypotensive episode (AHE) is generally defined as the sudden onset of a period of sustained low blood pressure. Acute hypotensive episodes are an important precursor to various health complications, some of which may be life threatening. It is one of the most critical conditions in an intensive care unit (ICU) for patient monitoring. Left untreated, AHE can lead to organ damage and may even cause death. If AHE can be predicted in advance then timely intervention can prevent such complications and may save the patient's life. Determining an appropriate medical intervention for such patients depends on ascertaining the cause of the hypotensive episode. Early identification of patients at risk for AHE helps not only in preventing the episodes but also in determining the best possible treatment for the patient. Much work has been done trying to predict AHE. Automated systems have arisen to prospectively identify patients who are at risk for an acute hypotensive episode. It is highly desirable in this art to predict an occurrence of an acute hypotensive episode to improve intervention and increase patient survival. The teachings hereof are directed towards this effort.

[0004] Accordingly, what is needed in this art are systems and methods for assessing patient risk for an occurrence of an acute hypotensive episode within the timeframe of a prospective prediction window using multiple vitals to improve predictive accuracy.

BRIEF SUMMARY

[0005] What is disclosed is a system and method for assessing patient risk for an occurrence of an acute hypotensive episode within the timeframe of a prospective prediction window using multiple vitals to improve predictive accuracy. In one embodiment, the present method involves the following. A training set is retrieved from a database. The training set comprises vital measurements for a plurality of intensive care patients. Each vital measurement x_t has been obtained at time t , where $t=1, \dots, N$, and N is the number of measurements obtained for that patient, with t being reckoned from a start of the vital measurement at pre-defined time intervals. The training set is used to train the present classifier system. The present classifier system, as disclosed herein in detail, functions to classify a yet unclassified patient into either a first or a second class. In the first class, the patient is identified as being at risk for sudden onset of an acute hypotensive episode

within the timeframe of a prediction window of w minutes in the future. In the second class, the patient is identified as not being at risk for the occurrence of an acute hypotensive episode. Once the classifier has been trained, one or more vital measurements of a previously unclassified patient are retrieved or otherwise obtained. The classifier system is then used to classify a next patient into one of the first and second classes. Various embodiments are disclosed.

[0006] Features and advantages of the above-described method will become readily apparent from the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The foregoing and other features and advantages of the subject matter disclosed herein will be made apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0008] FIG. 1 is a flow diagram which illustrates one embodiment of the present method for assessing patient risk for an acute hypotensive episode in accordance with the teachings hereof;

[0009] FIG. 2 is a continuation of the flow diagram of FIG. 1 with flow processing continuing with respect to node A; and

[0010] FIG. 3 is a block diagram of one example system for performing various aspects of the present method as described with respect to the flow diagrams of FIGS. 1-2.

DETAILED DESCRIPTION

[0011] What is disclosed is a system and method for assessing patient risk for an occurrence of an acute hypotensive episode within the timeframe of a prospective prediction window using multiple vitals to improve predictive accuracy.

[0012] A “subject” refers to a person being monitored for an acute hypotensive episode. The terms “subject” and “patient” are used interchangeably. The subject is typically a patient in an intensive care unit (ICU).

[0013] An “unclassified patient” is a person who is being classified by the present classifier system.

[0014] “Arterial blood pressure” or simply “blood pressure”, is a vital sign that is routinely monitored. Blood pressure is written as a ratio in mmHg (e.g. 120/80). The top number (systolic), which is also the higher of the two numbers, is a measure of the pressure in the arteries when the heart beats (i.e., when the heart muscle contracts). The bottom number (diastolic), which is also the lower of the two numbers, is a measure of the pressure in the arteries between heartbeats (i.e., when the heart muscle is resting between beats and refilling with blood). Systolic and diastolic blood pressures are typically measured using a device called a sphygmomanometer. Normal blood pressure is in the range of 90/60 to 130/80 mmHg. Hypertension (high blood pressure) is often defined when the subject's blood pressure rises above the normal range, i.e., greater than 130/80 mmHg. Conversely, hypotension (low blood pressure) is often defined when the subject's blood pressure falls below the normal range, i.e., less than 90/60 mmHg. Both hypertension and hypotension are important mortality predictors for patients with cardiovascular abnormalities and are precursors often leading to patient death in the ICU.

[0015] An “acute hypotensive episode” (AHE) also called an “acute hypotensive event”, is defined herein as a period of 30 minutes or longer during which at least 90% of the non-overlapping one minute averages of the arterial blood pres-

sure waveform are under 60 mmHg. A variety of different conditions can cause AHE including sepsis, myocardial infarction, cardiac arrhythmia, pulmonary embolism, hemorrhage, dehydration, anaphylaxis, hypovolemia, insufficient cardiac output, vasodilatory shock, and the effects of medication. In many cases, an acute hypotensive episode is a precursor to other complications. If an acute hypotensive episode can be predicted in advance then timely intervention can prevent complications and death. The present method utilizes vital measurements obtained from intensive care patients.

[0016] A “vital measurement” can refer to measurements associated with patient vital signs. Vital signs, or simply vitals, are used to measure the body’s basic functions. Vital measurements of the patient help assess the general physical health of a person and show progress toward recovery. The normal ranges for a person’s vital signs vary with age, weight, gender, and overall health. There are four primary vital signs: body temperature, blood pressure, heart rate, and respiratory rate, often notated as BT, BP, HR, and RR. Depending on the clinical setting, the vital signs may include other measurements such as blood glucose, oxygen saturation, blood CO₂, and Glasgow Coma Scale.

[0017] A “prediction window” is a period of time in the future such as, for instance $w \geq 60$ minutes, when an acute hypotensive episode is likely to occur.

[0018] “Mean Arterial Pressure” (MAP) is a function of systolic and diastolic pressure and is considered to be the perfusion pressure seen by organs in the body. MAP is approximated from systolic and diastolic pressure measurements as follows:

$$\text{MAP} \approx 2/3\text{DP} + 1/3\text{SP} \quad (1)$$

where DP is the diastolic pressure and SP is the systolic pressure. Diastolic pressure counts twice as much as systolic because $\frac{2}{3}$ of the cardiac cycle is spent in diastole when the heart muscle is resting between beats and refilling with blood. Mean arterial pressure is approximated. To determine mean arterial pressure with absolute accuracy, electronic equipment needs to be employed.

[0019] “Obtaining vital measurements” is intended to be widely construed and includes retrieving, receiving, capturing, calculating or otherwise acquiring vitals for use with the classifier system disclosed herein. Vital measurements can be obtained from a memory, storage device, or from a media such as a CDROM, DVD, and the like. Vital measurements can be obtained from a remote device over a network or downloaded from a web-based system or application which makes such measurements available.

[0020] A “training set” comprises records of vital measurements taken from ICU patients over intervals of every minute. Not all records are usable. Records are discarded that contain less than 6 hours of measurements including those that contained acute hypotensive episodes within the first 5 hours of recorded data. The training set used herein consisted of 500 records of patients from a first class and 1000 records of patients from a second class. As new data points become available, they are added to the training set. The training set is used to train a classifier system.

[0021] A “classifier system” comprises at least a processor and a memory. The processor retrieves machine readable program instructions from memory and executes those instructions causing the processor to classify an unclassified patient into a first or a second class. In the first class, the

patient is identified as being at risk for an acute hypotensive episode occurring within the timeframe of the prediction window. In the second class, the patient is identified as not being at risk for an acute hypotensive episode. The present classifier system performs in accordance with the following rules.

[0022] a) Let a first vector y_1 consist of vital measurements of subjects in the first class.

[0023] b) Let a second vector y_2 consist of vital measurements of subjects in the second class.

[0024] c) Let $\mu_1 = \text{mean}(y_1)$ and $\mu_2 = \text{mean}(y_2)$.

[0025] d) Let $\sigma_1 = \text{sd}(y_1)$ and $\sigma_2 = \text{sd}(y_2)$.

[0026] e) Let k be a value such that $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$.

[0027] f) Let n_1 be the number of y_1 values above $(\mu_2 - k\sigma_2)$.

[0028] g) Let n_2 be the number of y_1 values within a range of $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$.

[0029] h) Let n_3 be the number of y_2 values below $(\mu_1 + k\sigma_1)$.

[0030] i) Let n_4 be the number of y_2 values within a range of $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$.

[0031] j) Let $k_0 = \min(n_1 + n_2 + n_3 + n_4)$.

[0032] If the mean of the unclassified patient’s vital measurements averaged over at least a 1 hour time interval immediately preceding the start of the prediction window is less than $(\mu_1 + k_0\sigma_1)$, then the classifier classifies the patient into the first class, i.e., this patient is at risk for the occurrence of an acute hypotensive episode happening within the timeframe of w minutes in the future.

[0033] If the mean of the unclassified patient’s vital measurements averaged over at least a 1 hour time interval immediately preceding the start of the prediction window is greater than $(\mu_2 - k_0\sigma_2)$, then the classifier classifies this patient into the second class, i.e., this patient is not at risk for an acute hypotensive episode.

[0034] If the mean of the unclassified patient’s vital measurements averaged over at least a 1 hour time interval immediately preceding the start of the prediction window falls within the range of $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$, then the mean squared deviations of a last of the vital measurements from all points in the first and second vectors (y_1, y_2) are calculated, (d_1, d_2), respectively. If $(d_1 > d_2)$ then the classifier classifies the patient into the second class. Otherwise, this patient is classified into the first class.

[0035] Let Y_1, Y_2, Y_3, Y_4 denote vectors of indicator variables (which take values 0 or 1) with lengths $|Y_1| = |Y_2| = |y_1|$ and $|Y_3| = |Y_4| = |y_2|$. After the following computation, Y_1 will contain n_1 1’s indicating those values in y_1 that are greater than $\mu_2 - k\sigma_2$, and Y_2 will contain n_2 1’s indicating those values in y_1 that lie in the range $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$. Similarly, Y_3 and Y_4 contain indicator variables with respect to values in y_2 . If we denote the j^{th} element of vector Y_i for $i \in \{1, 2, 3, 4\}$ by x_{ij} and the j^{th} element of vector y_i for $i \in \{1, 2\}$ by y_{ij} , then k_0 can be obtained by minimizing the following relationship:

$$\sum_{i=1}^{|y_1|} x_{1i} + \sum_{i=1}^{|y_1|} x_{2i} + \sum_{j=1}^{|y_2|} x_{3j} + \sum_{j=1}^{|y_2|} x_{4j} \quad (2)$$

subject to these constraints:

$$x_{1i}y_{1i} + k\sigma_2 > \mu_2 \quad (3)$$

$$x_{2j}y_{1j} - k\sigma_1 > \mu_1 \quad (4)$$

$$x_{2i}y_{1i}+k\sigma_2<\mu_2 \quad (5)$$

$$x_{3i}y_{2i}-k\sigma_1<\mu_1 \quad (6)$$

$$x_{4i}y_{2i}-k\sigma_1>\mu_1 \quad (7)$$

$$x_{4i}y_{2i}+k\sigma_2<\mu_2 \quad (8)$$

$$x_{1i}\in\{0,1\}, x_{2i}\in\{0,1\} \quad (9)$$

$$x_{3i}\in\{0,1\}, x_{4i}\in\{0,1\} \quad (10)$$

for $1\leq i\leq |y_1|$, $1\leq j\leq |y_2|$, $k\geq 0$, and $k(\sigma_1+\sigma_2)<\mu_2-\mu_1$.

[0036] Standard optimization suites commonly found in the arts, such as CPLEX, can be utilized to solve the above-described minimization of Eq. (2). To minimize both false positives and false negatives, where a true positive is a correct identification in the first class, an interval-based margin is built which is based on the mean and standard deviation values in the first and second classes, as seen in the training data: $(\mu_1+k\sigma_1, \mu_2-k\sigma_2)$. A value falling below the lower boundary of the interval is considered to be in the first class and a value above the upper boundary is considered to be in the second class. By choosing the right value of k , the sum of the number of first class values falling above the lower bound of (n_1+n_2) and the number of second class values falling below the upper bound of (n_3+n_4) is effectively minimized.

[0037] It should be appreciated that the present classifier system can be run in a batch mode or in an incremental mode. As new training values arrives in both classes, vectors y_1 and y_2 are updated as well as the mean (μ_1, μ_2) and standard deviations (σ_1, σ_2) . If we let x be the sample added in the n^{th} round, μ_n and σ_n^2 denote the mean and variance, respectively, in the t^{th} round, the following can be used to compute the mean and variance in a real-time manner.

$$\mu_n = \mu_{n-1} + \frac{x - \mu_{n-1}}{n} \quad (11)$$

$$\sigma_n^2 = \frac{(n-1)\sigma_{n-1}^2 + (x - \mu_{n-1})(x - \mu_n)}{n} \quad (12)$$

[0038] It should be appreciated that the steps of “determining”, “analyzing”, “identifying”, “receiving”, “retrieving”, “processing”, “selecting”, “using”, “performing” and the like, as used herein, include the application of various signal processing and mathematical operations applied to data and signals, according to any specific context or for any specific purpose. It should be appreciated that such steps may be facilitated or otherwise effectuated by a microprocessor executing machine readable program instructions retrieved from a memory or storage device.

Flow Diagram of One Embodiment

[0039] Reference is now being made to the flow diagram of FIG. 1 which illustrates one embodiment of the present method for assessing patient risk for an acute hypotensive episode in accordance with the teachings hereof. Flow processing begins at step 100 and immediately proceeds to step 102.

[0040] At step 102, receive records containing vital measurements from a plurality of intensive care patients. Each vital measurement x_t has been obtained at time t , where $t=1, \dots, N$, and N is the number of measurements obtained for that

patient, with t being reckoned from a start of the vital measurement at pre-defined time intervals.

[0041] At step 104, use the vital measurements to train a classifier system which functions to classify an unclassified patient into a first class identifying this patient to be at risk for sudden onset of an acute hypotensive episode within the timeframe of a prediction window of $w\geq 60$ minutes in the future, and a second class identifying this patient to not be at risk for the occurrence of an acute hypotensive episode.

[0042] At step 106, obtain vital measurements of a patient to be classified. In one embodiment, the vital measurements are MAP and heart rate.

[0043] At step 108, use the trained classifier system to classify the unclassified patient into one of a first or a second class.

[0044] Reference is now being made to the flow diagram of FIG. 2 which is a continuation of the flow diagram of FIG. 1 with flow processing continuing with respect to node A.

[0045] At step 112, communicate the patient's classification to a display device. In other embodiments, the patient classification is communicated to any of: a storage device, a wireless handheld device, a laptop, tablet-PC, and a workstation.

[0046] At step 114, a determination is made whether the classified patient is at risk for an acute hypotensive episode occurring within the timeframe of a prediction window. If so then, at step 116, communicate a notification to a medical profession. In various embodiments hereof, the notification can take the form of an audio message, a text message, an email, a phone call, or a video. The notification may be an alert signal which takes the form of a message displayed on a display device or a sound activated at, for example, a nurse's station or control panel. The alert may take the form of a colored or blinking light which provides a visible indication that an alert condition exists. The alert signal may be communicated to one or more remote devices over a wired or wireless network. The alert may be sent directly to a handheld wireless cellular device of a medical professional. Thereafter, additional actions would be taken in response to the alert signal. Otherwise, if the patient is not at risk for an acute hypotensive episode occurring within the timeframe of a prediction window then processing continues with respect to node B, at step 118, add this newly classified patient's data to the training set.

[0047] At step 120, a determination is made whether to perform another classification. If so then processing repeats with respect to node C wherein, at step 108, more vital measurements are obtained from this same patient or another patient. Processing repeats in a similar manner. If it is determined that further patient classification is not to be performed then, in this embodiment, further processing stops.

[0048] It should be appreciated that the flow diagrams depicted herein are illustrative. One or more of the operations illustrated in the flow diagrams may be performed in a differing order. Other operations may be added, modified, enhanced, or consolidated. Variations thereof are intended to fall within the scope of the appended claims.

Block Diagram of System

[0049] Reference is now being made to FIG. 3 which shows a block diagram of one example system for performing various aspects of the present method as described with respect to the flow diagrams of FIGS. 1-2.

[0050] In FIG. 3, a training set (collectively at 301) comprising records containing vital measurements for a plurality of subjects are retrieved from a database 302. Database 302 is a storage device wherein records are stored, manipulated, and retrieved in response to a query. Such records, in various embodiments, take the form of patient medical histories stored in association with information identifying the patient along with medical information. Although the database is shown as an external device, the database may be internal to the workstation 311 mounted, for example, on a hard disk therein. The training set is provided to the classifier system 300 for training purposes. The vital measurements of the training set are obtained from systolic and diastolic measurements taken in a range of 10-60 minutes immediately preceding a start of a prediction window for both first and second classes.

[0051] In the embodiment shown, the classifier system 300 comprises a plurality of modules. Learning Module 303 processes the training data contained in the records of the training set such that the classifier system can be trained. The Learning Module 303 further functions to prune the training set, as desired, such that the classifier is trained with data which meet a pre-determined criteria, at least for accuracy and timeliness. Once training has completed, Learning Module 303 signals Classification Module 304 to receive a total of n vital measurements (collectively at 305) where $n \geq 1$ of a yet-to-be classified patient. The unclassified patient's vital measurements are received or are otherwise obtained by the classifier system which, in turn, proceeds to classify the unclassified patient into one of: a first class where the patient is identified as being at risk for the occurrence of acute hypotensive episode (AHE) within the timeframe of a prediction window in the future, and a second class where the patient is identified as not being at risk for an acute hypotensive episode. Processor 308 retrieves machine readable program instructions from Memory 309 and is provided to facilitate the functionality of the various modules comprising the classifier system 300. The processor, operating alone or in conjunction with other processors and memory, may be configured to assist or otherwise facilitate the functionality of any of the processors and modules of system 300.

[0052] The classifier system of FIG. 3 is shown in communication with a workstation 311. A computer case of the workstation houses various components such as a motherboard with a processor and memory, a network card, a video card, a hard drive capable of reading/writing to machine readable media 312 such as a floppy disk, optical disk, CD-ROM, DVD, magnetic tape, and the like, and other software and hardware needed to perform the functionality of a computer workstation. The workstation further includes a display device 313, such as a CRT, LCD, or touchscreen device, for displaying information, video, measurement data, computed values, medical information, results, locations, and the like. A user can view any of that information and make a selection from menu options displayed thereon. Keyboard 314 and mouse 315 effectuate a user input.

[0053] It should be appreciated that the workstation 311 has an operating system and other specialized software configured to display alphanumeric values, menus, scroll bars, dials, slideable bars, pull-down options, selectable buttons, and the like, for entering, selecting, modifying, and accepting information needed for processing in accordance with the teachings hereof. The workstation is further enabled to display MAPs and patient classifications as they are derived. The

workstation may further display interim values, boundary conditions, and the like, in real-time as the classifier system 300 performs its intended functionality as described herein in detail.

[0054] A user or technician may use the user interface of the workstation to set parameters, view/adjust/delete values in the training set, and adjust various aspects of the classifier system as needed or as desired, depending on the implementation. Any of these selections or input may be stored/retrieved to storage device 312. Default settings can be retrieved from the storage device. A user of the workstation is also able to view or manipulate any of the records contained in the training set 301 via pathways not shown.

[0055] Although shown as a desktop computer, it should be appreciated that the workstation 311 can be a laptop, mainframe, or a special purpose computer such as an ASIC, circuit, or the like. The embodiment of the workstation of FIG. 3 is illustrative and may include other functionality known in the arts. Any of the components of the workstation may be placed in communication with the classifier system 300 or any devices in communication therewith. Any of the modules of the classifier system 300 can be placed in communication with storage device 302 and/or computer readable media 312 and may store/retrieve therefrom data, variables, records, parameters, functions, and/or machine readable/executable program instructions, as needed to perform their intended functions. Each of the modules of the classifier system 300 may be placed in communication with one or more remote devices over network 317.

[0056] It should be appreciated that some or all of the functionality performed by any of the modules or processing units of the video processing system can be performed, in whole or in part, by the workstation 311 placed in communication with the classifier system 300 over network 317. The embodiment shown is illustrative and should not be viewed as limiting the scope of the appended claims strictly to that configuration. Various modules may designate one or more components which may, in turn, comprise software and/or hardware designed to perform the intended function.

[0057] The teachings hereof can be implemented in hardware or software using any known or later developed systems, structures, devices, and/or software by those skilled in the applicable art without undue experimentation from the functional description provided herein with a general knowledge of the relevant arts.

[0058] One or more aspects of the methods described herein are intended to be incorporated in an article of manufacture which may be shipped, sold, leased, or otherwise provided separately either alone or as part of a product suite or a service.

[0059] It will be appreciated that the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into other different systems or applications. Presently unforeseen or unanticipated alternatives, modifications, variations, or improvements may become apparent and/or subsequently made by those skilled in this art which are also intended to be encompassed by the following claims.

[0060] The teachings of any publications referenced herein are each hereby incorporated by reference in their entirety.

What is claimed is:

1. A method for assessing patient risk for an acute hypotensive episode, the method comprising:

receiving records containing vital measurements from a plurality of intensive care patients, each vital measurement x_t having been obtained at time t , where $t=1, \dots, N$, and N is the number of measurements obtained for that patient, with t being reckoned from a start of the vital measurement at pre-defined time intervals;

using the vital measurements as a training set to train a classifier system which classifies an unclassified patient into one of: a first class where the patient is identified as being at risk for an acute hypotensive episode occurring within a timeframe of a prediction window of w minutes in the future, and a second class where the patient is identified as not being at risk for an acute hypotensive episode;

obtaining at least one vital measurement of an unclassified patient; and

using the trained classifier system to classify the unclassified patient into one of the first and second classes based on the unclassified patient's obtained vital measurement.

2. The method of claim 1, wherein an acute hypotensive episode is defined as an interval $[x_t; x_t+30]$ in which at least 27 measurements are not greater than 60.

3. The method of claim 1, wherein the vital measurements are retrieved from a database containing physiological signals, patient vitals, and clinical data of patients in intensive care.

4. The method of claim 1, further comprising discarding records that contain less than 6 hours of vital measurements and discarding records of patients that have had an acute hypotensive event within the first 5 hours of recorded data.

5. The method of claim 1, wherein using only vital measurements in a range of 10-60 minutes immediately preceding a start of the prediction window for both first and second classes.

6. The method of claim 1, wherein the vital measurements comprises mean arterial pressure and any of: body temperature, blood pressure, heart rate, and respiratory rate.

7. The method of claim 6, wherein a first vector consisting of vital measurements of patients in the first class is y_1 and a second vector consisting of vital measurements of patients in the second class is y_2 , and where $\mu_1 = \text{mean}(y_1)$, $\mu_2 = \text{mean}(y_2)$, $\sigma_1 = \text{sd}(y_1)$, $\sigma_2 = \text{sd}(y_2)$, k is a value such that $(\mu_1 + k\sigma_1 < \mu_2 - k\sigma_2)$, and where n_1 is a number of y_1 values above $\mu_2 - k\sigma_2$, n_2 is a number of y_1 values within $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$, n_3 is a number of y_2 values below $\mu_1 + k\sigma_1$, and n_4 is a number of y_2 values within $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$.

8. The method of claim 7, wherein, in response to a mean of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding a start of the prediction window is less than $(\mu_1 + k_0\sigma_1)$, where $k_0 = \min(n_1 + n_2 + n_3 + n_4)$, classifying the unclassified patient into the first class.

9. The method of claim 7, wherein, in response to a mean of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding a start of the prediction window is greater than $(\mu_2 - k_0\sigma_2)$, where $k_0 = \min(n_1 + n_2 + n_3 + n_4)$, classifying the unclassified patient into the second class.

10. The method of claim 7, wherein, in response to the unclassified patient not being classified into any of the first and second classes, further comprising:

calculating a mean of values of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding the prediction window; and

in response to the calculated mean falling within $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$, comparing mean squared deviations of a last of the measurements from all points in the first and second vectors (y_1, y_2) , the deviations being (d_1, d_2) , respectively, and in response to $(d_1 > d_2)$, classifying the unclassified patient to the second class, otherwise classifying the unclassified patient into the first class.

11. A system for assessing patient risk for an acute hypotensive episode, the system comprising:

a storage device; and

a processor in communication with the storage device, the processor executing machine readable program instructions for implementing a classifier system for classifying an unclassified patient into one of: a first class where the patient is identified as being at risk for an acute hypotensive episode occurring within a timeframe of a prediction window of w minutes in the future, and a second class where the patient is identified as not being at risk for an acute hypotensive episode, the machine readable program instructions for performing:

retrieving, from the storage device, records containing vital measurements from a plurality of intensive care patients, each vital measurement x_t having been obtained at time t , where $t=1, \dots, N$, and N is the number of measurements obtained for that patient, with t being reckoned from a start of the vital measurement at pre-defined time intervals;

receiving at least one vital measurement of an unclassified patient; and

classifying the unclassified patient into one of the first and second classes based on the unclassified patient's obtained vital measurement.

12. The system of claim 11, wherein an acute hypotensive episode is defined as an interval $[x_t; x_t+30]$ in which at least 27 measurements are not greater than 60.

12. The system of claim 11, wherein the vital measurements are retrieved from a database containing physiological signals, patient vitals, and clinical data of patients in intensive care.

14. The system of claim 11, further comprising discarding records that contain less than 6 hours of vital measurements and discarding records of patients that have had an acute hypotensive event within the first 5 hours of recorded data.

15. The system of claim 14, wherein using only vital measurements in a range of 10-60 minutes immediately preceding a start of the prediction window for both first and second classes.

16. The system of claim 15, wherein the vital measurements comprises mean arterial pressure and any of: body temperature, blood pressure, heart rate, and respiratory rate.

17. The system of claim 16, wherein a first vector consisting of vital measurements of patients in the first class is y_1 and a second vector consisting of vital measurements of patients in the second class is y_2 , and where $\mu_1 = \text{mean}(y_1)$, $\mu_2 = \text{mean}(y_2)$, $\sigma_1 = \text{sd}(y_1)$, $\sigma_2 = \text{sd}(y_2)$, k is a value such that $(\mu_1 + k\sigma_1 < \mu_2 - k\sigma_2)$, and where n_1 is a number of y_1 values above $\mu_2 - k\sigma_2$, n_2 is a number of y_1 values within $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$, n_3 is a number of y_2 values below $\mu_1 + k\sigma_1$, and n_4 is a number of y_2 values within $(\mu_1 + k\sigma_1, \mu_2 - k\sigma_2)$.

18. The system of claim **17**, wherein, in response to a mean of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding a start of the prediction window is less than $(\mu_1 + k_0 \sigma_1)$, where $k_0 = \min(n_1 + n_2 + n_3 + n_4)$, classifying the unclassified patient into the first class.

19. The system of claim **18**, wherein, in response to a mean of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding a start of the prediction window is greater than $(\mu_2 - k_0 \sigma_2)$, where $k_0 = \min(n_1 + n_2 + n_3 + n_4)$, classifying the unclassified patient into the second class.

20. The system of claim **10**, wherein, in response to the unclassified patient not being classified into any of the first and second classes, further comprising:

calculating a mean of values of the unclassified patient's vital measurements averaged over at least a 1 hour time interval immediately preceding the prediction window;
and

in response to the calculated mean falling within $(\mu_1 + k \sigma_1, \mu_2 - k \sigma_2)$, comparing mean squared deviations of a last of the measurements from all points in the first and second vectors (y_1, y_2) , the deviations being (d_1, d_2) , respectively, and in response to $(d_1 > d_2)$, classifying the unclassified patient to the second class, otherwise classifying the unclassified patient into the first class.

* * * * *

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摘要(译)

所公开的是一种用于使用多个生命体征预测预测窗口的预期预测窗口的时间范围内评估患者发生急性低血压发作的风险的系统和方法，以提高预测准确性。在一个实施方案中，本方法包括以下方法。从数据库中检索训练集。训练集包括多个重症监护患者的重要测量值。在时间t获得每个生命测量 x_t ，其中 $t = 1, \dots, N$ 。N和N是针对该患者获得的测量的数量，其中t以预定义的时间间隔从生命测量的开始计算。训练集用于训练当前的分类器系统。分类器将尚未分类的患者分类为具有急性低血压发作风险的第一类患者或不具有发生急性低血压发作风险的第二类。

